

5G Observatory Quarterly Report 6

Up to December 2019



European 5G Observatory

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Contents

1. Executive summary	7
1.1. Status of 5G deployment in Europe and assessment against the 5G Action Plan.....	7
1.2. 5G deployment outside Europe.....	8
1.3. Framework conditions and public measures in the context of the 5G Action Plan	9
2. Recent major developments	11
2.1. Latest developments at EU level	11
2.2. Progress of national strategies and plans	12
2.2.1. Consultations: 26 EU MSs have launched public consultations on 5G.....	12
2.2.2. National strategies	13
2.3. 5G scoreboard.....	15
2.3.1. 5G scoreboard – EU-28	15
2.3.2. 5G scoreboard – International	16
2.4. Announcements of commercial launches	17
2.4.1. Europe.....	17
2.4.2. South Korea: all three players have launched 5G services.....	20
2.4.3. Australia	21
2.4.4. Japan	21
2.4.5. China	21
2.4.6. USA: 3 out of 4 major players have launched 5G services	22
2.4.7. Other countries.....	24
2.5. 5G pre-commercial trials.....	25
2.5.1. Analysis of the 222 trials registered so far	25
2.5.2. Trial cities.....	28
2.5.3. Digital cross-border corridors	29
2.6. 5G cities	31
2.7. Spectrum assignment by public authorities.....	34
2.7.1. Review of spectrum assignment progress	34
2.7.2. Allowing spectrum use for 5G.....	36
2.7.3. Outcome of the WRC'19	41
2.8. Product/market developments	41
2.8.1. Overview of the 5G baseband market as of early December 2019	42
2.8.2. 1 st 5G devices are there and not only dongles and CPEs	47
2.8.3. Infrastructure ecosystem.....	50
3. Annexes	55
3.1. National strategies and plans by MS	55
3.1.1. Austria.....	55
3.1.2. Belgium	56
3.1.3. Bulgaria	56
3.1.4. Croatia	57
3.1.5. Cyprus	57

3.1.6. Czech Republic	58
3.1.7. Denmark	59
3.1.8. Estonia	59
3.1.9. Finland	60
3.1.10. France	60
3.1.11. Germany	62
3.1.12. Greece	65
3.1.13. Hungary	66
3.1.14. Ireland	68
3.1.15. Italy	68
3.1.16. Latvia	71
3.1.17. Lithuania	71
3.1.18. Luxembourg	71
3.1.19. Malta	72
3.1.20. Netherlands	73
3.1.21. Poland	73
3.1.22. Portugal	74
3.1.23. Romania	74
3.1.24. Slovakia	75
3.1.25. Slovenia	76
3.1.26. Spain	77
3.1.27. Sweden	78
3.1.28. UK	78
3.2. 5G strategy and pioneer bands follow-up	80
3.3. 5G Spectrum comparison	82
3.5. International developments/trials	85
3.5.1. USA	85
3.5.2. China	86
3.5.3. South Korea	88
3.5.4. Japan	88
3.5.5. India	90
3.6. 5G commercial launch dates	91
3.7. Number of cell sites for 5G trials and commercial deployments	92
3.8. 5G network equipment – main manufacturers	94
3.8.1. Ericsson	94
3.8.2. Huawei	96
3.8.3. Nokia	96
3.8.4. Samsung	98
3.8.5. ZTE	99
3.9. Electromagnetic Fields (EMF) in the EU-28 Member States	99
3.10. TDD synchronisation in the EU-28 Member States	100
3.10.1. Austria	101
3.10.2. France	101
3.10.3. Ireland	102
3.10.4. Italy	102
3.10.5. Sweden	102
3.10.6. United Kingdom	102

Tables & Figures

Table 1:	Key trends related to 5G Action Plan measures	8
Table 2:	Assessment of 5G AP analysis criteria	10
Table 3:	Screen shot of the trials base in the European 5G Observatory.....	25
Table 4:	5G CAM cross-border corridors	29
Table 5:	5G key cities.....	32
Table 6:	Availability of 700 MHz spectrum in Member States (as of end December 2019)	37
Table 7:	Availability of 3.4-3.8 GHz spectrum in Member States (as of end December 2019).....	39
Table 8:	Availability of 26 GHz spectrum in Member States (as of end December 2019).....	40
Table 9:	Presentation of announced 5G chipsets.....	42
Table 10:	Number of 5G devices powered by baseband vendors as of end of December 2019	43
Table 11:	Simplified composition of the 5G device ecosystem as of December 2019	48
Table 12 :	Distribution of announced 5G devices by range of frequency band	50
Table 13:	Infrastructure equipment 5G solutions from major vendors	51
Table 14 :	5G infrastructure contracts	53
Table 15:	5G strategy and pioneer bands follow-up for EU-28 countries – December 2019	80
Table 17:	Number of cell sites/base stations for 5G trials and networks.....	93
Table 18:	Ericsson 5G portfolio	95
Table 19 :	Nokia 5G portfolio	97
Table 20 :	Adoption of ICNIRP limits in the EU-28 Member States	99

Figure 1:	5G scoreboard – EU-28 (December 2019)	15
Figure 2:	5G Scoreboard – International markets (December 2019).....	16
Figure 3:	EU countries with 5G commercial service – December 2019	17
Figure 4:	Verticals tested in 5G trials.....	26
Figure 5:	5G trials by country	26
Figure 6:	Frequency bands tested	27
Figure 7:	5G modem to be integrated in All-In-One SoCs.....	45
Figure 8:	The steps a device takes to market	47
Figure 9:	Huawei and Samsung 5G home routers for 5G Fixed Wireless Access.....	47
Figure 10:	OEMs planning to launch Qualcomm based x55 5G FWA CPEs.....	47
Figure 11 :	Distribution of 5G device ecosystem as of December 2019	48
Figure 12:	Comparison of BOM and ASP (average selling price) of 5G and non 5G variant of the Galaxy S10	49
Figure 13:	5G timeline in France.....	62
Figure 14:	5G strategy in 5 steps	63
Figure 15:	Key milestones of 5G strategy for Germany.....	63
Figure 16:	5G research centers in Germany	64
Figure 17:	5G timeline in Germany.....	64
Figure 18:	5G timeline in Italy	69
Figure 19:	5G timeline in Spain.....	78
Figure 20:	5G timeline in the UK.....	80
Figure 21:	Identified and assigned 5G spectrum (MHz) – Low bands.....	82
Figure 22:	Identified and assigned 5G spectrum (MHz) – Mid bands.....	83
Figure 23 :	Identified and assigned 5G spectrum (MHz) – High bands.....	83
Figure 24:	5G deployments – number of cell sites	93

Figure 25:	Presentation of Ericsson 5G solution.....	95
Figure 26:	Nokia AirScale Radio Access for 5G	96
Figure 27:	Samsung 5G products evolution.....	98
Figure 28:	Displaying of Samsung 5G FWA solution for the American market.....	98

1. Executive summary

This is the sixth quarterly report of the 5G Observatory for the fourth quarter of 2019.

1.1. Status of 5G deployment in Europe and assessment against the 5G Action Plan

On 14 September 2016, the Commission launched the 5G Action Plan to boost EU efforts for the deployment of 5G infrastructures and services across the Digital Single Market by 2020, and comprehensive coverage by 2025. The action plan sets out a clear roadmap for public and private investment on 5G infrastructure in the EU.

The European 5G Observatory provides updates on all market developments in EU-28, including actions undertaken by the private and public sectors, in the field of 5G. It also presents an analysis of the strategic implications of the 5G Action Plan and other public policy objectives.

European mobile operators have been working for two years with equipment manufacturers and vertical players on various trials in order to validate 5G's capabilities. At end-December 2019, it was clear that they are heavily involved in 5G testing with 181 trials reported at that time (up from 138 in Q4/2018) in EU-28 countries.

During the year 2019, many European mobile operators were preparing the commercial phase as the first 5G smartphones became available in the second or third quarter, and now commercial services are already available in a number of cities in Europe. Deployments are on-going with tens to hundreds of base stations to be turned on in many European cities. Many EU Member States enjoy 5G services (Austria, Finland, Estonia, Germany, Hungary, Ireland, Italy, Romania, Spain and the UK), and in some countries there are more than one 5G service provider: three players provide 5G services (Mobile and/or FWA) in the UK (EE, Vodafone, Three: FWA), three in Romania (Digi, Vodafone and Orange), two in Italy (TIM and Vodafone), Germany (T-Mobile and Vodafone) and Finland (Elisa and Telia). The latest announced commercial service launches took place in October 2019 (Vodafone Hungary, Telia Finland), November (Orange in Romania) and December (Eir in Ireland).

Key trends related to the 5G Action Plan measures, covering 5G roadmaps, spectrum, early deployment and pan-European multi-stakeholder trials, are presented in Table 1:

Table 1: Key trends related to 5G Action Plan measures

5G AP measures	Key trends
Announcements by operators, service providers or users	<p>At the end of 2019, 5G commercial services had been deployed in 10 EU countries. 5G commercial launches in Europe: Elisa (Finland and Estonia, network in June 2018 and full mobile services in June 2019), Ooredoo (Qatar) in May 2018. T-Mobile Austria (friendly customers), EE in May 2019, Vodafone Italy, Vodafone Spain, Vodafone UK, Telecom Italia in June 2019, T-Mobile Germany and Vodafone Germany in July 2019, Vodafone Ireland and Three UK (FWA) in August 2019, Orange Romania and Telia Finland in October 2019.</p> <p>5G commercial launches in the USA: Verizon (October 2018 for FWA and April 2019 for mobile services), AT&T (December 2018 for network and June 2019 for mobile services, Sprint in May 2019, T-Mobile in July 2019.</p> <p>5G commercial launches in South Korea in December 2018 for enterprise customers and in April 2019 for residential customers.</p> <p>5G commercial services in China launched in November 2019.</p> <p>5G planned launches: Japan in August 2020 (Pre-launches in 2019, notably for NTT DoCoMo autumn 2019).</p>
Promote early deployment in major urban areas and along major transport paths	<p>181 trials announced in EU-28. 41 trials in Russia, Turkey, San Marino, Switzerland and Norway.</p> <p>In 2017-2019, 11 digital cross-border corridors were announced and established for live tests of 5G in the EU.</p> <p>Three large-scale projects have been selected on these corridors (5G-CARMEN, 5GCroCo, 5G-MOBIX).</p>
Promote pan-European multi-stakeholder trials as catalysts to turn technological innovation into full business solutions	<p>Large trials are part of H2020 Phase 3 projects. Three projects (5G EVE, 5G-VINNI, 5GENESIS) started on 1 July 2018. They are implementing and testing advanced 5G infrastructures in Europe (EUR 15 to 20 million investment). Seven additional projects (5G-SOLUTIONS, 5G-TOURS, 5GDrones, 5G-HEART, 5GROWTH, 5G-SMART, 5G-VICTORI) focussed on trialling 5G across vertical industries started in June 2019.</p> <p>Eight projects (ARIADNE, 5G-CLARITY, 5G-COMPLETE, INSPIRE-5Gplus, LOCUS, MonB5G, TERAWAY and 5G ZORRO) started in November 2019 on the longer term vision.</p>

Source: IDATE DigiWorld – December 2019

1.2. 5G deployment outside Europe

In other regions of the world, 5G is also a very hot topic, and Qatar's Ooredoo announced 5G commercial service as early as May 2018. Nevertheless, it should be noted that availability of mobile 5G-ready devices was expected in the first half of 2019 and that mostly prototypes are available as of today.

In the USA, the four major mobile players launched 5G services in 2018 and 2019. Verizon launched its fixed wireless access service in October 2018 in four cities in the USA based on a proprietary standard. AT&T also announced the launch of a mobile 5G service based on the 3GPP standard in December

2018. The service was restricted to friendly¹ customers until the first quarter of 2019 and was extended to additional cities during the first quarter of 2019. Verizon also launched a mobile service in Chicago and Minneapolis in April 2019. Sprint launched its 2.5 GHz 5G service in May 2019 and T-Mobile USA also did two months later in July 2019.

After the announcement of limited commercial service targeting the enterprise market in early December 2018, the three South Korean operators launched 5G services on the same day in April 2019. In South Korea, 5G deployment is massive: after a rapid outdoor deployment; players are focusing on the provision of indoor 5G services.

Other 5G launches were also reported in other countries using the 3.5 GHz band: Australia (Telstra in 2018, Optus in January 2019), Bahrain (Viva in February 2019), Kuwait (Viva, Zain and Ooredoo in June 2019), Qatar (Ooredoo in May 2018 and Vodafone in August 2018), Lesotho (Vodacom in August 2018), Saudi Arabia (STC and Zain in June 2019), UAE (Etisalat in September 2018, Du in June 2019).

In China, the three mobile operators, China Mobile, China Telecom and China Unicom have launched 5G services on November 1st, 2019.

Japan is already very active in the 5G field and operators will commercially launch 5G in 2020.

1.3. Framework conditions and public measures in the context of the 5G Action Plan

Public authorities have started to take measures to facilitate the introduction of 5G. This ranges from national 5G strategies to the completion or preparation of 5G spectrum assignments.

The European Electronic Communications Code, which entered into force on 21 December 2018, sets important framework conditions as regards 5G investment in the EU. In particular, MS are required to make 5G pioneer bands available by end of 2020 with investment certainty and predictability for at least 20 years in terms of spectrum individual licensing. Moreover, it establishes a voluntary peer review for the consistent assignment of spectrum across the EU.

The 5G Action Plan also sets out key targets to be achieved by Member States on the roadmap to 5G. The first one aims at unlocking bottlenecks including identification of spectrum for the initial launch of 5G (the pioneer bands identified by RSPG). The second target was the identification of a full set of spectrum bands for 5G by the end of 2017 and working toward an approach for the authorisation of specific bands above 6 GHz.

At the end of December 2019, the most tested frequency band in Europe is by far the 3.6 GHz band (71% of the tests). The 26 GHz band is starting to gain traction.

¹ Friendly customers are employees of the mobile operator or people using the service for no charge in exchange for reports on the service
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Table 2: Assessment of 5G AP analysis criteria

5G AP analysis criteria	Assessment
Roadmaps and priorities for a coordinated 5G deployment	<p>The European Commission published a guidance document for national 5G strategies and roadmaps.</p> <p>Eleven MSs published fully-fledged national 5G roadmaps including spectrum strategies (Austria, Denmark, Estonia, Finland, France, Germany, Luxembourg, Spain, Sweden, The Netherlands, and the UK).</p> <p>Twenty-six² EU MSs have launched public consultations on 5G spectrum/strategy.</p>
Make pioneer spectrum bands available for 5G use ahead of WRC-19	<p>Member States are required to authorise the 700 MHz band by 2020, unless there are justified reasons for delaying it until mid-2022 at the latest.</p> <ul style="list-style-type: none"> • The 700 MHz band has been assigned in six MSs: Denmark, Germany, France, Finland, Italy and Sweden • The 3.4-3.8 GHz band has been assigned in accordance with 5G technical conditions³ in 10 MSs: Austria, Czech Republic, Finland, Germany, Hungary, Ireland, Italy, Latvia, Spain and United Kingdom • The 26 GHz band has been assigned in Italy. <p>In 13 Member States at least one spectrum auction is complete (as in September, 2019). The latest spectrum auction ended in October 2019 in Hungary in mid-bands.</p> <p>In 8 MSs at least one spectrum auction is scheduled for early 2020.</p>
Spectrum: usage of 5G pioneer bands and/or of other bands identified by the RSPG	Usage: some commercial usage of 5G spectrum yet in EU-28: 5G compatible devices appeared in the European market in March 2019 and 5G infrastructure building mainly started early 2019.
Service verticals: feasibility of vertical use cases based on deals inked with key vertical players	<p>Media & Entertainment: 35 trials</p> <p>Transport: 30 trials</p> <p>Automotive: 22 trials</p> <p>Other verticals: Industry 4.0, Agriculture, Smart cities, smart buildings, eHealth, Public Safety...</p>
Top 10 European countries where trials are organised	Spain, France, Italy, Germany, UK, Finland, Netherlands, Portugal, Estonia, Romania
Technologies (Non-Stand Alone, Stand Alone...)	Non-Stand Alone 5G (3GPP Release 15) for all mobile operators
Functionalities tested: virtual networks/edge computing, broadcast/streaming, Heterogeneous Networks...	Mainly throughput and latency are tested in the first trials in Europe. The media and entertainment vertical is the most important one among the reported trials.

Source: IDATE DigiWorld – December 2019

² A number of public consultations are now closed. Estonia and Latvia have not yet launched public consultations on 5G spectrum/strategy

³ Harmonised technical conditions in line with Commission Decision (EU) 2019/235 of 24 January 2019 on amending decision 2008/411/EC as regards an update of relevant technical conditions applicable to the 3400-3800 MHz frequency band

2. Recent major developments

2.1. Latest developments at EU level

5G is progressing well in Europe. The process has significantly accelerated since the end of 2017. Ambitious goals have been set at European level since 2016. The European Commission's 5G Action Plan of 14 September 2016, confirmed by the Member States in December 2017, targets ensuring commercial rollout of 5G in at least one major city in every Member State by the end of 2020 and uninterrupted coverage of all urban areas and major terrestrial transport paths by 2025.

The European Union regulatory framework for electronic communications has recently been reviewed and the new European Electronic Communications Code (EECC) entered into force on 21 December 2018. Member States will have two years to transpose it into national law, which will give a strong push to 5G and high-speed broadband networks as a whole.

The EECC will facilitate investments and entry into the market for wireless communications operators by:

- enhancing the deployment of 5G networks by ensuring the availability of pioneer 5G radio spectrum by the end of 2020 in the EU;
- providing operators with investment certainty and predictability for at least 20 years in terms of spectrum individual licensing;
- ensuring better coordination of planned radio spectrum assignments;
- supporting the entry of new spectrum users and economic operators through increased recourse to shared use of radio spectrum and general authorisation where possible, as well as easier spectrum trading and leasing;
- facilitating the deployment of 5G networks by introducing a light authorisation regime for small-area wireless access points;
- facilitating the roll-out of new, very high capacity fixed networks by making rules for co-investment more predictable and promoting risk sharing in the deployment of very high capacity networks;
- promoting sustainable competition for the benefit of consumers, with a regulatory emphasis on the real bottlenecks, such as wiring, ducts and cables inside buildings; and a specific regulatory regime for wholesale only operators.
- ensuring close cooperation between the Commission and the Body of European Regulators for Electronic Communications (BEREC), including in supervising measures related to the new access provisions on co-investment and symmetric regulation.

According to the UHF Decision of 20107 ((EU) 2017/899) all Member States are required to adopt national roadmaps regarding the licensing of the 700 MHz band.

On April 24, 2019, the European Commission discussed the authorisation processes under way with 26 Member States. The discussion on the objectives for such award procedures focused on issues such as how to define and achieve territorial coverage objectives, timely and sufficient spectrum to meet demand, the best means to ensure availability of advanced services for local or industrial users, the scope for network sharing to lower deployment costs, quality of service and the maintenance of competition.

Defragmenting the 3.4-3.8 GHz frequency band and enabling participation of vertical industries are additional issues raised by RSPG and to be tackled in the coming months.

In the last quarter 2019, the Electronic Communications Committee (ECC) issued a draft recommendation to a public consultation on “guidelines to support the introduction of 5G while ensuring, in a proportionate way, the use of existing and planned FSS transmitting earth stations in the frequency band 24.65-25.25 GHz and the possibility for future deployment of these earth stations”. The ECC also issued a consultation on cross-border coordination for three mobile broadband bands (700 MHz, L-Band and 3.4-3.8 GHz frequencies).

Seven additional 5G PPP projects (5G-SOLUTIONS, 5G-TOURS, 5GDrones, 5G-HEART, 5GROWTH, 5G-SMART, 5G-VICTORI) were launched early June 2019 closer involving vertical industries.

Eight “longer term vision” H2020 projects started in November 2019: ARIADNE, 5G-CLARITY, 5G-COMplete, INSPIRE-5Gplus, LOCUS, MonB5G, TERAWAY and 5GZORRO.

2.2. Progress of national strategies and plans

Most EU MSs started to examine 5G strategic issues through public consultations, often followed by 5G strategy documents in 2016 or 2017. The 5G strategies generally result from a national broadband strategy defined earlier in 2015 or 2016 and lasting up to 2020.

In order to facilitate a consistent approach across Europe, the European Commission has published in November 2018 a Report⁴ summarising the best practices and common elements that could be considered for national 5G strategies. The work done with experts from EU Member States covers key issues that range from deployment targets, spectrum and small cells to public financing programmes and 5G innovation support.

2.2.1. Consultations: 26 EU MSs have launched public consultations on 5G

By the end of December 2019, 26 EU MSs had finalised public consultations on 5G spectrum/strategy: Austria (2017, 2019), Belgium (2018), Bulgaria (December 2018), Croatia (2019), Cyprus (September 2019), Czech Republic (early 2019 and July 2019), Denmark (March 2018), Finland (2018), France (December 2017, October 2018, May 2019, July 2019, September 2019, December 2019), Germany (2018), Greece (2018 and 2019), Hungary (2019), Ireland (2019), Italy (2017), Lithuania (2018), Luxembourg (2018 and May 2019), Malta (2018), Netherlands (first half 2019), Poland (2018, 2019), Portugal (2018, 2019), Romania (December 2018, July 2019), Slovakia (2017, August and December 2019), Slovenia (2017 and 2019), Spain (2018), Sweden (2017 and June and December 2019) and the UK (2017 and 2019).

In the last quarter (October 1st-December 31st, 2019), public consultations were opened in Estonia and in the Netherlands.

In Latvia, reflections have progressed.

⁴ <https://circabc.europa.eu/ui/group/7da1d333-3dda-4a40-9d7c-0013e0c51c98/library/3179b0e0-061d-4eac-9742-e391d63b5cc6/details>
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5G strategies and plans by Member States are detailed in section 3.1 of the annex to this report.

2.2.2. National strategies

The national 5G strategies adopted to date have a number of facets as the 5G roadmaps set concrete targets, define priority areas and milestones. A spectrum section provides details on 5G potential auctions to be held in different 5G pioneer bands, and trial licences are often considered. Funding methods are presented and discussed, and measures to stimulate and mobilise key players from the telecom and vertical industries are also considered.

The review of progress made towards 5G market introduction shows various stages. Eleven MSs published fully-fledged national 5G roadmaps including spectrum strategies (Austria, Denmark, Estonia, Finland, France, Germany, Luxembourg, Spain, Sweden, The Netherlands, and the UK).

In 2019, six Member States were planning to publish their 5G strategies: Cyprus (planned 1/19, not published yet), Malta (planned 3/19, not published yet – Malta issued a discussion paper on 5G Demand and Business Models in May 2019), Hungary (planned 4/19, not published yet, but the multi-band auction process has been launched in July 2019), Portugal (planned 7/19, not published yet), Croatia (planned Q4/19, not published yet), and Lithuania (planned by end of 2019, not published yet). In Hungary, the National Media and InfoCommunications Authority has not published a fully-fledged 5G roadmap yet but started the 5G auction process for 700/2100/2600 and 3600 MHz frequencies in July 2019. It was expected to be finalised before end-2019. In Romania, following the public consultation on 5G strategy late in 2018, ANCOM published spectrum plans in June 2019. Slovenia asked for comments on its spectrum strategy published in May 2019.

Other countries provided details on their plans to award 5G pioneer frequencies:

- In Portugal, the multi-band auction process for 700/900/1800/2100/2600 and 3600 MHz spectrum has also been launched in November 2019. In December 2019, the Belgian regulator BIPT published its draft plan 2020-2022 for a public consultation. The document mentions plans to award 700/1500 MHz and 3.5 GHz frequencies and to renew authorisations for the 900/1800/2100 MHz bands which expire in 2021.
- The Dutch ministry of Economic Affairs and Climate issued a consultation on its plans to award 700 MHz, L-band and 2100 MHz bands for spring 2020.
- In Austria, the government aims to auction 700/1500/2100 MHz frequencies in March 2020 with coverage and roll-out conditions (main traffic routes should enjoy 5G services by year-end 2023, “virtual” nationwide coverage by year-end 2022).
- In Denmark, the Danish Energy Agency issued a consultation on the possibility of opening spectrum for private networks, particularly in the 3.5 GHz band.
- The Polish regulator UKE opened a consultation on starting prices and roll-out conditions for the 3.4-3.8 GHz auction in December 2019. Licences would include obligations to launch services over 10 base stations in one city within six months of the award date, 250 base stations by year-end 2023 and 500 base stations by year-end 2025.

In 2019, three Member States updated their national broadband strategies or spectrum strategies. In Austria, the government announced a new national broadband strategy up to 2030 with specific

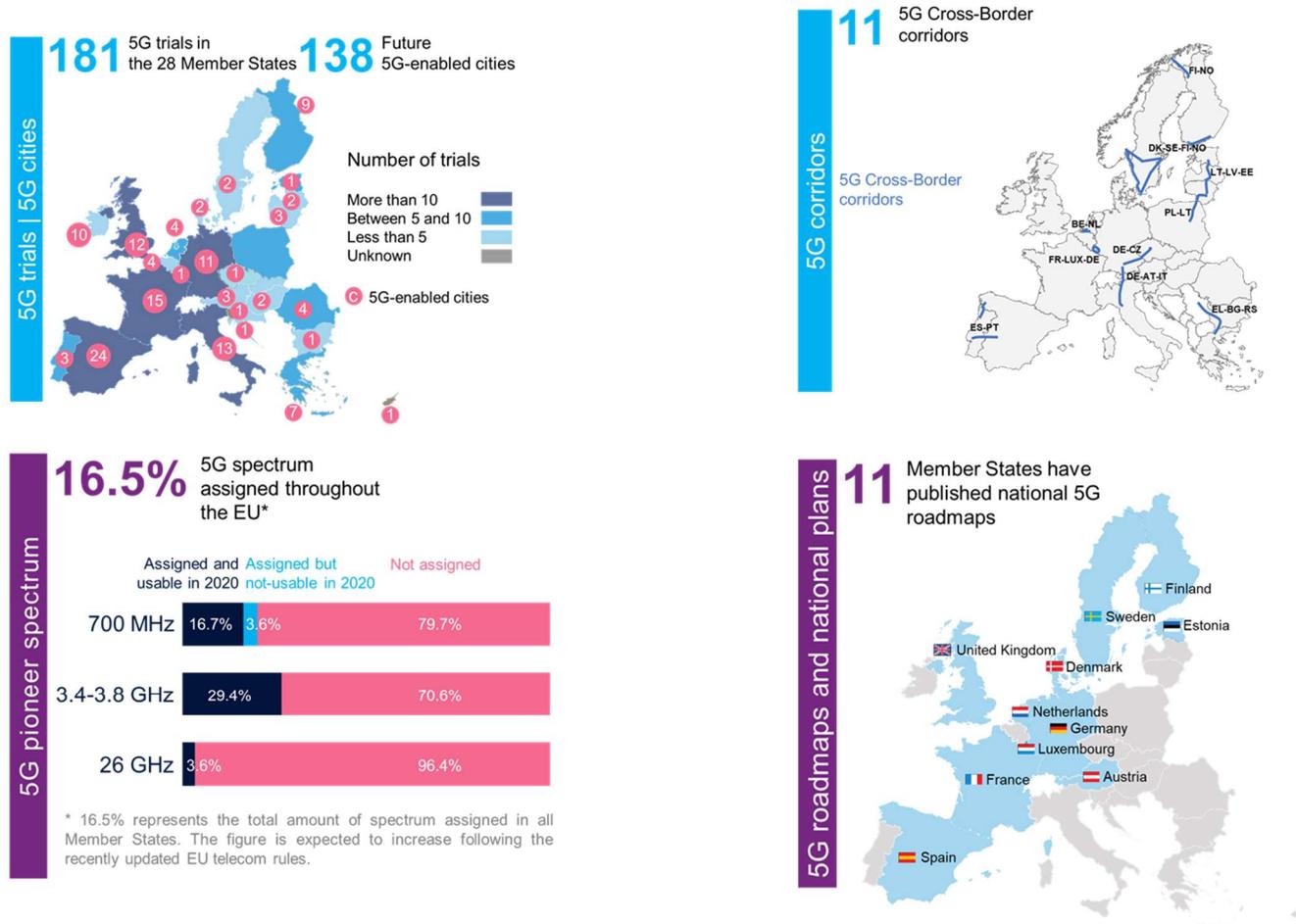
coverage goals (5G coverage along main roads by year-end 2023, nationwide coverage by year-end 2025). In Germany, a new mobile strategy was issued in September 2019. As part of this strategy, an agreement between authorities and 5G spectrum licences was signed. The five-point agreement aims at speeding up the planning, approval and development of 4G and 5G networks. It includes measures to close gaps in 4G mobile coverage and to position Germany as a 5G market leader. In the Netherlands, the new spectrum plan schedules a multi-band spectrum auction (700/1400/2100 MHz) for the first quarter 2020.

2.3. 5G scoreboard

2.3.1. 5G scoreboard – EU-28

The 5G scoreboard summarises the status of 5G trials, spectrum assignments, and measures on coverage, roadmaps and national plans in EU-28.

Figure 1: 5G scoreboard – EU-28 (December 2019)

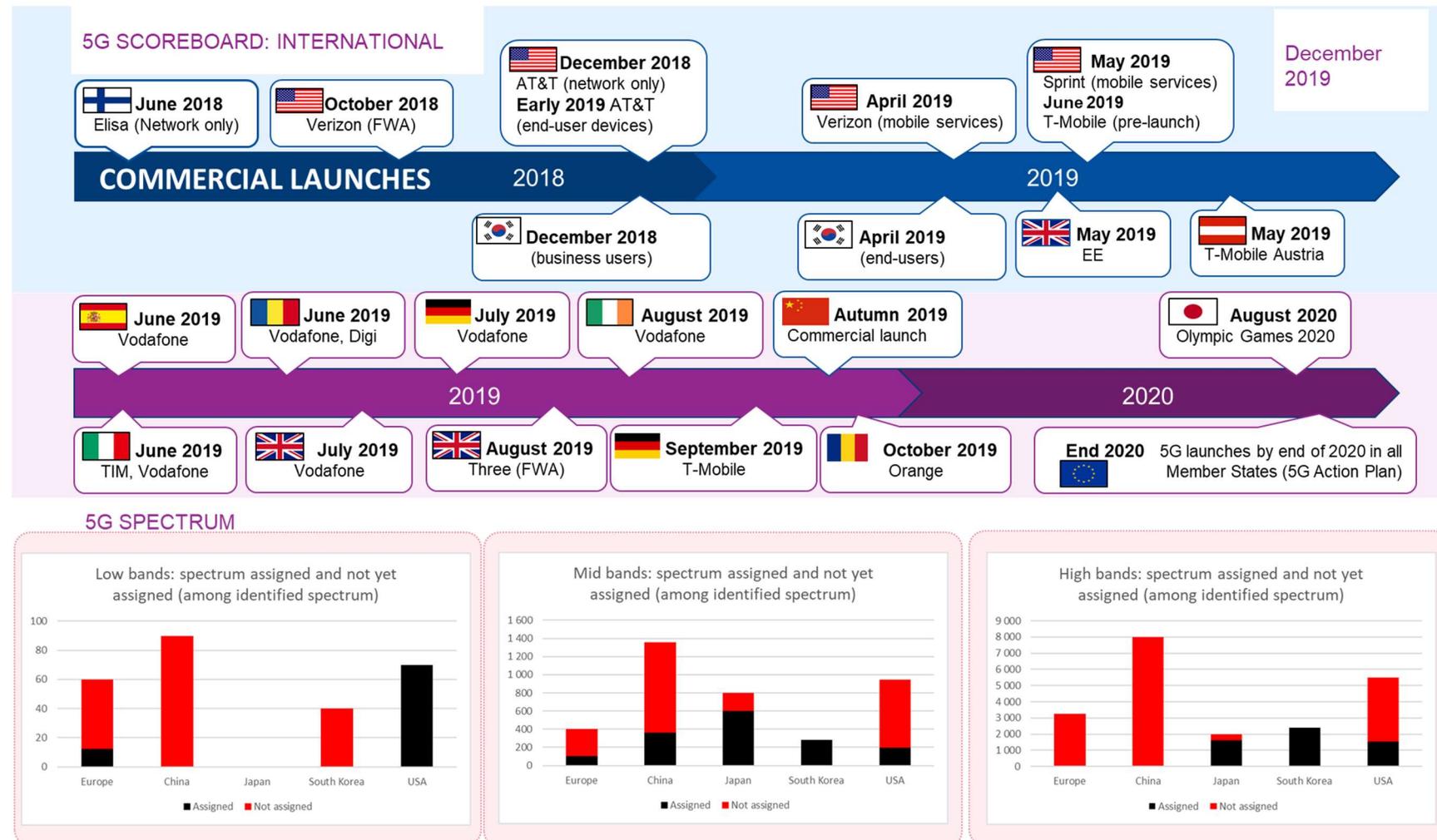


Source: IDATE DigiWorld

2.3.2. 5G scoreboard – International

The international version of the scoreboard details trials and timelines for 5G commercial launches and spectrum plans worldwide.

Figure 2: 5G Scoreboard – International markets (December 2019)



Source: IDATE DigiWorld

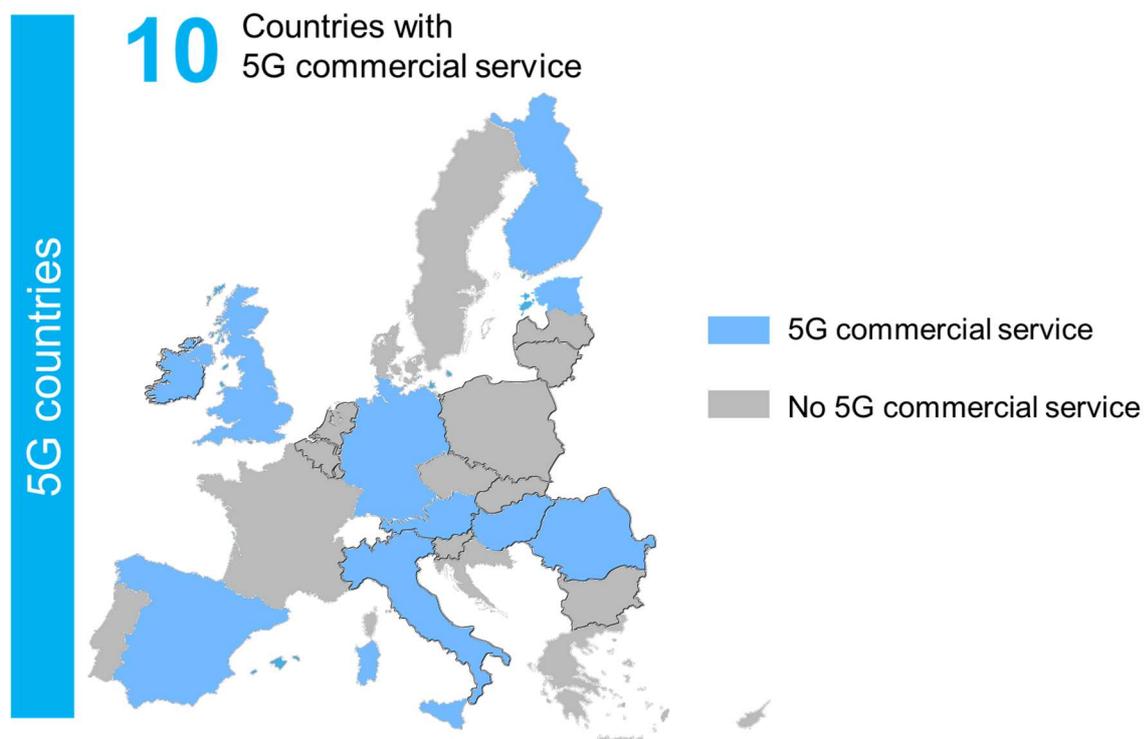
2.4. Announcements of commercial launches

5G is heating up in the world. Verizon launched a Fixed Wireless Access commercial service on October 1st, 2018. The number of alive 5G networks increased significantly in Europe and outside Europe since the beginning of 2019.

2.4.1. Europe

At the end of 2019, 5G commercial services had been deployed in 10 EU countries:

Figure 3: EU countries with 5G commercial service – December 2019



Source: IDATE DigiWorld

Austria

In Austria, T-Mobile announced in March 2019 commercial launch with friendly customers using the 3.6 GHz band. The operator announced it had deployed 25 base stations for this launch in rural areas. The terminals used are 5G routers, which allow connection in WiFi mode for households. The first 5G smartphones are expected by the end of 2019. A greater variety of models and larger numbers of 5G-enabled smartphones and tablet PCs will likely hit the market in 2020.

T-Mobile Austria received usage rights in the 3.4-3.8 GHz band on 7th March 2019, which provided the company the foundation to expand the 5G communications standard throughout Austria. In this auction, T-Mobile Austria acquired 110 MHz of spectrum throughout the country (11 packages of 10 MHz each in 12 regions), for a total price of EUR 57 million.

Three

Three Austria announced a 5G pre-launch after activating its 5G network in the city of Linz in June 2019. The operator activated, in September 2019, more 5G base stations in Worgl and Vienna. A commercial launch of the 5G service is expected to take place later in 2019, when 5G tariff plans will be presented.

The company secured 5G-suitable 3.5GHz spectrum covering all twelve designated regions of Austria for EUR 51.9 million at auction in March 2019.

Finland

Elisa reported its 5G network carried a 5G phone call on 27 June 2018 between the Estonian minister of Economy and her Finnish colleague in Finland. Tests performed showed data speeds of 2.2 Gbps. That said, the first 5G licences were made available in the 3.6 GHz band frequencies in autumn 2018.

Telia Finland launched 5G services in seven cities at the end of 2019. The operator offers Fixed Wireless Access and mobile services.

Germany

Deutsche Telekom

Deutsche Telekom switched on its 5G network on September 5th, in five German cities: Berlin, Bonn, Cologne, Darmstadt, and Munich. The company announced that the network is using 129 5G antennae across the country, 66 of them in Berlin, with bandwidths of 1 Gbps or more.

Customers can choose four 5G plans: the MagentaMobil S with 6 Go at 39.95 EUR/month, the MagentaMobil M with 12 Go at 49.95 EUR/month, the MagentaMobil L with 24 Go at 59.95 EUR/month, and the MagentaMobil XL with unlimited data at 84.95 EUR/month. The new plans are all 5G-enabled.

Vodafone Germany

Vodafone Germany started its 5G network in July 2019. At launch, customers are able to access 5G plans with several plans: 24.99 euros per month for 4 Go, 29.99 EUR per month for 12 Go and 34.99 EUR per month for 24 Go. Vodafone will offer two smartphones that can actually use the new network: The Huawei Mate 20 X 5G and Samsung's Galaxy S10 5G. The Gigacube 5G home router from Huawei will also be available.

Hungary

In October 2019, Vodafone Hungary launched a commercial 5G service limited to Budapest.

Ireland

Vodafone Ireland launched 5G services in August 2019 in selected areas of main Irish cities, including Dublin and Waterford. Two 5G-ready smartphones will be available to users in August and September 2019 – the Huawei Mate 20X 5G and the Samsung Galaxy S10 5G.

In early November 2019, Eir launched its 5G service in 10 towns and cities.

Italy

Vodafone

Vodafone Italy has launched its commercial 5G services in 5 cities on 6 June 2019 (Milan, Rome, Turin, Bologna and Naples). In Turin, the Vodafone network covers 80% of the city with 120 cell sites. The number of cities covered will increase up to 50 by YE2019 and to 100 by 2021. Vodafone offers three 5G smartphones: the Xiaomi Mi Mix 3 5G, the LG V50 ThinQ 5G and the Samsung Galaxy S10 5G.

Vodafone inked a network sharing 5G deal with Telecom Italia early 2019.

Telecom Italia

TIM launched its 5G service on June 24th, 2019 in parts of Rome and Turin. Additional cities will gradually be lighted. TIM offers three new dedicated 5G-ready plans of which 2 are marketed as true 5G. TIM Advance 4.5G offers speeds of up to 700 Mbps and costs EUR 19.99 per month and comes with unlimited calls and SMS plus 40 GB of data at speeds of up to 700 Mbps. By contrast, TIM Advance 5G is a true 5G plan. It costs EUR 29.99 per month and comes with unlimited calls and SMS plus 50 GB of data at speeds of up to 2Gbps. Finally, TIM Advance 5G Top plan costs EUR 49.99 for unlimited calls and SMS plus 100 GB of data at speeds of up to 2 Gbps. Customers on existing plans can sign up to a “5G ON” option at a cost of EUR 10 per month, with the first month free. Two 5G-capable smartphones are being offered by the company: The Samsung Galaxy S10 5G and the Xiaomi MIX 3 5G from Xiaomi. The Oppo Reno 5G will follow shortly.

Latvia

Latvian Mobile Telephone (LMT) launched 5G network in July 2019. Tele2 is carrying tests limited to a few base stations from September 2019.

Romania

Vodafone launched 5G services in Romania on 26 June, 2019 in areas of three cities. Customers can choose two 5G plans: The Red Infinity 17 with unlimited 5G data at EUR 17 per month and Red Infinity 25 with unlimited 5G data and more services at EUR 25 per month. The Huawei Mate 20x 5G is available to users.

Digi

RCS&RDS (Digi) announced its first 5G commercial service in June 2019, in areas of six cities. The company offers two 5G compatible smartphones: the Xiaomi Mi Mix 3 5G and the Huawei Mate 20x 5G.

Orange

In November 2019, Orange Romania launched 5G in Bucharest, Cluj-Napoca and Iasi.

Spain

Vodafone Spain launched its commercial 5G services at 3.7 GHz in 15 cities on June 15 with initial speeds of up to 1 Gbps (and 2 Gbps at YE2019): Madrid, Barcelona, Valencia, Seville, Malaga, Zaragoza, Bilbao, Vitoria, San Sebastian, La Coruna, Vigo, Gijon, Pamplona, Logrono and Santander. At launch, the service is reaching approximately 50% coverage in each of the 15 cities.

Switzerland

In Switzerland, Sunrise announced partial 5G commercial launch in March 2019 and full launch in September 2019. Swisscom launched in April 2019. At launch, Swisscom's network encompassed 100 sites in 50 cities and villages. The Swiss operator is targeting more than 90 per cent population coverage by the end of the year.

UK

EE in the UK launched 5G services on May 30 across six cities, including some areas of London, Edinburgh, Cardiff, Belfast, Birmingham, and Manchester. EE is launching its services with the OnePlus' 7 Pro 5G, Samsung's S10 5G, Oppo's Reno 5G, and the LG V50 ThinQ will also be available in June. Prices for EE's 5G plans start at GBP 54 (EUR 61) a month for 10GB of data, rising to GBP 74 (EUR 83) a month for 120GB. The operator said it expects customers to experience an increase in speeds of around 100-150Mbps. EE is using a Non-Standalone 5G New Radio deployment; from 2022, it will introduce the full 5G core network (5G StandAlone version).

Three UK (FWA)

3 UK switched on its 5G fixed wireless access network, becoming the third of the country's operators to offer services over the new technology. The company turned on its 5G infrastructure in a small number of locations in central London and it's offering a 5G home hub at 35 GBP (38 EUR) per month.

3 UK's strategy centered on building on assets from fixed business UK Broadband it acquired in 2017. The operator plans to launch 5G mobile services in several locations by the end of the year.

Vodafone

Vodafone launched 5G services in the UK in July 2019 in seven cities. It plans to offer 5G services in twelve additional UK cities by ear-end 2019.

Vodafone is offering unlimited data on mobile three speed-tiered data plans. Pricing is then scaled on speed delivered rather than the volume of data used. The Unlimited Lite plan runs at 2Mbps and costs 23 GBP (25.63 EUR) a month. The Unlimited offers speeds at 10Mbps and cost 26 GBP (28.97 EUR) a month. Finally, the Unlimited Max runs at the fastest speed possible by the network and the device and costs 30 GBP (33.43 EUR) a month.

Telefonica (O2)

Telefonica (O2) became on October 17, the latest mobile operator to switch on its 5G network in the UK. Services are available in six cities and towns: Cardiff, Belfast, Edinburgh, Leeds, London, and Slough.

2.4.2. South Korea: all three players have launched 5G services

3.5 GHz and 28 GHz spectrum were auctioned off in South Korea in June 2018. 5G services were launched in December 2018 for business customers and in April 2019 for residential users. It is expected that the deployment of nationwide 5G networks will be fully completed in 2022 or 2023.

SK Telecom, LGU+ and KT launched their 5G service in a number of cities on 1 December 2018 for business customers. The launches came earlier than previously announced and thus expected. In fact, all MNOs announced in July 2018 their intention to jointly launch 5G in March 2019. This intention

arrived one year after a first agreement signed in April 2018 on a shared 5G deployment and network. This first agreement's intention aimed at avoiding a very costly launch campaign when 4G came to reality back in 2011 and generating heavy cost savings of nearly 1 billion USD over the next ten years. In early March 2019, the commercial launch was delayed following the rejection by the government of proposed 5G pricing plans submitted by operators.

The three mobile operators reported 3 million 5G subscribers in October 2019 and plan to have 5 million subscribers at the end of the year.

2.4.3. Australia

Telstra in Australia launched its 5G service at the end of May 2019 as it had switched on over 200 5G sites since August 2018. The 5G service covers 10 cities to date, including parts of Melbourne, Sydney, Canberra, Brisbane, Adelaide, Perth, Hobart, Launceston, Toowoomba, and the Gold Coast. 25 additional cities will be lighted in the next 12 months including the major regional cities in Australia.

Telstra launched its services with the HTC 5G Hub hotspot and the Samsung Galaxy S10 5G. These devices were followed by the OPPO Reno 5G, expected on 11 June. The 5G service will initially be available as a free trial but the company plans to charge an extra AUD 15 per month (EUR 9.3/month). After the trial at the end of June new mobile plans will be introduced.

The operator previously acquired 3.6GHz spectrum for AUD 386 million (EUR 240 million), giving it 60MHz of contiguous 5G spectrum in all major capital cities and between 50 MHz and 80 MHz in regional areas.

2.4.4. Japan

Historically, Japan has been at the forefront of mobile technology. Japan targets the Tokyo summer Olympic Games to launch 5G. However, NTT DoCoMo announced it could pre-launch 5G in September 2019 with plans to deploy commercial 5G services across Japan by mid-2020. KDDI also intends to soft-launch by year-end 2019 with a full launch in 2020. Softbank intends to launch 5G by 2020. Rakuten Mobile was planning to launch its service in 2019 starting with 4G, with 5G following a few months later. But, in September 2019, Rakuten Mobile postponed the launch without further details.

In April 2019, The Ministry of Internal Affairs and Communications (MIC) has assigned spectrum in the 3.7 GHz, 4.5 GHz and 28 GHz bands to all MNOs in Japan. NTT DoCoMo received 3.6-3.7 GHz, 4.5-4.6 GHz and 27.4-27.8 GHz spectrum. KDDI got 3.7-3.8 GHz, 4.0-4.1 GHz and 27.8-28.2 GHz frequencies. Softbank was assigned 3.9-4.0 GHz and 29.1-29.5 GHz spectrum. Rakuten was issued 3.8-3.9 GHz and 27-27.4 GHz spectrum.

As from 2017, Japanese players performed a lot of 5G trials.

2.4.5. China

In December 2018, China issued test licences to players for national 5G trials until June 2020 (China Telecom: 3.4-3.5 GHz, China Unicom: 3.5-3.6 GHz, 260 MHz on 2515-2675 MHz and 4800-4900 MHz). The country awarded four 5G licences to China Mobile, China Unicom, China Telecom and China Broadcasting Network, earlier in June 2019, faster than anticipated.

China Telecom and China Unicom have reached a tentative agreement to jointly build a 5G network and share network infrastructure.

China Mobile, China Telecom and China Unicom have launched 5G services on November 1st, 2019. The operators unveiled their monthly 5G packages. Price plans are quite similar among the three MNOs. Entry-level plans cost 129 CNY (16 EUR) per month and offer 30GB data with 300 Mbps of download speeds and 500 minutes of voice and. Most expensive plans cost 599 CNY (76 EUR) and offer 300GB of data with download speeds of up to 1Gbps. Only high-end price plans offer 5G-like speeds.

The three Chinese operators had already signed up nearly 9 million 5G subscribers in advance.

2.4.6. USA: 3 out of 4 major players have launched 5G services

In the USA, Verizon 5G Home service was launched on October 1st, 2018, in limited areas of four US cities. AT&T turned off 5G mobile services in December 2018 on a limited scale, Verizon Wireless launched 5G mobiles services early April 2019, and Sprint in June 2019. T-Mobile pre-launched 5G services in July 2019 and plans to launch full service by year-end 2019.

Auctions for 28 and 24 GHz spectrum ended in January 2019 and May 2019 respectively. 39 and 47 GHz auctions are expected late in 2019.

Verizon

Before launching 5G services, Verizon performed a number of 5G trials. It launched 5G home service in October 2018 and 5G mobile services in April 2019. Since then, Verizon increased its nationwide coverage.

Trials

Since 2017, Verizon has been testing mm-wave 5G services in 11 cities (in Ann Arbor, Atlanta, Bernardsville, Brockton, Dallas, Denver, Houston, Miami, Sacramento, Seattle, and Washington, DC.). Verizon demonstrated a video 5G call at the 2018 Super Bowl and a NR data lab transmission with Nokia and Qualcomm in February 2018. In June 2018, Verizon tested two-way data transmission and multi-carrier aggregation and very high speeds outdoors. In August 2018, Verizon succeeded in transmitting a 5G signal to a moving vehicle.

In August 2018, Verizon and Nokia achieved a transmission of 5G NR signal to a receiver situated in a moving vehicle using spectrum in the 28 GHz band, in a trial carried out in New Jersey. In September 2018, Verizon, in partnership with Nokia, completed the transmission of a 5G mobile signal to a test van in Washington. The test was carried out with Verizon's mm-wave spectrum and 5G network core, along with Nokia's 5G radio equipment.

In September 2018, Verizon successfully transmitted a 5G signal on a commercial 5G NR network in Washington DC and Minneapolis on prototype devices.

Verizon 5G FWA service

Verizon 5G Home service was launched on 1 October 2018 in limited areas of four US cities (Houston, Sacramento, Indianapolis, Los Angeles). At launch, the service was charged at USD 70 per month (USD 50/month for existing customers). There are no annual contracts, no equipment charges and no data caps. For the first three months, an Apple TV or a Google Chromecast Ultra was offered for free (USD

40 after the first three months). At launch, speeds ranged from 300 Mbps to 1 Gbps, depending on location.

Verizon 5G mobile services

Verizon launched its 5G NR in selected areas of Chicago and Minneapolis in April 2019. This launch coincided with the offering of the new 5G moto mod, which was exclusive to Verizon. Verizon intends to launch its 5G mobile network in more than 30 U.S. cities by year-end 2019. At launch, the company's 5G service plan came with unlimited data, available for just USD 10 a month (with the first three months free) with any Verizon unlimited plan.

AT&T

Since early 2017, AT&T has been performing fixed wireless & mobile 5G trials in Austin, TX, Waco, TX, Kalamazoo, MI and South Bend, IN. It launched 5G services in December 2018 in 12 cities (Atlanta, Charlotte, N.C., Dallas, Houston, Indianapolis, Jacksonville, Fla., Louisville, Ky., Oklahoma City, New Orleans, Raleigh, N.C., San Antonio and Waco, Texas). It extended coverage in parts of 7 additional cities (Las Vegas, Los Angeles, Nashville, Orlando, San Diego, San Francisco and San Jose, Calif.) in the first half 2019. 12 additional cities.

The service is available with the Nighthawk hotspot device. It is charged at 499 USD upfront and a monthly USD 70 payment for 15 GB of data. AT&T announced plans to grow its mobile 5G device lineup with a 5G smartphone from Samsung later in 2019.

Trials

In November 2018, AT&T showcased its first mobile 5G device using mm-wave spectrum as well as the 'first mm-wave mobile 5G browsing session' in Waco, Texas. The described device is a NETGEAR Nighthawk based on Qualcomm Snapdragon X50 5G modem.

AT&T also achieved tests of wireless 5G data transfer over mm-wave spectrum bands, via a mobile form factor device. The trial was carried out in Waco, Texas.

Sprint

Sprint launched 5G services in May 2019 in three cities (Atlanta, Dallas Fort Worth, and Kansas City). In July 2019, it extended services to Chicago and in September 2019 to selected parts of Los Angeles, New York City, Phoenix and Washington DC.

The service was initially available on two devices, the LG V50 ThinQ and the HTC 5G Hub. For USD 80 per month, Sprint's Unlimited Premium launch tariff was charged at 80 USD per month at launch.

The Sprint 5G Non-Standalone network is using 2.5 GHz spectrum and massive 128-antenna MIMO equipment to be able to operate 4G at the same time. The use of lower frequencies will allow Sprint to increase faster its coverage and at lower costs.

T-Mobile USA

T-Mobile USA signed in August 2018 two 3.5bn USD contracts with Ericsson and Nokia to support its nationwide 5G network deployment. Under the terms of the contract, Ericsson will provide T-Mobile with its 5G NR hardware and software, as well as Ericsson's digital services solutions. The mobile operator is targeting early 2019 for its commercial launch. It also expects that its fixed-wireless access

service based on 5G networks will deliver speeds of 100 Mbps for up to two-thirds of the population in the coming years and will be reaching 90% of the country by 2024.

In July 2019, T-Mobile USA pre-launched its 5G services in selected parts of six US cities (Atlanta, Cleveland, New York City, Los Angeles, Dallas, and Las Vegas) using 28 GHz frequencies. It aims at launching true 5G services in 600 MHz frequencies by year-end 2019.

In early December 2019, T-Mobile launched its 5G network in the 600 MHz band. It covers more than 1 million square miles and 200 million people.

2.4.7. Other countries

Bahrain

Batelco and Viva announced they launched 5G services in June 2019.

Kuwait

All the three MNOs in Kuwait launched 5G services in July 2019.

Qatar

Ooredoo in Qatar claimed in May 2018 to be the first world player to launch 5G nationally with 50 sites registered late in July 2018 and 50 additional base stations to be added in August 2018. Ooredoo seems to be providing 5G wTTH (wireless To The Home) services on 3.5 GHz spectrum domestically with the very few compatible devices available (25 devices according to Gulf times).

Vodafone has also launched 5G services in August 2019.

UAE

Du announced the rollout in 2018 of a limited service of 5G. Du's announcement follows rival Etisalat's plans to roll out 5G commercial fixed devices in September 2018.

Du and Etisalat launched 5G mobile services in July 2019.

Saudi Arabia

The SA Kingdom set up a national 5G task force to prepare the foundations for a large scale 5G rollout before the end of 2019.

Since May 2017, CITC (Communications and Information Technology Commission) awarded 160 MHz of additional IMT spectrum in 700 MHz, 800 MHz, and 1800 MHz bands to mobile operators Mobily, STC and Zain.

CITC issued testing licences to all three operators in May 2018. The 3.6-3.8 GHz licences allow the MNOs to test 5G with 100 MHz of spectrum between June 2018 and year-end 2019.

Zain and STC launched 5G services in June 2019.

India

The Indian government is strongly backing 5G deployment but 5G is still in early stages of reflection.

The Department of Telecom (DoT) is harmonizing spectrum in the 3.3-3.6 GHz band and 26 GHz band, along with the 71-76 GHz, the 81-86 GHz and the 57-64 GHz frequencies as 5G candidate bands.

A reasonable target for 5G launch is 2022.

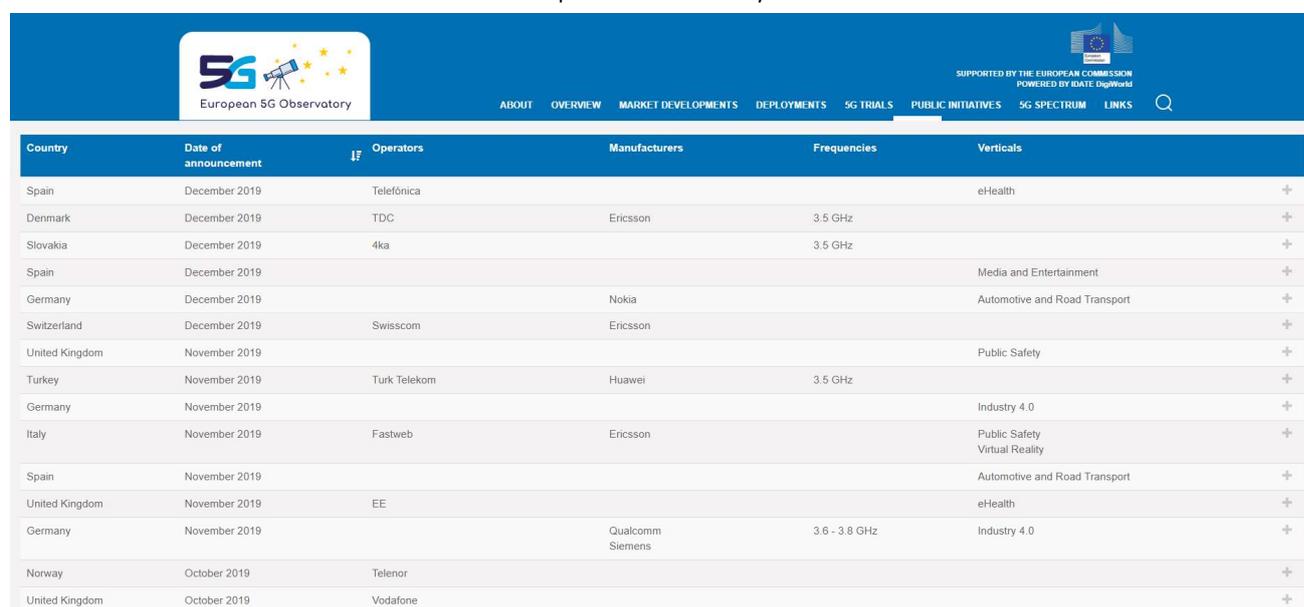
2.5. 5G pre-commercial trials

181 5G trials in the 28 MSs of the European Union and 222 trials including Russia, San Marino, Norway, Turkey and Switzerland

2.5.1. Analysis of the 222 trials registered so far⁵

5G trials are presented in the European 5G Observatory as shown in the figure below:

Table 3: Screen shot of the trials base in the European 5G Observatory



Country	Date of announcement	Operators	Manufacturers	Frequencies	Verticals
Spain	December 2019	Telefónica			eHealth
Denmark	December 2019	TDC	Ericsson	3.5 GHz	
Slovakia	December 2019	4ka		3.5 GHz	
Spain	December 2019				Media and Entertainment
Germany	December 2019		Nokia		Automotive and Road Transport
Switzerland	December 2019	Swisscom	Ericsson		
United Kingdom	November 2019				Public Safety
Turkey	November 2019	Turk Telekom	Huawei	3.5 GHz	
Germany	November 2019				Industry 4.0
Italy	November 2019	Fastweb	Ericsson		Public Safety Virtual Reality
Spain	November 2019				Automotive and Road Transport
United Kingdom	November 2019	EE			eHealth
Germany	November 2019		Qualcomm Siemens	3.6 - 3.8 GHz	Industry 4.0
Norway	October 2019	Telenor			
United Kingdom	October 2019	Vodafone			

Source: IDATE DigiWorld, December 2019

As many as 222 trials have been listed so far. The share of technical tests dropped significantly in the past nine months as some mobile operators have already launched 5G commercial services and others are planning 5G network deployment for 2020.

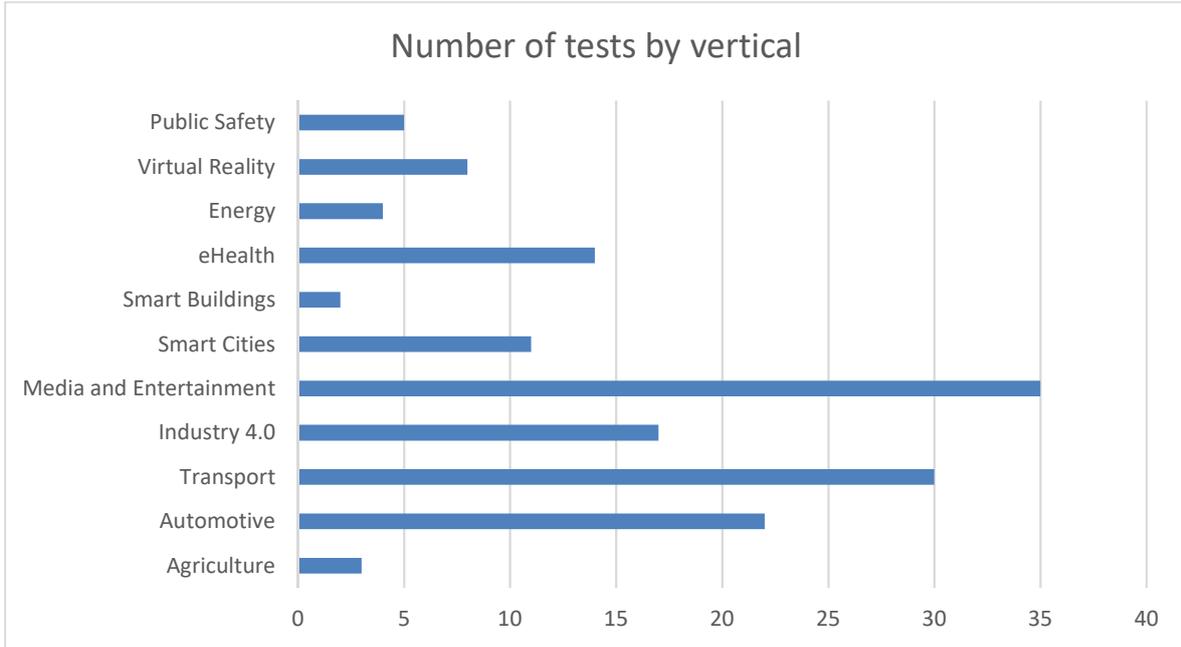
Media and automotive are the verticals majorly driving trials

The most trialled verticals are media and entertainment (35 trials) followed by transport (30 trials) and automotive (22 trials).

The 222 trials were organised in 30 countries (181 in 25 of the 28 MSs of the European Union and 41 in Russia, San Marino, Norway, Turkey and Switzerland). No trials have been registered so far in the following MSs: Cyprus, Malta, and Slovenia.

⁵ The analysis was made with the data available on the 5G Observatory on 12 December 2019

Figure 4: Verticals tested in 5G trials

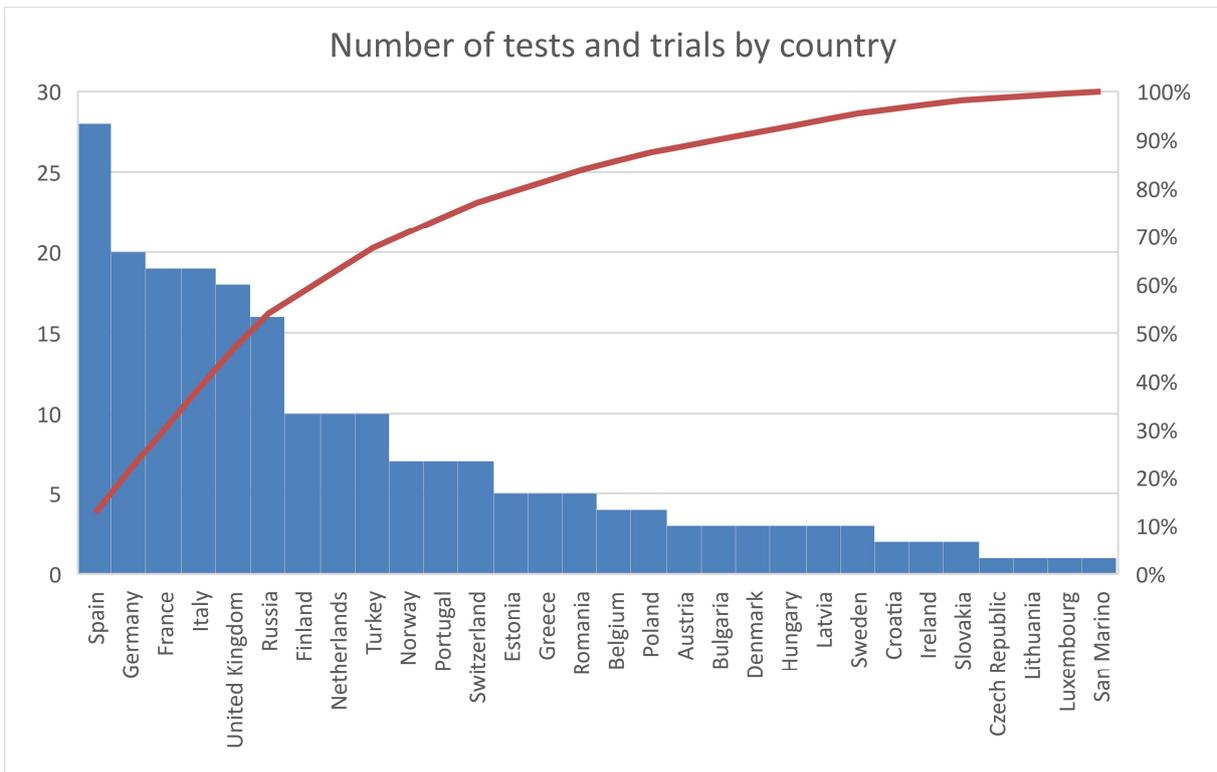


Source: IDATE DigiWorld, December 2019

The most numerous trials performed in Spain, France and Italy

Trials are the most numerous in Spain, Germany, France and Italy. These top four countries are totalling 39% of trials, reaching 47% when the UK is included. Spain remains the first and Germany ranks now in second. Italy and France were overtaken by Germany in number of tests lately.

Figure 5: 5G trials by country



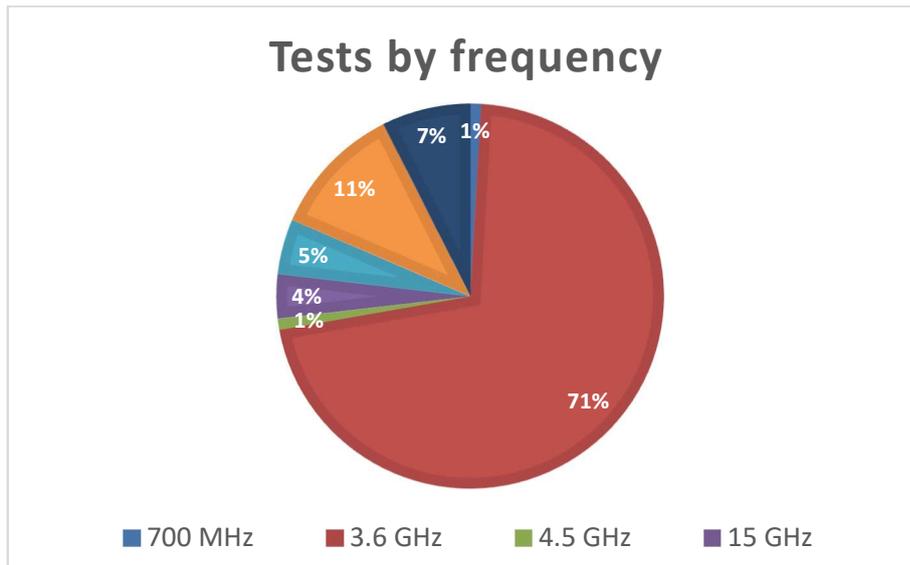
Source: IDATE DigiWorld, December 2019

On average, more than seven trials per country have been listed so far.

The 3.4-3.8 GHz still is the most tested frequency band by far

When indicated (frequency bands tested are available only in selected trials, representing 49% of all trials listed), the most used frequency band for trials is by far the 3.4-3.8 GHz (77 trials tested the 3.4-3.8 GHz frequencies out of 108 trials mentioning which band was considered). The 26 GHz band has been tested 5 times in Europe, and the 28 GHz band 12 times.

Figure 6: Frequency bands tested



Source: IDATE DigiWorld, December 2019

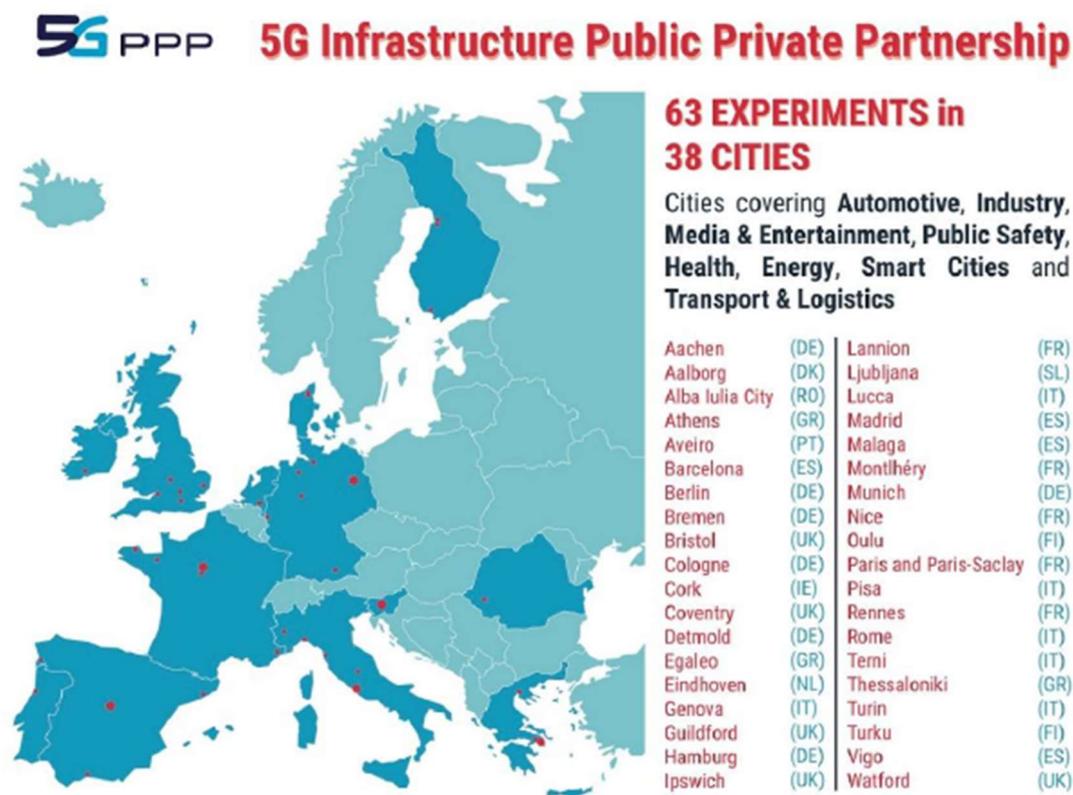
Level of maturity of 5G trials

We evaluate the level of maturity according to three categories:

- 1: Most important 5G pilots: with at least 2 cell sites and involvement of end users
- 2: Other 5G pilots and trials (number by country and by vertical)
- 3: Smaller tests/demonstrators (number by country)

Most trials, 64%, can be qualified as category 3 (small tests or demonstrators), 29% of them can be considered as intermediate (category 2), and about 7% are important tests (with at least 2 cell sites or more).

2.5.2. Trial cities



The European Commission's action plan of September 2016 confirmed by the EU Council in December 2017 targets the commercial rollout of 5G in one major city in every MS by 2020.

Specific cities in Europe announced their plans to become 5G Trials Cities, at the forefront of 5G trials and pilots. At the end of 2017, seventeen Trial Cities had been announced in 9 Member States: Amsterdam, Barcelona, Bari, Berlin, Espoo, L'Aquila, London, Madrid, Malaga, Matera, Milan, Oulu, Patras, Prato, Stockholm, Tallinn and Turin.

Three additional cities in 2 additional MS committed themselves to the target: Aveiro, Bristol and Ghent. In France, nine major regional cities were selected for 5G trials (Belfort, Bordeaux, Douai, Grenoble, Lannion, Lille, Lyon, Marseille, Nantes, Sophia-Antipolis et Toulouse) alongside eleven cities in Paris's suburbs (including Paris, Châtillon, Linas-Monthléry and Saclay). Major trials are taking place in Paris, Bordeaux and Lille. In Italy, the city of Lucca is involved in the H2020 project 5G City by offering the city's network infrastructure to test the possibilities that the new 5G technology can offer to the Public Administrations in the development of digital services.

In Denmark, Copenhagen has also been identified as a key 5G city.

2.5.3. Digital cross-border corridors

Eleven "digital cross-border corridors" established inter alia accommodating live tests of 5G for Cooperative Connected and Automated Mobility

Within the European 5G vertical strategy, Connected and Automated Mobility (CAM) is considered as a flagship use case for 5G deployment along European transport paths, in view of creating complete ecosystems around vehicles, beyond the safety services targeted by the Cooperative-Intelligent Transport System (CITS) roadmap of Europe. In order to prepare for the deployment of 5G cross-border corridors for CAM, the MSs signed, in March 2017 in Rome, a Letter of Intent (LoI) with the view to intensify cross-border cooperation for large-scale testing and pre-deployment. This agreement was preceded by bilateral initiatives between Luxembourg, France and Germany, and among the Nordic countries, and was followed in 2018 by a number of agreements between Spain and Portugal, between Bulgaria, Greece and Serbia, and between Estonia, Latvia and Lithuania over the "Via Baltica", with an extension between Lithuania and Poland. The table below presents the situation regarding the on-going initiatives.

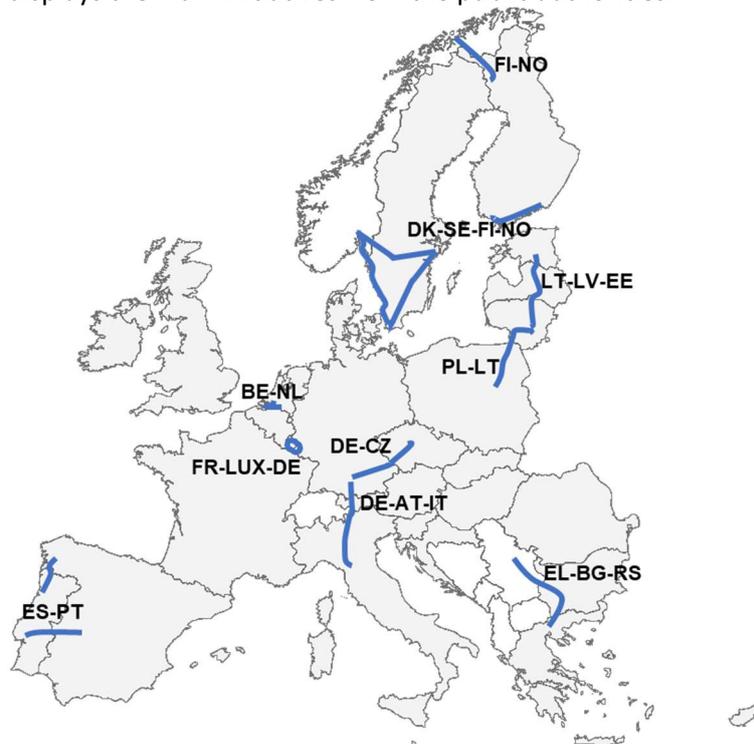
Table 4: 5G CAM cross-border corridors

Corridors	Political Commitment
Metz-Merzig-Luxembourg: FR-DE-LU	LoI between FR and DE in Sept. 2016. LU joined in Sept. 2017. Industry consultation in March 2018. Agreement for test bed signed.
Rotterdam-Antwerpen-Eindhoven: NL-BE	No LoI signed yet
Porto-Vigo: PT-ES	LoI signed on Digital Day 2018, 10 April 2018
Evora-Merida: PT-ES	LoI signed on Digital Day 2018, 10 April 2018
E8 "Aurora Borealis": NO-FI	C-ITS-TEN-T legacy. First 10km Aurora open in FI for testing since Nov. 2017. LoI not yet signed
Nordic Way2: NO-SE-FI-DK	Follows-on Nordic Way 1, funded under C-ITS/CEF, which demonstrated that providing C-ITS services over cellular networks works.
Brenner Corridor: IT-AT-DE	Ahead of DD2, Italy and the three presidents of Euroregion Tirolo-Südtirol-Trentino have confirmed their intention to work, in cooperation with other interested Member States, on the development of the 5G Corridor on the Brenner pass motorway. However, no LoI signed yet.
Thessaloniki, Sofia-Belgrade: EL-BG-RS	Letter of Intent signed in June 2018 during Digital Assembly in Sofia.

Corridors	Political Commitment
EE-LV-LT Via Baltica (E67) Tallinn (EE) – Riga (LV) – Kaunas (LT) – Lithuanian/Polish border	MoU to be signed on 27-28 Sept. 2018 in Riga at the 5G Techritory event. Although focused on C-V2X, elements of the Riga-Tallinn segment are ITS (Smart E67 project).
LT-PL Via Baltica Kaunas-Warsaw	LoI Signed on 5 Sept. 2018. Goal is to cooperate in V2X, C-ITS, 4G LTE, LTE Advanced and 5G with the view to promote CAD.
München-Praha	LoI signed on 18 July 2019. Goal is to cooperate in creating a 5G corridor with the CEF digital 2021-2027 in view and to “establish new cross-country digital platforms and offer new services in economic sectors which are strong both in the Czech Republic and Bavaria such as autonomous driving, robotics, e-health, Artificial Intelligence and Industry 4.0”

Source: European Commission

The following map displays the main initiatives from the public authorities.



Source: European Commission, December 2019

In addition to these initiatives, three Horizon 2020 projects were launched in November 2018 for the conduct of large-scale testing and trials of 5G connectivity for CAM over cross-border corridors, under the umbrella of 5G Public-Private Partnership (5GPPP). Benefiting from a nearly €50 million funding, for a combined total budget of €63 million, the three projects cover three 5G cross-border corridors: Metz-Merzig-Luxembourg (5GCroCo), Porto-Vigo between Spain and Portugal (5G-Mobix), and Bologna-Munich via the Brenner Path (5G-CARMEN). In addition, a small 8 km cross-border segment between Greece and Turkey will be deployed for testing as well.

2.6. 5G cities

The European Commission's action plan of September 2016 confirmed by the EU Council in December 2017 targets the commercial rollout of 5G in at least one major city in every MS by the end of 2020.

Specific cities in Europe announced their plans to become 5G Trial Cities, at the forefront of 5G trials and pilots. At the end of 2017, seventeen Trial Cities had been announced: Amsterdam, Barcelona, Bari, Berlin, Espoo, L'Aquila, London, Madrid, Malaga, Matera, Milan, Oulu, Patras, Prato, Stockholm, Tallinn and Turin. In France, nine major regional cities were selected for 5G trials (Belfort, Bordeaux, Douai, Grenoble, Lannion, Lille, Lyon, Marseille, Nantes, Sophia-Antipolis et Toulouse) alongside with eleven cities in Paris's suburbs (including Paris, Châtillon, Linas-Monthléry and Saclay). As at August 2018, three additional cities committed themselves to the target: Aveiro, Bristol and Ghent. A non-exhaustive list of 5G Trials Cities include Amsterdam, Aveiro, Barcelona, [Bari](#), [Berlin](#), Bristol, [Espoo](#), Ghent, L'Aquila, [London](#), Madrid, [Malaga](#), [Matera](#), [Milan](#), Oulu, Patras, Prato, [Stockholm](#), Tallinn and Turin.

These trial cities aim to provide support for a variety of technology and service demonstrations carried out during the 5G trialling phase, and provide valuable vertical use cases especially for Smart City concept to validate the trials in real user environments. When compared to the private sector, public entities such as cities usually have different interests even in similar use cases focusing e.g. on eHealth, energy, transport, smart buildings or digital service portals. In all of these domains, shared technology platforms, free access, open data and interfaces as well as the maximal involvement of local ecosystems and residents are common priorities.

- For example, the [city of Barcelona](#) is determined to transcend the “Smart City” concept and deploy a programme that integrates and coordinates local initiatives related to a truly digital transformation of the services the city offers to its citizens. Barcelona has just launched the 5GBarcelona strategy towards facilitating the deployment of trials and pilots across the city and so, becoming a 5G smart city. 5GBarcelona will have 5 nodes, to which more will be added until reaching a deployment of 20% of the territory in 2020.
- The [city of Berlin](#) aims to stipulate research and development of 5G technologies, and one of the city's main strategic interests is to enable an innovation-stipulating environment and technology infrastructure, which can eventually provide the 5G experience to the public on the streets of Berlin.
- The [City of Oulu](#) is challenged to modernize the city governance and processes in the framework of constrained public expenditure and demand for deploying disruptive technologies enabling digitization, automation and robotisation in public service delivery. One of the main strategic priorities is to enhance innovation led economic growth and competitiveness of the local economy and for companies to create employment outcomes for the people of Oulu, in order to ensure sustainable and healthy living environment. Arranging broadband connectivity (eMBB) and providing local free 5G network services network for mobile IoT based experiments is the first step to adopt the 5G technologies for citizens and city administration. City also targets people mobility related service trials and offers e.g. traffic-light data as open data for service development...
- Similarly, the [City of Patras](#) is aiming at organising, transforming and finally extending its current digital infrastructure into an open platform that will interconnect 5G related technologies. This digital transformation is performed in order to address e-administration issues related to the City of Patras while enhancing the quality of life of its citizens.
- [City of Bristol](#) as one of the main UK 5G Hub sites, together with University of Bristol, aims especially to demonstrate the 5G technologies for public. The Bristol target has been mainly to show the potential of 5G in shaping the future of social interaction, entertainment, urban

planning and public safety. The similar events such as “[Layered Realities - Weekend](#)”, arranged in March 2018, are planned for the near future. The promotional video from the event is also available. Bristol alongside Bath will be the home of enhanced visual experiences for tourists using Augmented Reality and Virtual Reality in major local attractions as part of the 5G Smart Tourism project which was awarded GBP5 million in March 2018.

- Telecom operators have announced additional trial cities. For instance in France, nine major regional cities were selected for 5G trials (Belfort, Bordeaux, Douai, Grenoble, Lannion, Lille, Lyon, Marseille, Nantes, Sophia-Antipolis et Toulouse) alongside eleven cities in Paris’s suburbs (including Paris, Châtillon, Linas-Monthléry and Saclay).

We estimate that there were 147 5G enabled cities at the end of December 2019 (138 5G enabled cities in EU-28) including 5G cities **identified by Member States** in the COCOM survey (questionnaire on action 1 of the 5G Action Plan for Europe) and identified in the 5G pan-European trials roadmap version 4.0⁵. Enabled cities include pilot 5G cities and 5G-live cities. The number of 5G cities has grown significantly thanks to 5G launches.

Table 5: 5G key cities

European Countries	5G Activities (5G Private Trials and Pilots, 5G National Programmes (incl. Platforms), 5G test Corridors, 5G Infrastructure PPP (Vertical Trials and Pilots and Platforms) and 5G UEFA EURO 2020.	Key Cities
Austria	5G Private Trials & Pilots, 5G test Corridors	Innsbruck, Linz, Worgl
Belgium	5G Private Trials & Pilots, 5G test Corridors	Antwerpen, Brussels, Ghent, Leuven
Bulgaria	5G Private Trials & Pilots, 5G test Corridors	Sofia
Croatia	5G Private Trials & Pilots	Jastrebarsko
Cyprus	5G Infrastructure PPP	Limassol
Denmark	5G Private Trials & Pilots, 5G test Corridors, 5G Copenhagen, Aalborg Infrastructure PPP	
Estonia	5G Private Trials & Pilots, 5G test Corridors,	Tallinn
Finland	5G Private Trials & Pilots, 5G TNF, 5G Finland, 5G test Corridors, 5G Infrastructure PPP	Espoo, Helsinki, Muonio, Oulu, Sodankylä, Tampere, Turku, Ylivieska, Vantaa
France	5G Private Trials & Pilots, 5G test Corridors, 5G Infrastructure PPP	Bordeaux, Chatillon, Douai, Lannion, Lille, Lyon, Marseille, Metz, Monthery, Nantes, Paris, Paris-Saclay, Nice, Rennes, Toulouse

⁵ The Table summarizes the key cities in EU involved in 5G activities related to 5G private trials and pilots, 5G National Programmes (incl. platforms), 5G test corridors, 5G Infrastructure PPP (vertical trials and pilots and platforms) and to 5G UEFA EURO 2020. All the content is based on publicly available information and does not claim to be exhaustive.

European Countries	5G Activities	Key Cities
(5G Private Trials and Pilots, 5G National Programmes (incl. Platforms), 5G test Corridors, 5G Infrastructure PPP (Vertical Trials and Pilots and Platforms) and 5G UEFA EURO 2020.		
Germany	5G Private Trials & Pilots, 5GBerlin, 5G test Corridors, 5G Infrastructure PPP	Aachen, Berlin, Bremen, Cologne, Detmold, Hamburg, Merzig, Munich, Reutlingen, Bonn, Darmstadt
Greece	5G Private Trials & Pilots, Athens5Glink, 5G test Corridors, 5G Infrastructure PPP	Athens, Egaleo, Kalamata, Patras, Thessaloniki, Trikala, Zografou
Hungary	5G Private Trials & Pilots	Budapest, Zalaegerszeg
Ireland	5G Private Trials & Pilots, 5G Infrastructure PPP, 5G UEFA EURO 2020	Dublin, Cork, Limerick, Galway, Waterford, Carlow, Castlebar, Dundalk, Drogheda and Kilkenny
Italy	5G Private Trials & Pilots, 5G MiSE, ROMA5G, 5G test Corridors, 5G Infrastructure PPP, 5G UEFA EURO 2020	Bari, Bologna, Genova, L'Aquila, Lucca, Matera, Milan, Naples, Pisa, Prato, Rome, Terni, Turin
Latvia	5G Private Trials & Pilots	Riga, Talsi
Lithuania	5G Private Trials & Pilots, 5G test Corridors,	Kaunas, Riga, Vilnius
Luxembourg	National Programme (1Q19), 5G test Corridors	Luxembourg-City
Netherlands	5G Private Trials & Pilots, 5G Groningen, 5G test Corridors, 5G Infrastructure PPP, 5G UEFA EURO 2020	Amsterdam, Amsterdam, Eindhoven, Groningen, Rotterdam
Norway	5G Private Trials & Pilots, 5G test Corridors, 5G Infrastructure PPP	Heroya, Kongsberg, Oslo, Tromso, Trondheim
Poland	5G Private Trials & Pilots, 5G test Corridors,	Gliwice, Krakow, Warsaw
Portugal	5G Private Trials & Pilots, Aveiro5GCity, 5G test Corridors, 5G Infrastructure PPP	Aveiro, Evora, Porto
Romania	5G Private Trials & Pilots, 5G Infrastructure PPP	Alba Iulia City, Cluj-Napoca, Bucharest, Iasi
Serbia	5G test Corridors,	Belgrade
Slovenia	5G Infrastructure PPP	Ljubljana
Spain	5G Private Trials & Pilots, 5GBarcelona, 5GTonic, 5G test Corridors, 5G Infrastructure PPP	Barcelona, Bilbao, Cadis, Castelldefels, Ferrol, Gijon, Huelva, Jaén, La Coruña, Logrono, Lugo, Madrid, Málaga, Merida, Pamplona, Sevilla, Talavera de la Reina, San Sebastian, Santander, Segovia, Valencia, Vigo, Vitoria, Zaragoza

European Countries	5G Activities	Key Cities
(5G Private Trials and Pilots, 5G National Programmes (incl. Platforms), 5G test Corridors, 5G Infrastructure PPP (Vertical Trials and Pilots and Platforms) and 5G UEFA EURO 2020.		
Sweden	5G Private Trials & Pilots, 5G test Corridors, 5G Infrastructure PPP	5G Gothenburg, Kista/Stockholm
Switzerland	5G Private Trials & Pilots	Burgdorf, Renens, Zurich. 50 cities covered by Swisscom
United Kingdom	5G Private Trials & Pilots, UK5G, 5G Infrastructure PPP	Belfast, Birmingham, Bristol, Cardiff, Coventry, Edinburgh, Ipswich, Guildford/Surrey, London, Manchester, Martlesham, Watford

Source: 5G-IA

2.7. Spectrum assignment by public authorities

5G pioneer bands identified at EU level are the 700 MHz, the 3.6 GHz (3.4-3.8 GHz) and the 26 GHz (24.25-27.5 GHz) frequencies. Whereas the 700 MHz band has been harmonised through an EC Implementing Decision (EU) 2016(687) of 28 April 2016, a '5G-ready' amendment of the 3.6 GHz implementing decision has been adopted in January 2019⁶. The European Commission adopted an Implementing Decision⁷ to harmonise spectrum in the 26 GHz frequencies in May 2019.

Member States have adopted a common deadline for the effective usability of pioneer spectrum in the European Electronic Communications Code, namely the 3.6 GHz band and at least 1 GHz within the 26 GHz band have to be assigned in all Member States by end of 2020.

All Member States have recognised the need for significant harmonised spectrum for 5G. Work is ongoing. The review of progress towards making spectrum available to 5G shows various stages. Spectrum assignments by MSs are detailed in the Annex section.

2.7.1. Review of spectrum assignment progress

In 13 MSs at least one spectrum auction is complete or on going as at end December 2019. 20.2% of 700 MHz spectrum, 29.4% of 3.4-3.8 spectrum and 3.6% of 26 GHz spectrum has been assigned in the EU-28 as at end December 2019.

The 700 MHz band has been assigned in six Member States: Germany (2015), France (2015), Finland (November 2016), Italy (October 2018), Sweden (December 2018) and Denmark (March 2019).

⁶ Commission Decision (EU) 2019/235 of 24 January 2019 on amending decision 2008/411/EC as regards an update of relevant technical conditions applicable to the 3400-3800 MHz frequency band

⁷ Commission Implementing Decision (EU) 2019/784 of 14 May 2019 on harmonisation of the 24,25-27,5 GHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services in the Union

The following list shows the Member States that have assigned the 3.6 GHz spectrum band so that it can be used in line with 5G technical conditions:

- Austria: 3.4-3.8 GHz, 190 MHz in 3.4-3.6 GHz and 200 MHz in 3.6-3.8 GHz, March 2019
- Czech Republic: 3.6-3.8 GHz in 2017
- Finland: 3.4-3.8 GHz (390 MHz), October 2018.
- Germany: 3.4-3.7 GHz, June 2019, assignment of 3.7-3.8 GHz started in December 2019
- Hungary: 3.4-3.8 GHz (90 MHz), 2016 & 3.6-3.8 GHz, October 2019
- Ireland: 3.6-3.8 GHz (360 MHz), May 2017
- Italy: 3.6-3.8 GHz (200 MHz), October 2018
- Latvia: 3.4-3.8 GHz (400 MHz) in November 2017 and September 2018
- Spain: 3.4-3.6 GHz (160 MHz), 2016 & 3.6-3.8 GHz (200 MHz), July 2018
- UK: 3.4-3.6 GHz (150 MHz), April 2018

In the mm-wave bands, only Italy has so far assigned spectrum in the 26 GHz band. Additional auctions in 26 GHz frequencies are expected in 2020.

At least one spectrum auction in a specific band scheduled for 2019

The auction procedure in at least one spectrum band was scheduled for 2019 in 8 MSs but is likely to be delayed until early-2020:

- Croatia, 3.4-3.8 GHz expected in 2020
- Cyprus, 700 MHz, 3.6 GHz and 26 GHz planned in November 2019 delayed to May 2020
- Estonia, 3.6 GHz, Q2 2019, auction suspended in April 2019, second half 2020
- Hungary, 700 MHz/2.1 GHz/3.6 GHz, not yet launched. 700 MHz, October 2020
- Ireland, 700 MHz, Q4 2020 (On 18 June 2019, ComReg issued Document 19/59, a response to consultation and further consultation on a Proposed Multi Band Spectrum Award for the 700 MHz, 2.1 GHz, 2.3 GHz and 2.6 GHz Bands.)
- Luxembourg: 700 MHz and 3.4-3.7 GHz, initially planned for H2 2019, now expected in 2020
- Lithuania, 3.6-3.8 GHz, expected first half of 2020. For 26 GHz: expected October 2020.
- Romania, 700 MHz/800 MHz/1500 MHz SDL/2600 MHz TDD/3.4-3.8 GHz, Q4 2019 now planned for first half 2020

Spectrum auctions scheduled in 2020

- Austria: 700/1500/2100 MHz/2300 MHz, Spring 2020
- Belgium, 700 MHz in 2020, 3.6-3.8 GHz in 2020, 1.5 GHz in 2020, 26 GHz: no award planned
- Bulgaria plans to auction the 3.6 GHz and 700 MHz bands in Q2 2020
- Czech Rep., 700 MHz and 3.5 GHz in April 2020
- Denmark, 2x30 MHz in 800-900 MHz frequencies, 100 MHz in 2300-2400 MHz frequencies, initially scheduled in September 2018, postponed, 3.5 GHz as from 2020, 26 GHz, Q3 2020
- Estonia, 700 MHz, first half 2020
- Finland, 26 GHz, spring 2020
- France, 3.4-3.8 GHz, April 2020, 26 GHz, 2020

- Greece, 700 MHz in July 2020, 3.4-3.6 GHz by year-end 2020
- Latvia, 700 MHz: award expected spring 2020. 26 GHz: award expected autumn/winter 2020.
- Lithuania, 3.4-3.8 GHz: first half of 2020 being considered. 26 GHz: award expected October 2020
- Luxembourg, for 700 MHz, 3.4-3.8 and 26 GHz: award expected first half of 2020
- Netherlands: 700/1400/2100 MHz, Q2 2020
- Poland, 3.6-3.8 GHz, June 2020
- Portugal, 700 MHz, before July 2020
- Slovenia, 700/1500/2100/2300/3500-3800 MHz, year-end 2020
- Slovakia, 700 MHz, Q2 2020
- Spain, 700 MHz-26 GHz, Q1 2020
- Sweden, 2.3 and 3.5-3.7 GHz, 2020
- UK, 700 MHz (80 MHz) Spring 2020, 3.6-3.8 GHz (120 MHz) by May 2020, 26 GHz: made local licences available on demand subject to co-ordination . test licences awarded in 2019. No clear market demand, award is not expected to take place in 2020.

Spectrum auctions scheduled as from 2021

- Belgium, 31.8-33.4 GHz and 40.5-43.5 GHz from 2022 to 2027
- Greece, 26 GHz, 2020
- Lithuania, 700 MHz: award expected before 30 June 2022
- Malta, 3.4-3.8 and 26 GHz: award expected before 2021
- Netherlands: 3.5 GHz, expected end of 2021/beginning of 2022
- Poland, 700 MHz, before 30 June 2022, 26 GHz: expected before 2022 (subject to market demand).
- Portugal, 26 GHz, 2021
- Romania, 26 GHz, 2021
- Slovakia, 26 GHz, after July 7, 2021

2.7.2. Allowing spectrum use for 5G

Allowing use of spectrum in low, mid and high bands is key for 5G. Effective usability of spectrum will highly contribute to the position of EU Member States in the 5G race.

Mid-band spectrum is defined as the baseline capacity layer, in favour of flexibility for many use cases with higher throughputs, wider spectrum and potential refarming of LTE spectrum. The 3.4-3.8 GHz band is the primary band in Europe with early availability.

High-band spectrum is known as the extreme capacity layer with large amounts of spectrum potentially available for very high capacity, very high data rates but limited coverage, partially offset by massive MIMO. The 26 GHz band (24.25 – 27.5 GHz) is the pioneer high band for 5G in Europe.

Italy was the first Member State to allow spectrum use for 5G in all pioneer bands in September 2018.

Usability of low-band (700 MHz) spectrum

700 MHz spectrum already assigned in Denmark, Finland, France, Germany, Italy and Sweden.

Germany was the first European country to assign 700 MHz spectrum in June 2015. To date, only six MSs have assigned 700 MHz spectrum: Denmark, Finland, France, Germany, Italy and Sweden.

Table 6: Availability of 700 MHz spectrum in Member States (as of end December 2019)

Member State	Frequencies	Tentative/Expected assignment date Date of completion	Comments
Austria	703-733/758-788 MHz	Spring 2020	Public consultation on conditions and targets held in Autumn 2019, till October 21. Frequencies will be granted with coverage conditions
Belgium	703-733/758-788 MHz	2020	
Bulgaria	703-723/758-778 MHz	Q2 2020	2x20 MHz release for 5G, consultation launched
Croatia	703-733/758-788 MHz	n/a	EC issued a decision on 8 November 2018 to initiate proceedings against Croatia
Cyprus	703-733/758-788 MHz	By May 2020	
Czech Rep.	703-733/758-788 MHz	April 2020	Auction rescheduled in October 2019
Denmark	703-733/758-788 MHz	March 2019	Assigned in March 2019, with use expected from April 2020
Estonia	703-733/758-788 MHz	H1 2020	
Finland	703-733/758-788 MHz	November 2016	5G services in 2019
France	703-733/758-788 MHz	November 2015	5G services in 2019/2020
Germany	703-733/758-788 MHz	June 2015	Spectrum approved for use in July 2019
Greece	703-733/758-788 MHz	July 2020	Spectrum available in December 2020
Hungary	703-733/758-788 MHz	October 2020	The procedure was launched in August 2019
Ireland	703-733/758-788 MHz	Q4 2020	Public consultation held during summer 2019
Italy	703-733/758-788 MHz	October 2018	5G services possible in 2022 due to TV use
Latvia	703-733/758-788 MHz	Spring 2020	
Lithuania	703-733/758-788 MHz	30 June 2022	
Luxembourg	703-733/758-788 MHz	First half of 2020	Public consultation in Q3 2018 and Q3 2019
Malta	703-733/758-788 MHz	June 2021	Availability date for 5G commercial use
Netherlands	703-733/758-788 MHz	Spring 2020	Final recommendations disclosed. Plan updated in June 2019
Poland	703-733/758-788 MHz	Before 30 June 2022	Delay requested from 2020 to 2022 in December 2018
Portugal	703-733/758-788 MHz	Before July 2020	Auction is scheduled to begin in April 2020
Romania	703-733/758-788 MHz	Q4 2019	“National Strategy for the Implementation of 5G in Romania” between November 20th and December 21st, 2018 Available as from beginning of 2020
Slovakia	703-733/758-788 MHz	Q2 2020	The band will be released after 30 June 2020
Slovenia	703-733/758-788 MHz	YE2020	Public consultation issued in May 2019. Auction delayed to YE2020 in December 2019
Spain	703-733/758-788 MHz	Q1 2020	
Sweden	703-733/758-788 MHz	December 2018	40 MHz assigned, available as from Jan. 1 st , 2019 till Dec. 31 st , 2040
UK	703-733/758-788 MHz	Spring 2020	80 MHz. Public consultation on auction design till December 9 th , 2019

Source: IDATE DigiWorld, based on NRA information

Usability of mid-band (3.4-3.8 GHz) spectrum

3.4-3.8 GHz spectrum already assigned in 10 Member States: Austria, Czech Republic, Finland, Germany, Hungary, Ireland, Italy, Latvia, Spain and United Kingdom.

3.4-3.8 GHz spectrum has been assigned⁸ in 2016 in Hungary, in May 2017 in Ireland, in Czech Republic in 2017, in April 2018 in the United Kingdom, in July 2018 in Spain and (the upper half of the band) in September 2018 in Italy. Parts of 3.4-3.8 GHz spectrum were awarded in Latvia in November 2017 and September 2018. Finland assigned the 3.6 GHz band in September 2018. In March 2019, Austria assigned 3.6 GHz spectrum. The 3.6 GHz auctions ended in June 2019 in Germany raising unprecedented amounts.

In France, ARCEP and the Government disclosed the assignment procedure, prices and reserve prices for mid-band frequencies late in November 2019.

Outside Europe, the USA is less advanced in this spectrum range. The FCC established a three-tier spectrum sharing system for spectrum at 3.5 GHz in 2015. In 2017, the FCC started to analyse how 3.7-4.2 GHz spectrum could be relevant for mobile broadband. Earlier in 2018, the FCC identified spectrum at 3.4 GHz as a government band for a potential reallocation for mobile broadband.

⁸ Parts of this frequency band are used for 4G fixed wireless access

Table 7: Availability of 3.4-3.8 GHz spectrum in Member States (as of end December 2019)

Member State	Frequencies	Tentative/Expected assignment date Date of completion	Comments
Austria	3410-3800 MHz	March 2019	Four months after approval of the May 2018 tender document (period of approval not limited by law)
Belgium	3400-3800 MHz	2020	
Bulgaria	3400-3800 MHz	Q2 2020	
Croatia	3400-3800 MHz	2020	
Cyprus	n/a	By May 2020	n/a
Czech Rep.	3600-3800 MHz 3400-3600 MHz	April 2020 2017	Auction rescheduled in October 2019
Denmark	n/a	2020	n/a
Estonia	3400-3800 MHz	n/a	Auction expected in Q2 2019 for 390 MHz of spectrum Auction suspended in April 2019
Finland	3400-3800 MHz	October 2018	
France	3400-3800 MHz	April 2020	Public consultation in October 2018, launch of the process in Autumn 2019. Reserve prices disclosed in November 2019
Germany	3400-3700 MHz 3700-3800 MHz	June 2019 December 2019	Full availability in 2022, early stage in 2019 100 MHz dedicated to vertical sites, applications opened on November 21st, 2019
Greece	3400-3600 MHz	2020	Public consultation issued in Q1 2019 Another public consultation expected by YE2019
Hungary	3400-3600 MHz 3600-3800 MHz	June 2016 (90 MHz) Delayed)	For 4G. New technical criteria to be elaborated for 5G 310 MHz for 5G
Ireland	3410-3435 MHz and 3475-3800 MHz	May 2017	Available from January 2019
Italy	3600-3800 MHz	October 2018	
Latvia	3400-3800 MHz	November 2017 September 2018	Remaining 50 MHz
Lithuania	3400-3800 MHz	First half of 2020	Public consultation in Q2 2018 including the 3800-4200 MHz band. New public consultation in Q3 2018. Another public consultation closed in April 2019
Luxembourg	3400-3700 MHz	First half of 2020	Public consultation in Q3 2018 and May 2019
Malta	n/a	Before 2021	Public consultation in Q2 2018
Netherlands	3500-3700 MHz 3400-3450/3750-3800 MHz	End of 2021/beginning of 2022	Final recommendations disclosed. Spectrum available from September 2022 Spectrum available from 2026
Poland	3400-3600 MHz 3600-3800 MHz	n/a June 2020	Public consultation in Q3 2018
Portugal	n/a	June 2020	Auction is scheduled to begin in April 2020.
Romania	3400-3800 MHz	H1 2020	90 MHz TDD valid from 2020 to 2025, 400 MHz available from 2026
Slovakia	3400-3600 MHz 3600-3800 MHz	July 2015 2017	Not for 5G. Licences until 2025.
Slovenia	3500-3800 MHz	YE2020	Public consultation issued in May 2019. Auction delayed to YE2020 in December 2019
Spain	3400-3600 MHz 3600-3800 MHz	2016 July 2018	160 MHz assigned for 4G (and usable for 5G) For 5G
Sweden	3400-3800 MHz	2020	Auction scheduled for March 2020 but could be postponed
UK	3400-3600 MHz 3680-3800 MHz	April 2018 By May 2020	150 MHz assigned in the 3.4-3.6 GHz band 120 MHz to be assigned. Public consultation on auction design till December 9 th , 2019

Source: IDATE DigiWorld, based on NRA information

Usability of high-band (24.25-27.5 GHz) spectrum

26 GHz spectrum is assigned in Italy

Italy was the first Member State to auction 1 GHz of the 26 GHz band; at world level, it ranks second, after South Korea, which already awarded 2,400 MHz spectrum at 28 GHz in June 2018. The USA ranks third globally with 1550 MHz of such spectrum. The FCC auctioned 24 (24.25-24.45/24.75-25.25 GHz, 2x100 MHz and 5x100 MHz) and 28 GHz spectrum (27.5-27.925/27.925-28.35 GHz, 2x425 MHz) in 2018-2019, raising respectively 2.023 billion USD (1.794 billion EUR) and 703 million USD (623 million EUR). The upper 37 GHz, the 39 GHz and the 47 GHz auction began on time on December 10th, 2019. As at December 19th, 2019, bids raised almost 4 billion USD.

Table 8: Availability of 26 GHz spectrum in Member States (as of end December 2019)

Member State	Frequencies	Tentative/Expected assignment date Date of completion	Comments
Austria	24.25-27.5 GHz	n/a	Public consultation on plans for 26 GHz in June 2019
Belgium	n/a	No award planned	Consultation launched
Bulgaria	24.25-27.5 GHz	n/a	Consultation launched
Croatia	24.25-27.5 GHz	n/a	
Cyprus	24.25-27.5 GHz	By May 2020	
Czech Rep.	24.25-27.5 GHz	n/a	Earmarked for 5G in 2019
Denmark	n/a	Q3 2020	
Estonia	24.25-27.5 GHz	n/a	
Finland	26.5-27.5 GHz	Spring 2020	Parts of the range are already available for shared use
France	26.5-27.5 GHz	2020	Public consultation in Q2 2018
Germany	26.5-27.5 GHz	2019	General authorisations Application procedure for local/regional use
Greece	24.25-27.5 GHz	2021	Public consultation scheduled for YE2019/Q1 2020
Hungary	26.5-27.5 GHz	n/a	Public consultation in July 2019, limited demand for 5G. Auction put on hold
Ireland	n/a	n/a	Spectrum assigned in 2017 but restricted to point-to-point (P2P) links
Italy	26.5-27.5 GHz	October 2018	
Latvia	n/a	Autumn/winter 2020	
Lithuania	n/a	October 2020	
Luxembourg	24.5-27.5 GHz	First half of 2020	
Malta	n/a	Before 2021	
Netherlands	24.5-27.5 GHz	From 2020	Ongoing consultations
Poland	26.5-27.5 GHz	Before 2022 (subject to market demand)	Band reorganisation envisioned
Portugal	n/a	2021	
Romania	24.25-27.5 GHz	2021	
Slovakia	24.5-27.5 GHz	Will be assigned after July 7, 2021	
Slovenia	26 GHz	January 2018	Two blocks (56 and 112 MHz) awarded, but not available for 5G
	26 GHz	YE2020/2021	Public consultation issued in May 2019 for 5G
Spain	n/a	2020	Potential rearrangement. 1.4 GHz of spectrum could be assigned
Sweden	24.25-27.5 GHz	2020	Auction process considered and consultations launched
UK	24.25-26.5 GHz		Call for inputs in July 2017. Local licences available on demand subject to co-ordination

Source: IDATE DigiWorld, based on NRA information

2.7.3. Outcome of the WRC'19

The 2019 World Radiocommunication Conference WRC-19 ended on November 22nd, 2019. During four weeks, many agenda items were debated, including Agenda Item 1.13 on mm-wave bands for 5G and Agenda Item 1.6 and 9.1 on the satellite sector. Provisional Final Acts are available [here](#).

Under Agenda Item 1.13, delegates agreed to make frequencies in very high bands such as the 26 GHz (24.25-27.5 GHz), 40 GHz (37-43.5 GHz), 45.5-47 GHz, 47.2-48.2 GHz and 66-71 GHz available for 5G services and to protect existing radio usages. In total, 17.25 GHz of spectrum has been identified for IMT. Out of this number, 14.75 GHz of spectrum has been harmonized worldwide, reaching 85% of global harmonization.

- The 26 GHz (24.25-27.5 GHz) band was identified for 5G. Long-term protection of the EESS in the frequency band 23.6-24 GHz was considered as vital for weather prediction and disaster management (resolution 750). European satellites concerned are those from the Copernicus programme and those from the European Agency Eumetsat.
 - It was thus decided that unwanted emissions of 5G stations brought into use before 1 September 2027 shall thus adopt an out-of-band emission limit of:
 - -33 dBW in any 200 MHz of the passive EESS band for 5G base stations until September 1st, 2027.
 - After 1 September 2027, the limit will be more restrictive, to -39 dBW in any 200 MHz. This new more restrictive limit will apply only to new 5G sites.
 - In Europe, technical conditions are based on the work performed by CEPT and ITU-R. The unwanted emission power level is considered in terms of TRP. TRP is to be understood as the integral of the power transmitted from all antenna elements in different directions over the entire radiation sphere. The RSPG is now considering an amendment of Commission Implementing [Decision EU 2019/784 of May 2019](#) (-42 dBW in any 200 MHz for each base station and -38 dBW in any 200 MHz for each terminal) to consider this outcome.
- The bands 45.5-47 GHz and 47.2-48.2 GHz were also identified for 5G usage in certain countries, mainly outside Europe.
- The existing identification of the band 4800-4990 MHz for IMT applications was extended to some additional countries, while maintaining the existing conditions for protection of other services in the band.
- WRC-19 also agreed new rules to increase global access to connectivity and broadband communications through new satellite technologies
- In addition, WRC-19 defined a plan of studies to identify frequencies for new components of 5G, including High Altitude Base Stations (HIBS). They may be used as part of terrestrial IMT networks to increase coverage in under-served areas.
- The agenda for the next WRC-23 was agreed under AI 10. Among the 19 Agenda Items, AI 1.2, AI 1.3 and AI 1.5 deal with IMT. AI 1.2 will consider IMT identifications in 3300-3400 MHz (footnote to be amended in Region 1, Region 2), 3600-3800 MHz (Region 2), 6425-7025 MHz (Region 1), 7025-7125 MHz (global), 10000-10500 MHz (Region 2). AI 1.3 will consider primary mobile allocation in 3600-3800 MHz (Region 1). AI 1.5 will review 470-960 MHz in Region 1.

2.8. Product/market developments

In recent months, the 5G chipset market has evolved quite a bit with major 5G baseband vendors announcing a second generation of chipset, new players emerging, one old player leaving the 5G baseband market and another one threatening the future development of its chipset portfolio. The development status of those chipsets varies quite a lot. As of beginning of December, 2019, around 15

5G chipsets had been in development or released but at the end of December 2019, only 8 chipsets could be considered as commercially available (two from Qualcomm, three from Huawei, 2 from Samsung and one from Mediatek). As of end of September 2019, we reported only 5 of them. Of all the products announced, it is sometimes unclear whether they are a new product in development or just a renaming of an existing 5G chipset in development.

2.8.1. Overview of the 5G baseband market as of early December 2019

Three players already with a second generation 5G chipset

Table 9: Presentation of announced 5G chipsets

Vendor	Product name	Announcement	Availability	Throughputs	Comments
Qualcomm	X50 (baseband)	First announced in 2016	End of 2018	Up to 5 Gbps	Discrete baseband, need to be implemented with 2G/3G/4G baseband. 18 OEM announced to use X50
Qualcomm	X55 (basebands)	February 2019	Expected to ship in 2H 2019	Up to 7 Gbps in the DL, 3 Gbps in the UL	Now support FDD in sub 6 GHz with up to 200 MHz bandwidth
Qualcomm	Snapdragon 865	December 2019	Q1 2019	Up to 7.5 Gbps in the DL / 3 Gbps in the uplink	Does not integrate x55 modem, an indication of the way toward more mature ecosystem. Qualcomm explains that this decision derives from the willingness not to compromise modem performance
Qualcomm	X52 (basebands)	December 2019		Up to 3.2 Gbps / 1.6 Gbps	
Qualcomm	Snapdragon 765 and 765G	December 2019	Q1 2020	Up to 3.2 Gbps / 1.6 Gbps	
Samsung	Exynos 5100	August 2018	End of 2018	Up to 2 Gbps in sub 6 GHz and 6 Gbps in mmWaves	Integrated multimode 2G/3G/4G/5G chipset, built on 10nm process, fully compatible with 3GPP Rel 15
Samsung	Exynos 5123	October 2019	mass production expected to begin by the end of 2019	Up to 7.35 in mmWave and 5.1 GHz in sub 6GHz. In LTE: 3 Gbps/422 Mbps	Built using a 7nm EUV process. It also support 1024 QAM in 4G
Samsung	Exynos 980	September 2019	Mass production by the end of 2019 and devices available in the beginning of 2020	Up to 2,5 Gbps/1,28 Gbps and up to 3,55 Gbps through LTE/5G Dual connectivity	SoC with integrated 5G baseband, do not support mmWaves
Hi-Silicon	Balong 5G01	February 2018	End of 2018	Up to 2.3 Gbps	Only for Huawei products, designed for fixed 5G devices
Hi-Silicon	Balong 5000	January 2019		Up to 4,6 Gbps at sub 6GHz and 6,5 Gbps on mmWaves	Dubbed as the first single chip multi mode modem (2G/3G/4G/5G) and first to support 2CC of 100MHz
Hi-Silicon	Kirin 990 5G	sept-19	End of Q4 2019/2020	Up to 2,3 Gbps/1,5 Gbps	mass production thought to start in Q3 2019, along the introduction of the Huawei Mate 30 model
Mediatek	Helio M70 (MT6885)	June 2018	2019-2020	Up to 4,7 Gbps (DL) / 2,5 Gbps (UL)	Devices powered by Helio M70 to be available in early 2020 while being sampled in Q3 2019. Partnership with

Vendor	Product name	Announcement	Availability	Throughputs	Comments
					China Mobile. It will use 7 nm EUV process from TSMC
Mediatek	Dimensity 1000 SoC / MT6885 based on Helio M70	May 2019	sampling in Q3 2019, available in devices in Q1 2020	Up to 4,7 Gbps (DL) / 2,5 Gbps (UL)	5G SoC with an Helio M70 integrated. First commercial devices launched on 27th of December, 2019 with the Oppo Reno 3 in China
Mediatek	MT6873 (based on Helio M70)	October 2019	mass production in Q2 2020 for availability in commercial phones in Q3 2020	Up to 4,7 Gbps (DL) / 2,5 Gbps (UL)	No mm-wave support

Source: IDATE DigiWorld

Those chipsets seem fairly similar, with support for 5G NR radio interface, both in Non-Standalone (NSA) and SA (Standalone), up to 8 channel aggregation, 256 QAM modulation in the downlink and support for both sub-6 GHz frequency bands and mm-waves. Because more bandwidth is available in the mm-waves than in the sub-6 GHz band, possible performance differs depending on the frequency band used. In detail though, not all those chipsets are similar though with sometimes little difference, sometimes bigger difference that hint at a more complicated situation than saying that Qualcomm is simply ahead of the competition.

Unlike in the early days of 4G, the 5G baseband offering is much more interesting. Qualcomm is leading the market, being the first to announce and make its 5G baseband commercially available and after releasing its first fully multimode 5G/4G/3G/2G modem X55, now to be found in commercial devices, it is releasing an integrated 5G SoC with the Snapdragon 765 and 765G. At the end of October 2019, Qualcomm said it already had 230 5G devices from more than 40 OEMs announced or in development with Qualcomm 5G silicon. Based on data from GSACOM from end of August 2019, 71 announced 5G devices were based on Qualcomm 5G baseband (57%), while 11 (9%) were on Huawei, 2% on Mediatek and 1 (1%) on Samsung. As compared to the end of May, Qualcomm had the biggest growth of device announcements. It should however be reminded that quite a big share of device announced (31%) could not be associated with a specific 5G baseband name.

Table 10: Number of 5G devices powered by baseband vendors as of end of December 2019

Baseband vendor	Number of devices
Qualcomm	71
No data	39
Huawei	11
Samsung	1
Mediatek	2

Source: IDATE based on gsacom

Those figures are quite logical as Huawei and Samsung have been initially developing their own baseband for their own devices both to reduce their dependence on other silicon manufacturer and to increase their differentiation capabilities through deeper integration between hardware and software. While those figure still highlight the dominance of Qualcomm on the market, the simple fact that those players were able to develop their own 5G baseband to be used on their flagship devices is a telling example of the progress they have made as compared to 10 years ago. In addition to using their own baseband or SoC in their devices (e.g. Huawei is using its Balong 5000 in numerous 5G CPE and dongles as well as in its own smartphone such as the Mate X, the Mate 20x 5G while its integrated

5G SoC power the Mate 30 5G and Mate 30 Pro), those players are also trying to sell their 5G silicon to OEMs. In November 2019, Vivo notably announced that its x30 smartphone would be powered by Samsung All-in-One 5G chipset Exynos 980.

Although Qualcomm certainly has a market and technological maturity that is still to be proved for other players, both Huawei and Samsung on the paper show promising progress. Qualcomm x50 initial 5G baseband indeed was a discrete 5G only modem that has to be paired with a 2G/3G/4G modem to work and while supporting both mm-waves and sub 6 GHz spectrum with associated RF components, only TDD mode in the sub 6 GHz band was supported. Qualcomm x55 announced at MWC 2019 is in essence the first complete 5G solution from Qualcomm with integrated support for both 2G/3G/4G/5G, FDD and TDD mode in the sub 6 GHz and support for 2 Carrier Aggregation of 100MHz in the sub 6GHz. The associated RF components also come with the support for the 26 GHz mm-wave band that will be used in Europe notably and is able to support the 28 GHz band if necessary. This new baseband is now powering the new 5G devices that are being launched right now.

Similarly, Huawei has announced its second generation of 5G baseband with similar improvement to a somewhat limited 1st generation. Announced in January 2019, one month before Qualcomm X55, Huawei boasted to be the 1st to release a full multimode 5G chipset as well as capable of supporting 2 carrier aggregation in the sub 6GHz to support up to 4.6 Gbps. Samsung with its Exynos 5100 had a multimode 5G modem but did not support 2 CA in the sub 6 GHz spectrum until it announced the Exynos 5123 in October 2019. This modem, to be paired with Samsung Exynos 990 SoC, which does not have cellular connectivity integrated, will support up to 7.35 Gbps in mmWave, on pair with Qualcomm x55 and up to 5.1 Gbps in sub 6 GHz.

New baseband ahead from other players

If Qualcomm, Huawei and Samsung are the top three 5G baseband players, two other vendors (excluding Intel that dropped the 5G baseband market) have announced 5G solutions, Mediatek and UniSoC. Mediatek, after announcing the Helio M70 back in June 2018 announced its integrated 5G SoC in May 2019 and has seen its first OEM commercial product launched at the end of December 2019 with the Oppo Reno 3 that will be sold in China. With this mid-tier solution, Mediatek is well geared too to increase its position in the 5G device market.

As for Unisoc which announced the Makalu Ivy510 at MWC 2019, it is targeting the (Chinese notably) mid-tier smartphone and IoT market. Unisoc was previously known as Spreadtrum and had development partnership with Intel for LTE chipset for Chinese device but the partnership over 5G has been dropped and Unisoc is now following its own route with a commercial availability for early 2020.

Figure 7: 5G modem to be integrated in All-In-One SoCs



Source: Mediatek

... and Intel, quitting the 5G smartphone modem market

In April 2019, as Qualcomm and Apple announced they had dropped all litigation worldwide and reached a 6-year licence agreement together with a multi-year chipset supply, Intel followed with the announcement that they would quit the 5G smartphone modem market. Intel had announced two 5G basebands in November 2017 and 2018, the second one believed to replace the first one, but although Intel stated that those products would be available during the 2nd half of 2019, there was skepticism on its ability to achieve this timeline. Reportedly, Intel had difficulties in developing its 5G smartphone baseband and faced multiple delays in the development of their 5G offering.

In a context of severe legal battle with Qualcomm over IP licensing and royalties, Apple had tried to diversify its sourcing of 5G connectivity solutions and was known as Intel's (by far) biggest customer for cellular baseband. Because of Intel delays in the development of its 5G solution and market pressure for Apple to develop a 5G iPhone, Apple saw the solving of its dispute with Qualcomm as the most relevant way of solving this issue. This, plus Intel's difficulties in its development led Intel to leave the 5G baseband market, reportedly focusing on network infrastructure instead.

This news is of particular interest in the development of the 5G device ecosystem. Despite the supply agreement with Qualcomm, Apple is believed to be continuing the development of its own 5G chipset, something that will still take time for Apple, 2023-2025 being the horizon often mentioned by analysts for an Apple modem to reach a commercial iPhone. At the end of July 2019, Apple purchased most of Intel 5G business for that matter for 1 billion USD. This will enable Apple to integrate its modem more closely in its own Ax SoC and thus reduce power consumption and release place for other component thanks to the reduced footprint within the device.

The uncertain future of Huawei chipsets

As a result of the economic war between China and the US, Huawei products were banned in the US. While this interdiction will directly affect only the US and considerably disrupts Huawei's ambition to become the n°1 smartphone manufacturer in the world, it may more generally affect the development of Huawei smartphones as the sale of American technology to Huawei has also been made illegal. A direct consequence is the inability for Huawei to use Google Android and associated services (leaving Huawei with AOSP, the open source version of Android) in the short term. This is notably causing the new Mate 30 Pro, announced in September 2019 to come without any Google service. More importantly this will cause more difficulties in continuing the development of its own chipset through its silicon company HiSilicon if no agreement is found.

Indeed, Huawei, as every smartphone vendor, heavily relies on ARM IP design for the development of its chipset and while still unclear in the detail, ARM has reportedly decided to stop any contact with Huawei, some of its IP design and tool originating from the US, before restarting limited contact with the Chinese firm. While Huawei will be able to leverage the IP and tools it has already got from ARM, it may have to completely rethink the design of its chipset, should this ban continue to be implemented. In the short term this is not an issue as Huawei can rely on its existing generation of chipset but this may be a sizeable issue in the future, especially for its flagship devices.

Mid-range 5G chipsets on their way

In 2020, 5G chipsets will continue their expansion in lower-tier smartphones with the announcement of the Snapdragon 765 et 765G in December 2019, which will sport an integrated 5G modem contrary to Qualcomm flagship chipset, the Snapdragon 865. In order to maintain a right Bill of Material for its mid-tier platform Qualcomm also created a new baseband, the X52, that is not as powerful as the x55 that was announced in February 2019. Indeed, this x52 support half the throughput of the x55 that will be paired with the Snapdragon 865 because of a capability to aggregate only half of the spectrum that the x55 is capable of aggregating. As an example, the x55 can aggregate up to 800 MHz in the mm-wave spectrum (8x100 MHz) while the x52 in the SD 765 can only aggregate 400 (4x100 MHz). The same goes with sub-6GHz where the x55 can aggregate up to 2x100 MHz vs 100 MHz for the x52. In the end, what this choice reveal is also that the level of maturity is not yet enough for the highest network performance to be directly integrated in Qualcomm most powerful System on Chip.

In a context of increased competition on the 5G chipset (and despite few of them being used in commercially launched devices) Qualcomm had previously announced that it would bring 5G connectivity to its Snapdragon 6xx and 7xx series in 2020. With the announcement of those two new 5G SoC, other chipsets in the Snapdragon 6xx series remain to be announced in 2019.

In a similar move, Mediatek, which saw its first commercial device (the Oppo Reno 3) powered by its 5G chipset on the 27th of December, 2019 announced that it intended to launch another 5G chipset for mid-range devices in 2020. This chipset, codenamed MT6873 will start mass production in Q2 2020 for availability in commercial devices in Q3 2020.

2.8.2. 1st 5G devices are there and not only dongles and CPEs

The release of 5G baseband and RF systems is the first step before commercial devices. Usually, when a new radio technology is released, basebands are developed and implemented in relatively simple devices such as mobile WiFi hotspots, before more complex devices such as smartphones, where integration is always more challenging. Before fully commercial devices can be made available, several steps are required.

Figure 8: The steps a device takes to market



Source: IDATE DigiWorld, September 2018

This time, with 5G, Fixed Wireless Access was one of the first use cases, rather than mobile usage and first commercial devices announced have been 5G home routers, such as the one announced by Huawei at MWC 2018 in Barcelona, or the one by Samsung. Those early devices have been more specifically designed for carrier partners Verizon in the US and in South Korea, and have already received their approval by the FCC.

Figure 9: Huawei and Samsung 5G home routers for 5G Fixed Wireless Access



Source: Huawei and Samsung

Those first devices are available in indoor and outdoor versions. Since then however, the ecosystem has continued its expansion alongside that of the smartphone devices. An illustration of this is the announcement in October 2019 by Qualcomm that over 34 OEMs planned to use its X55 5G modem alongside a specifically designed for FWA antenna solution.

Figure 10: OEMs planning to launch Qualcomm based x55 5G FWA CPEs



Source: Qualcomm

Smartphones and modules, most popular form factors indicates an already relatively rich ecosystem powered by 5G basebands

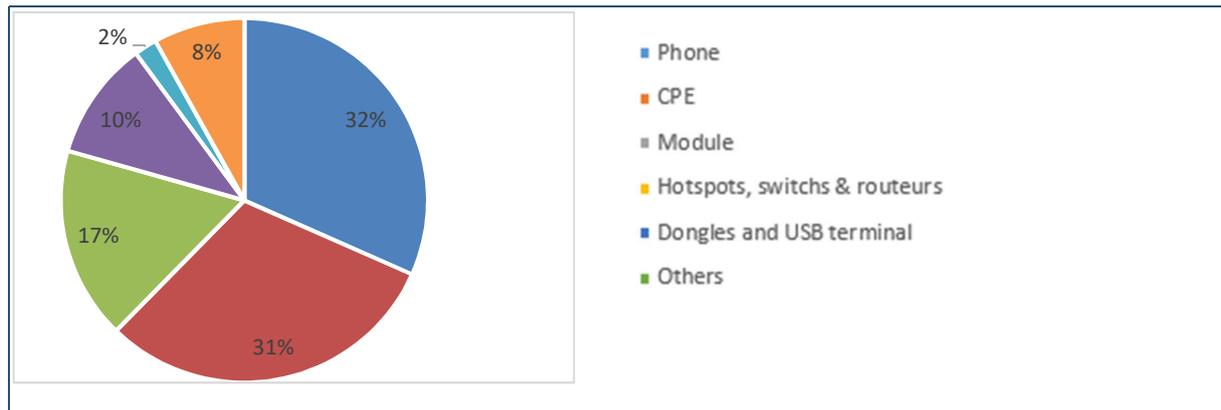
But since those early 5G devices designed for fixed wireless usage, the first mobile 5G networks have been launched in the world and the device ecosystem, thanks to the enabling basebands, has “considerably” widened. As of mid-December 2019, indeed, Gsacom reported 199 5G devices announced by 76 different vendors and 15 different categories of form factors, some of which are fairly similar. As a comparison, at the same time, Gsacom reported around 15,000 different LTE devices.

Table 11: Simplified composition of the 5G device ecosystem as of December 2019

Formfactors	# of devices announced
Phone	63
CPE	61
Module	34
Hotspot	13
Router	7
Robot	3
Tablet	3
Television	3
Snap-on dongle	2
Drone	2
Laptop	2
USB terminal	2
Head mounted display	2
Switch	1
Vending machine	1

Source: gsacom

Figure 11 : Distribution of 5G device ecosystem as of December 2019



Source: gsacom

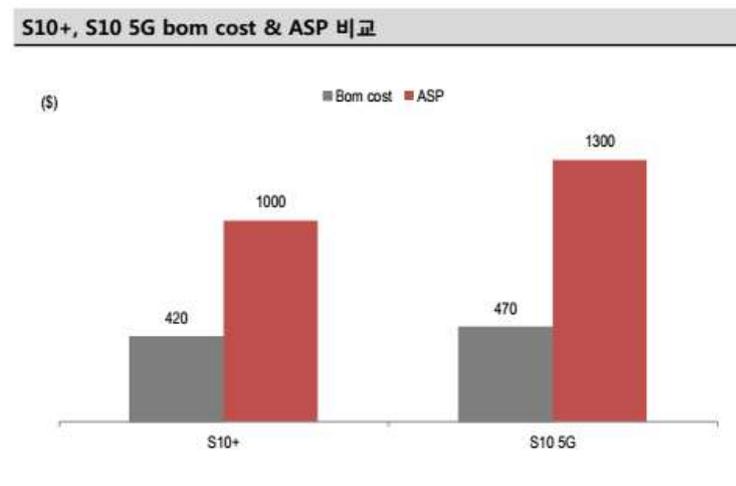
The fact that smartphones are the 1st category of devices announced together with modules is a noteworthy fact. CPEs and modules, are usually the first devices to go to the market when a device ecosystem is building up but smartphone usually come afterwards

In detail most of the devices launched in 2019 have been based on Qualcomm Snapdragon 855 along an X50 modem but in 2020, most devices will be based on second generation 5G baseband and heated

competition with first devices powered by Mediatek 5G solutions. While initial 5G devices often had either sub 6 GHz, either mm-wave RF system, 2020 should also see first mmWave+sub6 GHz devices. The reason for not including support for both frequencies is to be found in the different geographical/market choices regarding frequency bands for deployment, but also in the cost that those additional frequency bands incur. At this stage, the RF and antennas add a significant toll to the total Bill of Material (BOM) of 5G devices without even talking of power consumption, time has not yet come for worldwide 5G devices supporting all the 5G frequency bands.

If we look at the price of 5G smartphones, they mostly come with a premium versus not 5G smartphones as it is exemplified with the Samsung Galaxy S10 5G. It should be noted that the 5G version of the S10 does come with more additional features than just the 5G connectivity. Eventually, what the analysis of Bill of Material and Average selling price shows is that even though the cost of the components is higher for the 5G variant of the smartphone, its selling price secures a higher margin for the device manufacturer today.

Figure 12: Comparison of BOM and ASP (average selling price) of 5G and non 5G variant of the Galaxy S10



자료: IHS, SK증권

Source: SK Telecom and HIS

Tomorrow, as lower-tier 5G solutions are released on the market thanks to a wider 5G baseband/SoC portfolio, the premium price for 5G device should decrease. This decrease of price will come principally at this stage of cost optimizations and “reduced” 5G performance as compared to high-end 5G solutions as exemplified by the difference between the Snapdragon 765 and the x55 modem that is found in the snapdragon 865. The 5G performance of the Snapdragon 765 is still far better than the best 4G possible performance, topping at a theoretical downlink throughput of 3.2 Gbps but is still below the 7.5 Gbps that the x55 is capable of. Of course, this differentiation doesn’t really matter when the capabilities of the network do not even match this level of throughput.

“5G ready” smartphones are going to be marketed

An interesting thing to notice is the fact that because of longer replacement rate in some countries (closer to 4-5 years than 2 years) for smartphones, some MNOs will rather sell 5G-ready devices (i.e. devices supporting 5G even though 5G has not yet been deployed in the network) than 4G only device. The rationale for this carrier demand is to be able to switch as many users as possible on the less-costly 5G network when it is deployed. In countries where 5G launch are imminent, the same decision could

be taken by operators and also device manufacturers that want to be able respond to the consumer demand not to invest in 4G phones when 5G is coming soon.

The 3.5 GHz frequency band, not mm-wave is the most popular frequency bands for 5G

Despite much noise around mm-waves deployment abroad, the sub 6 GHz device ecosystem is doing strong and especially the 3.5 GHz band which provides interesting capabilities with a mix of coverage and capacity when wide bandwidth configuration are used (100 MHz). More precisely, the n78 band (3.5 GHz) is the most popular frequency band in terms of devices announced mirroring the sizeable number of network believed to use this frequency band. Given the wide availability of this frequency band worldwide, this is not a big surprise but definitely an interesting fact for European 5G networks. While not providing as much bandwidth as mm-waves (largest possible bandwidth configuration is 100 MHz) it is providing a much larger coverage. As compared to lower frequency bands, it still sport better capacity and is better suited to massive MIMO deployment in the field because of the much smaller antennas required.

Thanks to features such as Dynamic Spectrum Sharing, a 5G device ecosystem for “legacy frequencies” is also being built with devices announced supporting several of those bands (such as the much used 1800 MHz, 2100 or 700 (APT) MHz) and even though no 5G network have been yet deployed in those bands.

Not surprisingly again, much of the mm-wave device ecosystem is driven by the need to support US 5G network. No devices yet have been announced for n258 (26 GHz) which will be the mm-wave frequency of choice in Europe (and China) for latter deployments.

Table 12 : Distribution of announced 5G devices by range of frequency band

Frequency band range	Number of devices announced
39 GHz (mainly US)	11
28 GHz (mainly US)	15
n257 (JP, SK and US)	5
n258 (Australia, China, Europe)	0
n261 (Verizon)	10
between 3.5 and 5 GHz (Global)	100
between 1.8 and 2.6 GHz (Global)	106
< 1.8 GHz (Global)	50

Source: gsacom, halberdbastion and IDATE

2.8.3. Infrastructure ecosystem

Infrastructure equipment is probably even more important than devices in the early building of an ecosystem, as they are used to test the technology features and concepts, even as the technology is being standardized within 3GPP. Equipment vendors were early in announcing their effort in building 5G technology, often by announcing trials efforts with Mobile Network Operators and/or chipset

manufacturers. Those demonstrations were often focused on pieces of technologies or concepts, such as Massive MIMO, the use of mm-wave in different mobility scenarios...

As industry efforts have now resulted in early (and accelerated) standardization of the technologies and as first operators have now started the launch of their 5G networks, all equipment vendors have built and presented a 5G solution.

Those solutions share more or less the same features, although each vendor has designed its solution around its main strength. These features are:

- **3GPP Release 15 compliance:** Release 15 is the first official release of 5G. Before that, some equipment vendors have worked around unfinalized versions of the standard, or as is the case of network operators having built a pre-standard (such as Verizon with the 5GTF). As the Release 15 of 3GPP has seen its specs frozen, infrastructure equipment now highlights their full Rel. 15 compliancy.
- **End-to-end offering:** in the race to being the most advanced vendor, it is important to show full end-to-end product portfolio, which means having a core network solution, a transport solution, a base-station adapted to different scenarios (e.g. such as indoor or outdoor), and a “front-end” solution with diverse antenna solutions
- **A (virtual) core network solution:** this is built to be deployed in the cloud for maximum flexibility and to support the deployment of certain network functions at different places in the network, in a centralized or more or less distributed (up to the edge of the network) way
- **Support for massive MIMO:** Massive MIMO, beam forming and beam tracking and beam steering are key features to attain increased spectrum efficiency in 5G. The support of this feature is thus key for equipment vendors to assert 5G ambitions
- **Support for sub 6 GHz and mm-wave:** While mm-wave has received much of the attention in the race to 5G because of all the challenges associated in operating a radio network in these frequency bands (the 26 and 28 GHz bands notably), but C band below 6 GHz has also seen traction because of its roaming capabilities for 5G. In Europe, nearly all 5G deployments that have already taken place have been in this band rather than in the 26 GHz band, because of its better coverage capabilities and the feeling of operators that they are not yet running out of capacity (as compared to the U.S. for instance).

Below, we present the 5G portfolio of each equipment manufacturer. Their claim is often similar and as for device baseband, those claims can be seen through different angles. The table **Erreur ! Source du renvoi introuvable.** below summarises what stands out from each vendor solution:

Table 13: Infrastructure equipment 5G solutions from major vendors

Equipment vendor	Most notable for	Device manufacturer
Huawei	FWA and end to end solution (up to the baseband for devices)	Yes
Ericsson	End to end solution. Indoor and outdoor solution, spectrum sharing between 4G and 5G	No
Nokia	End to end solution. Cloud solution. ReefShark chipsets for network solutions	No
ZTE	End to end solution. Massive MIMO, Ultra Dense Networks	Yes
Samsung	Provision of RAN equipment with mm-wave capabilities, FWA and end to end solution (up to the baseband for devices)	Yes

Source: IDATE DigiWorld, December 2019

5G expanding into lower frequency band for increased coverage (and capacity)

In 2020 and beyond, after early deployments, 5G will slowly expand its coverage thanks to lower frequency bands. This however won't be possible without flexible solution such as Dynamic Spectrum Sharing (DSS) which enable to seamlessly and dynamically "refarm" 4G spectrum for 5G application. Instead of dedicating a fixed portion of a frequency band to 4G or 5G, the idea is to support both 4G and 5G users in the same frequency band. It is such especially useful for sub 3.5 GHz bands used by 4G (the mid and low frequency bands of 5G) as it will expand 5G coverage outside the spotty area where "higher band 5G" has been deployed. This feature support has been announced with Qualcomm x55 5G chipset at MWC 2019 and is set to be supported by most equipment vendors (Ericsson, Nokia, Samsung, ZTE...). Other baseband vendors such as Mediatek are also supporting this feature in their latest chipset.

It should not be seen as a way to deploy 5G in a single band but as a way to increase throughput in low frequency bands where little bandwidth is available. DSS is thus meant at being used in carrier aggregation configuration. In the very low frequency bands such as in the 600 MHz or even in the 700-800 MHz band, the spectrum available is often very limited and as such offer very limited performance.

5G infrastructure contracts announcements

The first significant 5G infrastructure contracts have been announced in the previous months and are summarized in the table below:

Table 14 : 5G infrastructure contracts

Country	MNOs	Equipment Vendors	Amount	Time period	Additional information
Denmark	TDC	Ericsson	n/a	5 years	TDC will start rolling out of Ericsson 5G New Radio (NR) hardware and software products in 2019
Germany	Deutsche Telekom	n/a	20 bEUR	2018-2021	5G launch in 2019. Target 99% pop. Coverage (90% geo. Coverage) by 2025
Germany	Telefonica Deutschland	50% of the RAN will be handled by Huawei	n/a	n/a	
Norway	Telenor	Ericsson	n/a	n/a	Telenor selected Ericsson for its RAN ditching Huawei which supplied its 4G network
UK/Ireland	Three	n/a	>2 bGBP (2.3 bEUR)	2018-	5G launch in H2 2019. 62 MEUR in CAPEX in H1 2018/100 MEUR per year (Spectrum, fibre network, 20 new data centres, CA)
Spain	Telefonica	Huawei	n/a	n/a	Huawei will be selected as one of the vendor for the core network
France	Orange	Decision in early 2019	A share of 7.4 bEUR		Orange intends to spend 7.4 bEUR in investments in 2018, a 3% increase compared to 2017. Orange will enhance its fibre deployment and the LTE coverage and prepare 5G.
Outside Europe					
USA	T-Mobile USA	Nokia	3.5 bUSD	2018-	5G launch in 2019. Building of a 3GPP 5G NR nationwide network using 600 MHz and 28 GHz spectrum and Nokia's 5G technology (AirScale radio platforms and cloud-native core, AirFrame hardware, CloudBand software, SON and 5G Acceleration Services)
USA	T-Mobile USA	Ericsson	3.5 bUSD	2018	5G NR equipment, digital services solutions, including dynamic orchestration, business support systems (BSS) and Cloud Core
China	All three MNOs (CM, CU, CT)	Nokia	>2 bEUR	2018-2019	5G launch in 2019. 1-year deal for 4G radio and fixed access equipment, IP routing and optical transport equipment. Investments dedicated to 4G networks' upgrade pave the way to 5G
China	All three MNOs (CM, CU, CT)	Nokia	2.2 bUSD	2019	In November 2019, Nokia signed deals with China Mobile, China Unicom and China Telecom, for a total of \$2.24 billion. The contracts cover network upgrades and 5G construction. Ericsson also signed contracts with the three operators but the amount was not disclosed.
South Korea	SKT	Mainly Samsung (5G), Ericsson, Nokia	9 bUSD (o/w Ericsson, 5 bUSD for 5G)	2017-2019	IoT, 5G, IA, autonomous vehicles Ericsson announced a contract in March 2019 for 5G standalone core networks technology, implementation and operations
South Korea	KT		23 trillion KRW (20.5 bUSD)	2018-2023	5G R&D (5G Open Lab in Seoul), 5G tests and launch, other tech. Ericsson announced a contract in March 2019 for 5G NR hardware and software for KT's 3.5 GHz Non-Standalone (NSA) network
Japan	NTT DoCoMo		1 trillion JPY (8.8 b USD)	2018- 2023	1 trillion JPY on infrastructure (590 bJPY in 2018, up from 570 bJPY initial target). 10 bJPY (80 KEUR) for offering pre-commercial 5G services in limited locations by Sept. 2019 (official target for launch)

Country	MNOs	Equipment Vendors	Amount	Time period	Additional information
Japan	Rakuten	Nokia, AltioStar...	Total CAPEX of \$5bn	2019-2021?	Fully virtualized 4G network ready for 5G
Japan	Softbank	Nokia, Ericsson	Undisclosed		Nokia's 5G AirScale for the 5G RAN Ericsson: primary 5G vendor for the deployment of a multi-band 5G network

Source: IDATE DigiWorld, December 2019

In the race to 5G contracts for equipment manufacturers, it is difficult to say who is really winning so far because of not all the figures being released and made public. Ericsson for instance states that it currently has 78 5G commercial agreements or contracts with unique operators out of which 31 have been publicly announced and out of which 24 are live 5G networks. While the American ban on Huawei has been seen as an opportunity for its competitors it has not prevented the Chinese infrastructure vendor to claim the leadership in the past but this is something that is difficult to follow over the time. Recently, Huawei claimed at last 60 5G contract of which with 28 European operators. As for Nokia, it secured 50 commercial contracts for 5G at the end of October, making it potentially the last of the 3 equipment vendor in the 5G race.

But figures do not tell the whole story. Behind the figure, indeed, Nokia has claimed in the past to be leading in terms of the comprehensiveness of the 5G solution sold to operator. In an article to Fierce Wireless, Sandro Tavares, Nokia's head of global mobile networks marketing said that "More than half of the deals that we have signed actually include more than just radio". It should be noted here also that most of the MNOs usually contract with several network vendors.

3. Annexes

3.1. National strategies and plans by MS

3.1.1. Austria

Main points

- Between July 2017 and September 2017, RTR launched a public consultation on 5G spectrum auctions.
- 3.4-3.8 GHz SCA (Simple Clock Auction) took place in March 2019.
- 700 MHz/1500 MHz/2100 MHz, expected in March 2020
- 5G Strategy for Austria, April 2018.
- All MNOs started 5G trials.
- T-Mobile Austria 5G launch in March 2019

RTR consulted three times on 5G spectrum between July 2017 and February 2018, finally opting for a SCA on 3.4-3.6 GHz bands scheduled in February 2019. On May 28th, 2018, TKK decided on the revision of the Position Paper on Infrastructure Sharing in Mobile Networks.

The Austrian Government set up a steering group for 5G in February 2017. The [“5G strategy for Austria”](#) document was approved in April 2018.

The document defines three phases:

- Pre-commercial 5G tests are expected to be held during the first phase by mid-2018
- By year-end 2020, nationwide availability of 100 Mbps connections should be almost reached. This creates the basis for a nationwide expansion of 5G. At the same time, the market launch of 5G in all provincial capitals should take place.
- In Phase 3, 5G should be accessible across the main traffic roads by year-end 2023, followed by nationwide coverage two years later.

It lists 24 actions in terms of spectrum, funding, research..., translating into ten concrete measures for 5G applications.

On Dec 20, 2018, the consultation on the product and auction design for the award 700/1500/2100 MHz started. The tender is expected in autumn 2019 and the auction in Q1 2020.

In June 2019, RTR issued a consultation on potential assignments of the 2.3 GHz and 26 GHz bands. The 2.3 GHz band was mentioned in the 2016 Spectrum Release Plan whereas the 26 GHz was not.

In August 2019, the Austrian Government announced the new national broadband strategy ‘Breitbandstrategie 2030’. The strategy aims to provide nationwide access to gigabit-capable broadband services by the end of 2030.

The goals are:

- Nationwide access to 100 Mbps speeds by end 2020
- Launch 5G in all federal state capitals by end 2020

- Becoming a ‘5G pilot country’ by early 2021
- 5G coverage along all main traffic routes by end-2023
- Nationwide coverage of 5G by the end of 2025.

In September 2019, the RTR chief said 700/1500 (eight blocks of 10 MHz) /2100 MHz (12 blocks of 2x5 MHz) frequencies to be auctioned in March 2020 will be granted under coverage conditions. A public consultation on conditions and targets was open till October 21, 2019. The government aims for main traffic routes to have 5G services available by the end of 2023, and to have “virtually nationwide” 5G coverage by the end of 2025. 700 MHz licences will include coverage of 900 underserved communities with speeds of 30 Mbps download and 3 Mbps upload, 90% of federal and state roads – to enjoy at least 10 Mbps download and 1 Mbps upload.

3.1.2. Belgium

- Draft strategic plan 2020-2022 late in 2019

Royal Decrees adopted in July 2018 among which draft regarding the 700 MHz, 1500 MHz and 3600 MHz bands. Plans released in September 2018.

In July 2018, Royal Decrees were adopted among which draft regarding the 700 MHz, 1500 MHz and 3600 MHz bands. In September 2018, the BIPT released its plans for the introduction of 5G in Belgium. 700 MHz, 3400-3800 MHz and 1500 MHz (SDL, or Supplementary Downlink) frequencies are expected to be auctioned in the autumn of 2019. The 26 GHz band auction will not take place before 2021. Upper frequencies (31.8-33.4 GHz and 40.5-43.5 GHz) should be auctioned as from 2022.

The BIPT provided consultations on the introduction of 5G in Belgium in September 2018, a communication regarding the introduction of 5G in Belgium (September 2018) and the national strategy for 700 MHz band in October 2018. The BIPT gave details on the 700 MHz auction in November 2018. Bids will start at a reserve price of 20 million EUR per 5 MHz block for 20-year licences.

In May 2019, the BIPT issued a consultation on its draft decision to deny CityMesh’s request to add some municipalities to its 3.5 GHz band licence. It also opened a public consultation to assess interest in using the 26GHz band for 5G services. It believes it possible to assign six blocks of 200 MHz without migrating the band’s existing users, while a further ten blocks would be available once the spectrum is vacated.

BIPT published its draft strategic plan 2020-2022 for public consultation until December 8, 2019. The document mentions plans to award the 700 MHz, 1500 MHz, and 3.5 GHz bands, and to renew rights for the 900 MHz, 1800 MHz, and 2.1 GHz bands, which expire in March 2021. The auction has been delayed due to a disagreement over how the amount raised by the sale should be distributed.

3.1.3. Bulgaria

5G border corridor Bulgaria, Greece, Serbia.

The Communications Regulation Commission (CRC) of Bulgaria closed a public consultation on frequency allocations in October 2017. It proposed to sell eight blocks of 5 MHz in the 1.5 GHz band (1452-1492 MHz), three paired blocks of 5 MHz in the 2 GHz band (1920-1935 MHz/2110-2125 MHz), 14 paired 5 MHz blocks of frequency division duplex (FDD) spectrum in the 2.6 GHz band (2500-2570

MHz/2620-2690 MHz), ten blocks of 5 MHz TDD spectrum in the 2.6 GHz band (2570-2620 MHz), 34 blocks of 5 MHz in the 3.6 GHz band (3430-3600 MHz) and further 22 blocks of 5 MHz TDD in the 3.6 GHz band (3645-3700 MHz and 3745-3800 MHz). The auction is scheduled for the second quarter 2020.

In July 2018, Bulgaria, Greece and Serbia signed an agreement to develop an experimental 5G cross-border corridor (Thessaloniki – Sofia – Belgrade) that will test autonomous vehicles.

In December 2018, Bulgaria’s telecommunications authority (CRC) opened a public consultation procedure on a draft decision to adopt an updated regulatory policy for management of radio spectrum. It includes a proposal to redistribute spectrum in the 3400-3800 MHz band for 5G use and define the conditions for use of at least 1GHz of spectrum in 24.25-27.5 GHz band.

Another public consultation was launched on elements of a new radio spectrum policy including redistribution at 1800 MHz, allocation of 2000 MHz frequencies, use of 3400-3800 MHz spectrum, conditions for releasing 1 GHz of 24.25-27.5 GHz frequencies for 5G, allocation of 700 MHz to mobile services.

In October 2019, CRC indicated it had taken actions for the harmonisation of the 5G pioneer bands by amending the regulatory framework.

3.1.4. Croatia

Strategy for Broadband Development in Croatia 2016-2020.

The [Strategy for Broadband Development](#) in Croatia for 2016-2020 was adopted in July 2016. It aims at achieving full broadband deployment by a technology neutral approach. The estimated budget for the implementation of the Strategy measures is circa 770 MEUR.

A round table on “introduction of the 5G network in Croatia” was held in May 2018. On January 25, 2019, HAKOM issued a public consultation for allocating spectrum in 2.5-2.69 GHz for the period of May 2019 until October 2024. The frequencies could be used for 5G.

According to HAKOM, at the 3400-3590 MHz band 90 MHz is now available and after 4 November 2023 the whole band will be available countrywide. The 3590-3800 MHz band will be available countrywide after 31 December 2020. The 24.25-27.5 GHz band is available countrywide.

In March 2019, Croatia adopted a new plan with 5G as a priority. At the same time, Tele2, A1 and Croatian Telekom were awarded spectrum in band 7 (2500-2690 MHz).

3.1.5. Cyprus

Updated Cyprus Broadband Plan 2016-2020⁹

⁹

[http://www.mcw.gov.cy/mcw/dec/dec.nsf/all/46C0AB062D81E9D7C225838600407D2A/\\$file/%CE%91%CE%BD%CE%B1%CE%B8%CE%B5%CF%89%CF%81%CE%B7%CE%BC%CE%AD%CE%BD%CE%BF%20%CE%95%CF%85%CF%81%CF%85%CE%B6%CF%89%CE%BD%CE%B9%CE%BA%CF%8C%20%CE%A0%CE%BB%CE%AC%CE%BD%CE%BF%20%CF%84%CE%B7%CF%82%20%CE%9A%CF%8D%CF%80%CF%81%CE%BF%CF%85.pdf?openelement](http://www.mcw.gov.cy/mcw/dec/dec.nsf/all/46C0AB062D81E9D7C225838600407D2A/$file/%CE%91%CE%BD%CE%B1%CE%B8%CE%B5%CF%89%CF%81%CE%B7%CE%BC%CE%AD%CE%BD%CE%BF%20%CE%95%CF%85%CF%81%CF%85%CE%B6%CF%89%CE%BD%CE%B9%CE%BA%CF%8C%20%CE%A0%CE%BB%CE%AC%CE%BD%CE%BF%20%CF%84%CE%B7%CF%82%20%CE%9A%CF%8D%CF%80%CF%81%CE%BF%CF%85.pdf?openelement)

In 2016, the Cyprus Broadband Plan 2016-2020 was published and updated in December 2018, in order to be aligned with the targets of the European Gigabit Society and the 5G Action Plan.

The document covers the strategic objectives, the broadband actions and the national roadmap for 5G. In the long term the objectives are 100% coverage with 30 Mbps and 50% household penetration with 100 Mbps by 2020. The Official procedure for licencing the 5G priorities bands (700 MHz, 3.6 GHz and 26 GHz) is expected in Q4 2019.

On August 30, 2019, the Cyprus government issued a consultation on its plans to auction the 700 MHz, 3.4-3.8 GHz, and 26 GHz bands. The consultation will be opened to public comment until September 27, 2019. The auction was scheduled for November 2019. Results are not disclosed. Licencees will have to provide 40% 5G geographical coverage within 2 years and 85% within 5 years.

700 MHz

Cyprus is working hard to resolve outstanding problems relating to the 700MHz band and include it in the auction of 5G spectrum since there is a cross-border coordination problem with a third country (Turkey).

3.4 -3.8 GHz band

There is growing interest in the market for 5G, so in January 2019 the government gave three (3) pilot (trial) national licences in 3.4 -3.8 GHz band to the three (3) existing mobile operators, with 100 MHz bandwidth each, in order to test the equipment and the relevant applications.

26 GHz

Cyprus is planning to also authorize this band according to the expected harmonized EU Decision.

3.1.6. Czech Republic

- National Plan for the Development of Next Generation Networks 2016-2020.
- 3.7 GHz spectrum auctioned off. Spectrum auctions in the 700 MHz and 3.5 GHz frequencies scheduled for January 2020
- The Government of the Czech Republic adopted the National Plan for the Development of Next Generation Networks in October 2016.
- The Czech Telecommunication Office (CTU) auctioned off 3.7 GHz spectrum in 2017 to four bidders, including two new players:
 - Telecom 5G: two 40 MHz blocks 3720-3760 MHz and 3760-3800 MHz
 - O2 Czech Republic: one block 3680-3720 MHz
 - PODA: 3640-3680 MHz
 - Vodafone Czech Republic: one block 3600-3640 MHz
 - Each 40 MHz block was sold for CZK 203 million (9.2 million USD), for a total of CZK 1.015 billion.

This spectrum seems to be dedicated to “Geographically localised BWA with fixed, mobile or nomadic terminals” and not 5G (source: CTU - <http://spektrum.ctu.cz/en/band/3400-3600-mhz?filter%5BfrequencyFrom%5D=3&filter%5BfrequencyFromUnit%5D=GHz&filter%5BfrequencyTo%5D=4&filter%5BfrequencyToUnit%5D=GHz>).

- Consultation for the 3.4-3.6 GHz band took place from June 2018 until January 2019.
- At the beginning of 2019, CTU gave more details on the 5G auction that includes the 700 MHz and the 3.4-3.6 GHz bands for consultation until 25 January 2019. In June 2019, the CTU published the draft plan of the 700 MHz (2x30 MHz, 703–733/758–788 MHz) and 3.5 GHz bands auction (190 MHz, 3410-3600 MHz). The auction was rescheduled to April 2020, in October 2019. The regulator wants frequency allocations granted in April and frequency blocks available to operators by mid-2020. The minimum price for individual auction blocks will be 6.3 billion CZK (240 million EUR). Terms and condition of the auction:
 - Successful bidders will have to cover municipalities currently identified as white spaces.
 - They must cover 95% of the population of all these communities within three years of the allocation.
 - By January 2025 100% of the backbone network of railway and road corridors, and 95% of municipalities above 50,000 must be covered.
 - Within ten years the winning operators must cover 99% of the population and 90% of the territory of each district of the Czech Republic.

3.1.7. Denmark

5G Action Plan for Denmark published.

The national 5G plan was published in February 2019. In March 2019, Denmark completed its auction of the 700, 900 and 2,300 MHz bands, TDC, Hi3G and TT-Netvaerket, raising total proceeds of DKK 2.21 billion (EUR 296 million). The licences are valid from April 2020.

- Hi3G Denmark ApS won 2 x 10 MHz in the 700 MHz band and 2 x 10 MHz in the 900 MHz band at a total cost of almost 65 million EUR
- DC A/S won 2x15 MHz in the 700 MHz band, 2x10 MHz in the 900 MHz-band, 60 MHz in the 2300 MHz band and 20 MHz for SDL in the 700 MHz-band at a total cost of almost 217 million EUR
- TT-Netvaerket P/S won 2x5 MHz in the 700 MHz band and 2x10 MHz in the 900 MHz band at a total cost of 14 million EUR

According to the 5G Action Plan, the 3.5 GHz band is expected to be made available for 5G in 2020. It is further expected that 5G will be introduced in the 26 GHz band afterwards.

In December 2019, the Danish Energy Agency has issued a consultation on spectrum for private 5G networks, particularly in the 3.5 GHz band. Responses to the consultation are asked by January 6, 2020.

3.1.8. Estonia

Estonia conducted a consultation on 5G in April 2018. The NRA, TJA, indicated in May 2018 that an auction would be organised for the 3.6 GHz band.

In January 2019, the Minister of Entrepreneurship and Information Technology signed a draft regulation setting the basis, so that electronic communications operators can start developing 5G networks in the 3.6 GHz band.

In March 2019, a 5G spectrum roadmap was issued with plans to auction 700 MHz spectrum in the first semester 2020. The potential of spectrum in the 40-44 GHz and 66-71 GHz ranges was mentioned.

The auction for 390 MHz of spectrum in the 3.6 GHz band was suspended in April 2019 following a complaint about the rules of the tender. Levikom Eesti, a provider of IoT and fixed-wireless internet services, said that auctioning only three licences in the 3.6 GHz band would favour the country's trio of incumbent cellcos, while also hampering competition.

In October 2019 the Ministry of Economic Affairs and Communications launched a consultation about a public tender of spectrum at 700 MHz and 26 GHz (24.25–27.5 GHz) for mobile broadband services. The consultation was scheduled to run until mid-December 2019.

3.1.9. Finland

Main points

- The 700 MHz band frequencies was assigned in November 2016.
- In May 2018, the government launched a consultation to free spectrum in the 3.6 GHz band.
- The 3.6 GHz band spectrum auctions took place in September 2018.
- Elisa, first 5G network in Europe launched in June 2018.
- Early award of trial licences to a large number of companies (October 2015-October 2017).

5G Test Network Finland (5GTNF) is a consortium of industrial partners (vendors, including Nokia, MNOs including Telia and Elisa, FICORA, Finnish universities and research institutes including Aalto, Oulu, Turku, VTT...) aiming at providing the best and most appealing 5G test network environment and ecosystem.

At the end of 2018, the Finnish Ministry of Transport and Communications has published a new strategy for digital infrastructure. The strategy contains Finland's 5G deployment plan and deals especially with the 3.6 GHz and 26 GHz bands.

In March 2019, the Finnish Ministry of Transport and Communications published a document called "Turning Finland into the world leader in communications networks – Digital infrastructure strategy 2025". It details the strategy for promoting the implementation of 5G and supporting optical fibre construction in Finland.

3.1.10. France

Main points

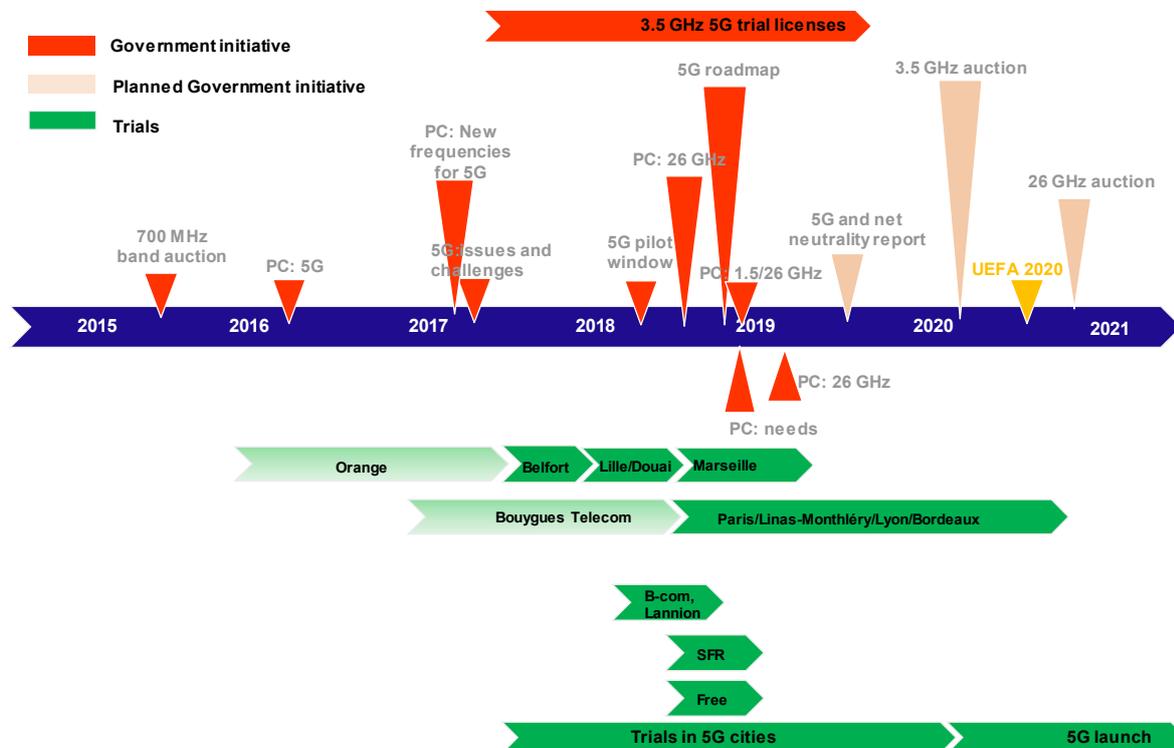
- 700 MHz frequencies assigned in December 2015.
- Consultation on 5G, 2016.
- Trials licences and trial cities, 2017.
- 5G pilot window, Jan. 2018.
- Provision of mid-band spectrum for trials in selected cities.
- Ongoing discussions and study to open up 3.4-3.8 GHz and 26 GHz spectrum to 5G.
- 5G roadmap, July 2018.
- 3.5 GHz auction expected in March 2020

The 5G road began in 2016 when ARCEP launched a public consultation on 5G. The process accelerated in 2017 when ARCEP consulted on its 5G roadmap and awarded trial licences.

- In March 2017, ARCEP published a report in “5G: Issues and Challenges”
- In January 2017, ARCEP launched a public consultation on “New frequencies for the regions, businesses 5G and innovation”.
- Creation of a 5G pilot window 5G@arcep.fr in January 2018. ARCEP opened a 5G pilot window for assigning frequencies to stakeholders wanting to perform full-scale 5G pilot trials (ports, hospitals, connected roadways...).
- On May 22nd, 2018, ARCEP launched a public consultation on making the pioneer 26 GHz band available to kick-start 5G rollouts. It ran until 18 June 2018.
- 5G trial authorisations in many cities. Ongoing and completed trials (when mentioned) include: Marseille (Orange), Lille/Douai (Orange), Sophia-Antipolis, Chatillon (Orange ended), Linas, Pau, Paris (Ericsson ended, SFR ended, Bouygues Telecom ended, SFR, Orange), Sophia-Antipolis (Orange-EDF-Eurecom ended), Vélizy (Bouygues Telecom ended, SFR), Linas-Monthléry (Bouygues Telecom, Orange), Bordeaux Mérignac (Bouygues Telecom ended, Bouygues Telecom), Nantes (SFR ended), Lyon (SFR ended, Bouygues Telecom), Pau (Orange ended), Toulouse (SFF-Airbus ended), Grenoble (CEA-Leti), Saint Denis (Orange), Cesson-Sévigné (b<>com ended), Lannion (b<>comn ended), Nozay (Nokia ended), Cesson-Sévigné, Saint Maurice de Rémens (Bouygues Telecom), Toulouse-Franczal (SFR), Ouistreham (CEA Leti).
- Mid-July 2018, ARCEP disclosed the French 5G roadmap and announced the launch of four priority areas:
 - Free up and assign 5G spectrum; ARCEP is currently working hard on future connectivity needs and on freeing-up and awarding 3.4-3.8 GHz spectrum
 - Facilitate development of new uses and applications
 - Support deployment of new infrastructures
 - Ensure transparency and discussion on 5G deployments and on public exposure
- A public consultation on the 1.5 GHz band was opened between July 30th and September 30th, 2018.
- A public consultation on award procedures, procedures sequencing and on requirements was opened between October 26th and December 19th, 2018 to collect ideas and needs from operators, local authorities, vertical market players, economic stakeholders and all interested parties. ARCEP will be holding a second consultation on the call or calls to tender, which it will then propose to the Government. The call for tenders was expected by year end 2019.
- In February 2019, the French government and the national regulatory authority, ARCEP, issued a call for 5G trials in the 26 GHz frequency band in France.
- ARCEP issued a consultation on planned continued use of the 3.4-3.8 GHz band for wireless local loop services in May 2019.
- In July 2019, ARCEP opened a public consultation on the terms and conditions for the allocation of 5G spectrum in the 3.4GHz-3.8GHz band. The regulator is planning to release 31 TDD blocks (10MHz each) in the 3490MHz-3800MHz band. The procedure will include a first stage, in which operators can obtain frequency blocks for optional commitments, before a second stage (auction), which will allow candidates to obtain additional frequencies. Each bidder will be allowed to purchase a maximum of 100MHz. Operators could be obliged to offer 5G in at least two cities before the end of 2020. The obligations to support the deployment of 5G equipment are the following: 3,000 sites by 2022, 8,000 (2024) and 12,000 (2025).
- In September 2019, the head of French regulator ARCEP suggested that the country may opt for a sharing regime in the 26 GHz band, in which verticals will be able to gain access to spectrum.

- Late in November 2019, reserve prices were disclosed for the mid-band frequency assignment procedure. Up to four 50 MHz lots will be assigned on demand at 350 MEUR each and up to eleven 10 MHz lots will be auctioned with a 70 MEUR reserve price.
- In December 2019, ARCEP issued a consultation about plans to award the 700 MHz in Reunion and Mayotte, and the 3.4-3.8 GHz band in Mayotte, during 2020.

Figure 13: 5G timeline in France



Source: IDATE DigiWorld, as of December 2019

Other public initiatives

The other public initiatives aim to create appropriate ecosystem in the country to create a dynamic buoyant ecosystem favorable to innovation:

- The initiative “La French tech”
- The initiative “France Très Haut Débit” (Optic Fiber)
- The programme "Nouvelle France Industrielle" (New Industrial France) created in October 2013 by French government to boost productivity and investments in 34 industrial sectors. The initial budget of 3.7 billion EUR. The programme gathers industrial players, public institutions, competition committees, operators, and well-established research organizations for 13 priority actions where fiber broadband and 5G are key elements.

In February 2019, the French government and the national regulatory authority, Arcep, issued a call for 5G trials in the 26 GHz frequency band in France. In October 2019, ARCEP announced that eleven players had been selected to carry out trials in the 26 GHz band.

3.1.11. Germany

Main points

- The 700 MHz frequencies assigned in June 2015.

- “5G for Germany”, autumn 2016.
- 5G spectrum roadmap, 2018.
- Final conditions for 5G Auction, November 2018.
- 3.4-3.7 GHz (300 MHz) and 2 GHz (2x60 MHz) 5G auction ended in June 2019 raising 6.55 billion EUR (of which 4.18 billion EUR for 36 GHz spectrum). Licences include coverage obligations.
- 100 MHz reserved for local and regional purposes. Applications opened on November 21st, 2019

5G initiatives

The Bundesnetzagentur published its “Frequency Compass” in July 2016 in a view to identify areas for regulatory action on spectrum for 5G. More detailed Points of Orientation were published in December 2016.

The Government launched in autumn 2016 its “5G Initiative for Germany”. In a paper released in September 2017, the Federal Government describes the national 5G strategy (context, actions, rollouts) over the period to 2025. It defines five field of actions, key milestones and allocates 80 MEUR to 5G research initiatives in 5G research centres:

Figure 14: 5G strategy in 5 steps

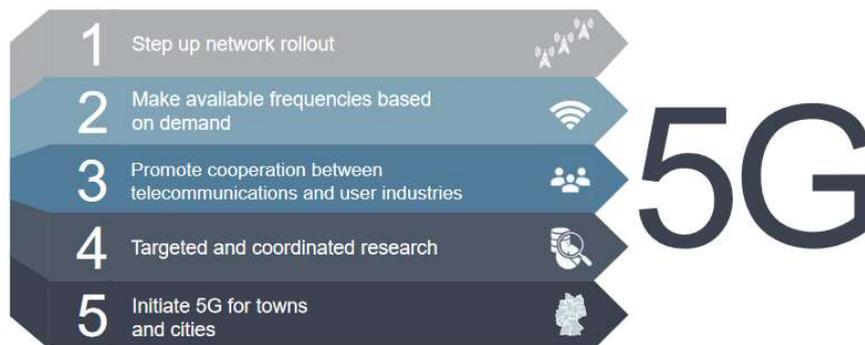


Figure 7 – Five fields of action to develop the 5G lead market in Germany
Source: Federal Government

Source: The Federal Government, 5G Strategy for Germany, 2017

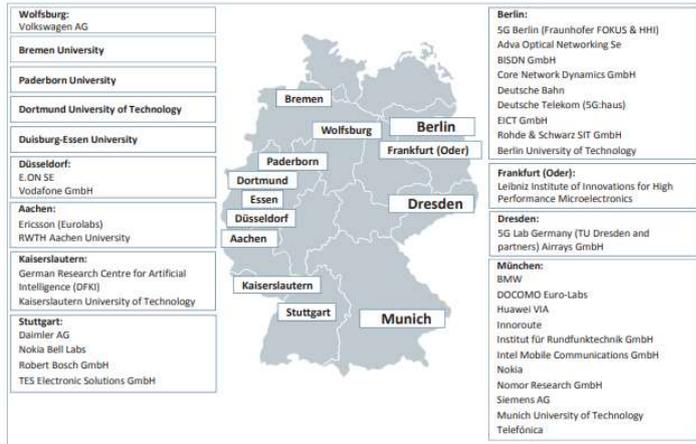
Figure 15: Key milestones of 5G strategy for Germany

2016	2017	2018	2019	2020
<ul style="list-style-type: none"> ▪ First test beds with 5G relevance ▪ Working group of the Federal Government and the federal states to implement the DigiNetzG ▪ Start of 5G Dialogue Forum 	<ul style="list-style-type: none"> ▪ Start of consultations on making 5G frequencies available ▪ Start of 5G competition 	<ul style="list-style-type: none"> ▪ Evolution of the support framework with regard to gigabit networks ▪ Procedure for making frequencies available 	<ul style="list-style-type: none"> ▪ Evaluation and, if necessary, evolution of the 5G Strategy 	<div style="text-align: center;"> <h1>5G</h1> <h2>Rollout</h2> </div>

Figure 11 – Milestones of the 5G Strategy for Germany (as at June 2017)
Source: Federal Government

Source: The Federal Government, 5G Strategy for Germany, as at July 2017

Figure 16: 5G research centers in Germany



Source: The Federal Government, 5G Strategy for Germany, as at July 2017

Based on the submitted views, the German NRA released key elements and launched a formal demand for nationwide assignments in the 2 GHz and 3.6 GHz bands in June 2017.

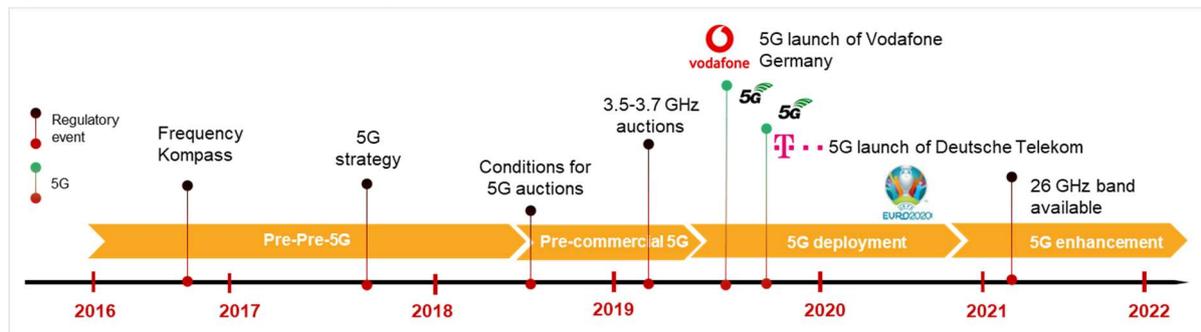
In January 2018, the German NRA released a [draft consultation](#) setting out that scarce spectrum in the 2 and 3.6 GHz bands would be auctioned. [Decisions I and II](#) were published in May 2018.

- In the 2 GHz band, 2x40 MHz will be made available as from 1st, January 2021. An additional 2x20 MHz will be available as from 1st January 2026.

In the 3.6 GHz band (3.4-3.7 GHz), some of the spectrum is assigned de facto on a nationwide basis (until 2021/2022) will be available as from 1st January 2022 (earlier stage as from 2019). Other public initiatives award conditions and auctions rules for 5G were released on November 26th, 2018.

The 5G spectrum auctions begun spring 2019. The qualification procedure was open from November 26th, 2018 until January 25th, 2019. Coverage conditions have been strengthened while the 5G timetable seems to have been softened. Conditions are set in two stages (2022 and 2024). BNetzA should now prepare the application process for the verticals (mainly industrial sites) for the upper 100 MHz of 3.6 GHz (3.7-3.8 GHz) within a few weeks.

Figure 17: 5G timeline in Germany



Source: IDATE DigiWorld, 5G markets in Europe, November 2019

The final draft conditions require minimum data rates of 100 Mbps available by the end of 2022 in 98% of households in each state, all federal highways, and all main roads and along the major railway routes. The regulator said that the minimum coverage rules will not be applicable to any new entrant.

Bundesnetzagentur’s document also includes expectation that operators would work together on providing coverage in areas not economically viable for each to install their own equipment.

Coverage requirements:

- At least 100 Mbit/s for at least 98% of households in each federal state by the end of 2022,
- At least 100 Mbit/s and a maximum latency of 10 ms for all German motorways by the end of 2022
- At least 100 Mbit/s and a maximum latency of 10 ms for all federal roads with connectivity function levels 0 or 1 by the end of 2022,
- Of at least 100 Mbit/s and a maximum latency of 10 ms for all other federal roads by the end of 2024,
- At least 50 Mbit/s for all state roads by the end of 2024
- At least 50 Mbit/s for seaports and the inland waterways core network by the end of 2024
- At least 100 Mbit/s for rail routes with more than 2,000 passengers daily by the end of 2022, at least 50 Mbit/s for all other rail routes by the end of 2024,
- And, by the end of 2022:
 - Operation of 1,000 "5G base stations", and
 - Operation of 500 base stations with a transmission rate of at least 100 Mbit/s in not-spots.

The 3.6 GHz band auctions started in March 2019. On June 5, 2019, the regulator ramped up minimum bids in an attempt to wrap up the 5G spectrum auction. The process ended on June 12, 2019 raising 6.55 billion EUR after 497 rounds. Deutsche Telekom bid 2.17 billion EUR for 130 MHz of the 420 MHz of spectrum allocated in the 2 and 3.6 GHz frequencies. Vodafone got 130 MHz for 1.88 billion EUR and Telefonica got 90 MHz for 1.42 billion EUR. Drillisch paid 1.07 billion EUR for 70 MHz. Frequencies will be available as from 2021 or 2026.

The Minister for transport and digital infrastructure in Germany updated the national mobile strategy in September 2019. A 5-point plan was announced. The central topic raised deals with coverage issues (extending coverage) and especially with ways and means to reduce white spots in 4G and consequently in 5G.

National mobile operators agreed to i) provide reliable voice and data services in 99% of households nationwide by the end of 2020, and 99% of households in each state by 2021, especially in rural areas, ii) increase intra-cooperation and build at least 1,400 masts accessible to any operator, iii) meet a minimum of 100 Mbps speeds across major transport routes, iv) and install base stations in “white spots” unserved rural areas. Dedicated funds for Municipalities will be opened to help them actively contribute to improve mobile coverage.

3.1.12. Greece

Main points

- Trial licences in 3.4-3.8 GHz frequencies issued in Q1 2019 with award of licences expected in Q4 2019.
- 5G cross-border corridor (Bulgaria, Greece, Serbia).
- EETT expects to see 5G trials using upcoming trial licences.
- EETT expects to award 3.4-3.8 GHz spectrum at the end of 2020.

- 700 MHz auction is scheduled in July 2020. Spectrum will be available for both mobile and fixed services in 2021.

In March 2018, the EETT announced the results of its public consultation on the award of spectrum in the 3400-3800MHz band for 4G/5G use.

In July 2018, Bulgaria, Greece and Serbia signed an agreement to develop an experimental 5G cross-border corridor (Thessaloniki – Sofia – Belgrade) that will test autonomous vehicles.

In October 2018, EETT launched a consultation on the granting of rights to use spectrum between 3400–3800 MHz and 24.25–27.5 GHz bands for 5G testing.

In January 2019, the Hellenic Telecommunications and Post Commission (EETT) issued the Technical Announcement entitled “Review of Frequency Bands for the Deployment of 5G Networks” aiming to inform all interested parties (incumbent and new providers of electronic communication networks, equipment manufacturers, radio-spectrum users in general, verticals) with respect to the radio frequency bands that are currently under review by EETT and are expected to be used for the deployment of fifth generation (5G) wireless broadband networks in the near future, taking also into consideration the relevant developments at a European level.

Late in January 2019, EETT issued a public consultation on the potential issuance of mobile licences for the 1500 MHz band.

In October 2019, the auction for 3.5 GHz spectrum was postponed to the end of 2020.

3.1.13. Hungary

“Digital Success Programme 2.0”. Strategic study.

European 5G hub for 5G.

700 MHz/2100 MHz/2600 MHz auctions scheduled for October 2019. Results are not disclosed so far.

3.6 GHz auction scheduled for September 2019. Results are not disclosed so far.

In July 2017, the domestic Government stated three major objectives for Hungary in its [“Digital Success Programme 2.0”](#). [Strategic study](#).

- Hungary to become a European hub for 5G developments by 2018
- Hungary to play a leading regional role in testing applications based on 5G technology
- Hungary to be among the first to adopt 5G technology after 2020.

The 5G coalition with up to 50 Hungarian government institutions, companies, business chambers, universities, research institutes and professional and civic organisations was formed mid-June 2017. The 5G Coalition set goals including drawing up a 5G development strategy and creating a testing environment to give Hungary a say in setting global 5G standards, aiming for the nation to become an early 5G adopter from 2020.

The NMHH issued a public consultation in June 2019 (comments expected by July 8, 2019) on its plans to auction 700 MHz, 2.1 GHz, 2.6 GHz and 3.6 GHz. The auction was expected late in 2019 but as the

consultation showed limited market demand, it should be held in 2020. Four MNOs have applied for the auction on 8 August 2019 and after the formal review the Authority entered three operators only (Magyar Telecom, Telenor and Vodafone). Digi Communications appealed the decision of the NMHH. The decision was upheld late in November 2019.

700 MHz

NMHH plans to auction 708-733/763-788 MHz band, 50 MHz in five lots. The starting date of the onsite bidding was scheduled to start Tuesday, 1 October 2019. Spectrum will be available as from September 2020.

2100 MHz

NMHH plans to auction the 2.1 GHz band (1980/2155-2170 MHz or 30 MHz in three lots of 2x5MHz), and the 2.6 GHz band (2500-2690 MHz, 15 MHz).

The onsite bidding of the 2100 MHz band starts at 10 am Monday, 7 October 2019. In the case of the 2600 MHz frequency band, the onsite bidding was scheduled to start at 10 am Monday, 23 September 2019.

3.4-3.8 GHz

In June 2016, NMHH auctioned off 3.4-3.8 GHz spectrum to Vodafone and Digi. Licences for 60+20 MHz TDD usage at present in the lower part of the band. Vodafone: 3410-3470 MHz, Digi: 3470-3490 MHz. New technical criteria for the introduction of 5G can be implemented (under elaboration).

In June 2019, NMHH announced it expects to auction 310 MHz of 3.6 GHz spectrum (31 lots of 10 MHz). The onsite bidding was scheduled to start at 10 am Wednesday, 25 September 2019.

26 GHz band

- Intensive fixed service use currently in 24.5-26.5 GHz sub-band.
- Expiry date of most of the licences is 2027.
- Negotiation with present frequency users is ongoing.
- 26.5-27.5 GHz sub-band suitable for early introduction of 5G
- Strategy for implementing new technical criteria for the introduction of 5G is under elaboration and the rules for the transition period are to be developed.
- The Authority also considers 26 GHz spectrum for 5G. However, due to lack of demand on that specific band (Public consultation held on that topic during Summer 2019), plans are on hold

Other bands

The June 2019 consultation also deals with 2.1 (two lots of 2x7.5 MHz) and 2.6 GHz (15 MHz) spectrum, expected to be auctioned at the end of 2019.

In September 2019, NMHH indicated that the three mobile operators Magyar Telekom, Telenor and Vodafone had registered to participate to the auction announced on 18 July 2019. Digi Hungary was left out of the auction.

3.1.14. Ireland

3.4-3.8 GHz band

360 MHz of TDD spectrum has already been auctioned in 2017. Licences for 5G services started in January 2019 and will expire on 31 July 2032 (fifteen years).

“The Auction resulted in the successful assignment of all 360 MHz of TDD spectrum. The Auction offered this spectrum in 594 lots spread over nine geographic regions (four rural and five urban) and is assigned on a contiguous basis.” (Source: ComReg)

- Imagine Communications Ireland Ltd (Imagine), currently the largest Wireless Internet Service Provider (WISP) obtained spectrum rights of use for 60 MHz in each of the rural regions;
- Airspan Spectrum Holdings Ltd (Airspan), a new entrant and the UK arm of a US global provider of 4G broadband wireless systems and solutions. Airspan's products serve operators and markets such as smart utilities, transportation and public safety in both licenced and licence exempt frequency bands. Airspan obtained spectrum rights of use for 25 MHz in the rural regions and 60 MHz in the cities;
- Vodafone Ireland Ltd, a mobile network operator obtained 85 MHz in rural regions and 105 MHz in the cities;
- Three Ireland Hutchison Ltd, obtained 100 MHz nationally;
- Meteor Mobile Communications Ltd, obtained 80 MHz in the rural regions and 85 MHz in the cities.

700 MHz, 2.1/2.3/2.6 GHz bands

From June 2019 to July 30, 2019, ComReg issued a consultation the 700 MHz, 2.1 GHz, 2.3 GHz, and 2.6 GHz bands.

It proposes to attach “precautionary” coverage obligations to the 700 MHz band. ComReg proposes to use a combinatorial clock auction.

The 700 MHz band should be auctioned in 2020.

26 GHz bands (24.745 – 25.277 GHz paired with 25.753 GHz – 26.285 GHz)

The 26 GHz auction took place from April to June 2018. 840 MHz or 15 of 19 Lots of 2 × 28 MHz in the range 24.745 – 25.277 GHz paired with 25.753 GHz – 26.285 GHz was auctioned to the three mobile players in place. Each mobile player got 280 MHz. Vodafone paid 550,000 EUR while Three and Meteor Mobile paid 350,000 EUR.

It consisted of a “sealed bid combinatorial auction” using a second price rule and applying processes and rules as set out in the Information Memorandum. Winning Bidders will pay approximately 5 million EUR for spectrum rights of use, comprising 1.25 million EUR in upfront fees of 3.75 million EUR in spectrum usage fees which will be paid over the 10-year duration of the licences.

3.1.15. Italy

Main points

- 5G for Italy, 2016, 5G strategy, pushed by TIM, around identified cities and application areas.
- Trial licences and trial cities, mid-2017.

- 700 MHz/3.5 GHz auctions in October 2018, 26 GHz spectrum auctions, October 2018, first in Europe.
- Launch of Vodafone and TIM 5G service in June 2019

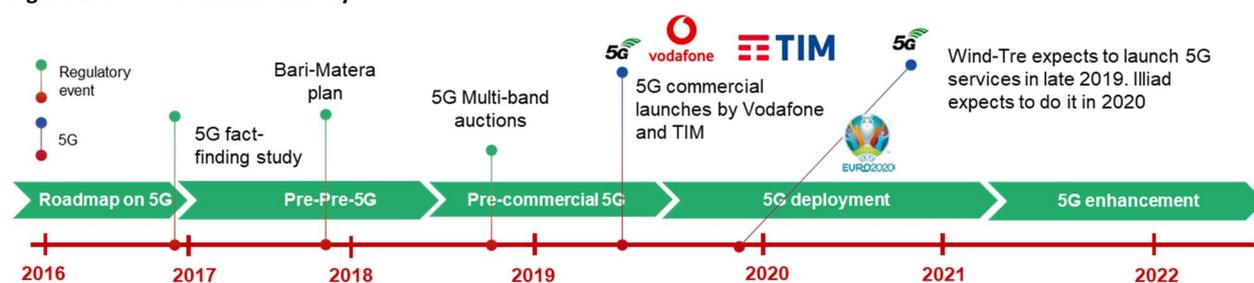
The Italian 5G strategy kick-started late in 2016 when the domestic NRA announced the start of a fact-finding survey for the development of mobile and wireless systems towards the 5G and the utilization of the spectrum above 6 GHz.

In March 2017, the Government selected five 5G trial cities, including Milan (Vodafone), Prato (Wind Tre-Open Fiber), L'Aquila (Wind Tre-Open Fiber), Bari and Matera (Telecom Italia-Fastweb-Huawei Technologies), that will use 100 MHz of 3.6-3.8 GHz spectrum. Provisional licences are valid from September 2017 to 2020.

At year-end 2017, the “[Bari-Matera plan](#)” involving MNOs, cities, research centers and equipment vendors was unveiled and began. The 60 MEUR over four years (2018-2021) plan gathers 55 partners including seven universities and research centers, public interest communities, vertical leaders, start-ups and telecom players (TIM, Fastweb, Huawei). The plan focuses on ten application areas including media/virtual reality, smart port, smart city, smart agriculture, public safety, industry 4.0, health 5.0, road safety, tourism and culture, and environmental monitoring over 70 use cases.

In May 2018, the NRA announced 5G multi-band spectrum auctions (in the 700 MHz, 3.6-3.8 GHz and 26 GHz bands). 700 MHz and 26 GHz spectrum auctions ended respectively in September and October 2018. The five 26 GHz lots of 26 GHz spectrum raised 167.3 million EUR. 700 MHz frequencies raised globally 2.04 billion EUR. The 3.6-3.8 GHz spectrum auction hit over 4 billion EUR.

Figure 18: 5G timeline in Italy



Source: IDATE DigiWorld, 5G markets in Europe, November 2019

Coverage obligations

To ensure widespread improvements in mobile coverage across the Italy, the Ministry of Economic Development, based on the national regulatory authority (AGCOM) rules, has established **coverage obligations for the 700 MHz FDD band and 3600-3800 MHz band.**

Concerning the **700 MHz FDD band**, the coverage obligations will require winning bidders to roll out improved mobile coverage of national population, tourist locations and main national road and rail transport routes.

700 MHz FDD
National population coverage
Within 36 months of the nominal availability of frequencies, each winning bidder has to reach at least the coverage of 80% of the national population; the new entrant has 12 months more to achieve the same coverage goal. Within 54 months of the nominal availability of frequencies, the winning bidders have to collectively reach the coverage of 99.4% of the national population .
National road and rail transport routes coverage
Within 42 months of the nominal availability of frequencies, the winning bidders have to collectively cover all the main national road and rail transport routes.
Tourist locations coverage
Within 66 months from the creation of the lists of Italian tourist locations, each winning bidder is required to cover at least 90% of the tourist locations included in the list associated with the rights of use awarded; the new entrant has 12 months more to achieve the same coverage goal.

Concerning the **3600-3800 MHz band**, the coverage obligations require **80 MHz** winning bidders to roll out improved mobile coverage in a **mandatory list of municipalities**. Within 90 days from the date of the award, the winning bidders have to submit a list of municipalities to be covered to the Ministry of Economic Development. Then, the winning bidders have **72 months** from the date of the award to prove they are ready to provide on demand the 5G service in all municipalities of their mandatory list. The mandatory list has to include at least 10% of all Italian municipalities under 5.000 inhabitants. All Italian municipalities under 5.000 inhabitants out the mandatory lists are signed in a free list. Any subject, which is not an TLC operator, from 120 days from the award can declare to the Ministry its willingness to offer the service in a municipalities of free list, using leasing contract with 3600-3800 MHz winning bidders.

Finally concerning the **3600-3800 MHz band**, the coverage obligations require **20 MHz** winning bidders to reach the coverage of **5% of the population of each Italian region**.

In September-October 2018, the NRA auctioned 60 MHz of 700 MHz spectrum for 2 billion EUR, 200 MHz of 3.6-3.8 GHz spectrum for 4 billion EUR and 1,000 MHz of 26 GHz for 167 million EUR.

- Globally 1,275 MHz are offered for sale broken down into 700 MHz frequencies (75 MHz), all the upper part of the 3.4-3.8 GHz frequencies (200 MHz divided in two blocks of 80 MHz and two blocks of 20 MHz in 3.6-3.8 GHz) and all the upper part of 26 GHz frequencies (1 GHz divided in five 200 MHz blocks in 26.5-27.5 GHz).
- Telecom Italia, Wind, Tre, Vodafone, Iliad and Fastweb submitted bids for about 2.48 billion EUR, in line with the government's expectations (2.5 billion EUR). As a new player, Iliad was allowed to bid for a reserve package of up to three blocks in 700 MHz frequencies worth of 676.5 million EUR.
- The process started mid-September and ended on October 2nd, 2018. The whole auction ended after 14 days of intense bidding, far above expectations, reaching 6.55 billion EUR of which 4 billion EUR for the highly-coveted mid-frequencies.
- The 700 MHz auction process ended mid-September 2018. 700 MHz frequencies raised globally 2.04 billion EUR. Telecom Italia announced it had paid 680.2 million EUR for 2x10 MHz.

Iliad paid 676.5 million EUR for 2x10 MHz. Vodafone spent 683.2 million EUR for 2x10 MHz. Licences are valid 15 years, starting in 2022.

- The mi-band auction ended on October 2nd, 2018, 14 days after start and 171 rounds. Telecom Italia and Vodafone won the largest blocks of spectrum (80 MHz each) for approx. 1.7 billion EUR each. Respectively they paid 1.694 billion EUR and 1.685 billion EUR. Wind and Iliad paid 483.9 million EUR each for 20 MHz of spectrum each (483.92 million EUR for Wind and 483.9 million EUR for Iliad). Overall, the 3.7 GHz auction hit over 4 billion EUR reaching 4.3 billion EUR. The average price of spectrum closed at 18 cEUR/MHz/PoP/10 years significantly higher than in the UK or in Spain.
- The auction for 26 GHz frequencies have not shown a huge interest by players. The five lots were allocated, raising a total of 167.3 million EUR. Telecom Italia paid its lot 33 million EUR, Iliad received another lot for a little less at 32.9 million EUR, while Fastweb, Wind and Vodafone paid 32.6 million EUR each.
- On 21 February, TIM Italy and Vodafone have agreed on a passive network sharing deal for 5G including all 22,000 antenna sites controlled by the operators.

3.1.16. Latvia

1500 MHz

At the beginning of 2019, SRPK cancelled Lattetelecom's rights of fixed use of 1427-1452 and 1492-1517 MHz frequencies as from 2021. SRPK intends to provide mobile 5G services in 1427-1517 MHz frequencies.

In August 2019, Latvia's regulator issued a consultation on its plans to auction the 1432 – 1492 MHz band before January 2021. The consultation was closed on September 4.

3.4-3.8 GHz

100 MHz of 3.4-3.8 GHz frequencies partially auctioned off in November 2017. LMT obtained the two 50 MHz blocks (3400 MHz-3450 MHz and 3650 MHz-3700 MHz) for the reserve price of 250,000 EUR a piece. The concessions are valid for 10 years, from January 2019 to December 2028.

Remaining 50 MHz of 3.5 GHz spectrum auctioned off in September 2018. SPRK auctioned off 50 MHz of spectrum for 5G services at 3550-3600 MHz to Tele2 Latvia in September 2018. The auction raised 6.5 million EUR for a 10-year licence valid from January 1st, 2019.

3.1.17. Lithuania

RRT opened a [public consultation on the use of 3.4-3.8 GHz and 3.8-4.2 GHz frequencies](#) from April to May 2018. A second public consultation on the use of 3.4-3.8 GHz frequencies was issued between October and November 2018. The consultation closed in April 2019.

3.4-3.8 GHz frequencies are expected to be awarded in 2019. 700 MHz frequencies are expected to be awarded before 2022.

3.1.18. Luxembourg

5G Strategy, September 2018.

Two public consultations have been launched on spectrum for 5G to date followed by the released of the Luxembourg 5G Strategy on September 13th, 2018.

In May 2019, a public consultation was launched on the use of 700 MHz and 3.4-3.6 GHz spectrum for 5G.

The auction of 700 MHz/3.4-3.7 GHz spectrum is expected by June 2020.

In July 2019, Luxembourg's Department of Media, Telecommunications and Digital Policy launched a call for projects involving 5G mobile communications or similar technologies, such as IoT or smart cities. The initiative aims to facilitate the emergence of innovative technologies and services, in line with the country's National 5G Strategy. Projects should have a duration of between six and 24 months.

700 MHz/3.4-3.7 GHz

Assignment of the 700 MHz and 3.4-3.7 GHz bands is scheduled for the 2020. Spectrum from 3.7-3.8 GHz will be considered separately. It is intended to be used by local applications.

26 GHz

The 26 GHz frequencies are expected to become available in the second half of 2020.

Auctions

5G auctions should take place by the end of 2019 with licences duration of 15 or 20 years. A five-year automatic extension will also be granted.

3.1.19. Malta

In February 2017, the Malta Communications Authority (MCA) revised its test and trial-licensing regime to further support the carriage of technology trials such as 5G and IoT. In November 2017, the MCA released an update of its [strategy for 2018-2020](#). Main tasks include:

- Awarding the 800 MHz band and continuing process to clear the 700 MHz band.
- Publishing and commencing implementation of the National Spectrum Management Strategy.
- Continuing scoping work on spectrum earmarked for 5G. Managing information as the means to promote competition.
- Continue making the case for assumption of ex-post competition regulation powers.
- Maintaining the compliance framework set at safeguarding a competitive environment

In June 2018, the MCA released the [National Roadmap](#) for the UHF band between 470-790 MHz. The 700 MHz band will be made available for commercial wireless mobile broadband services as from June 2021. The roadmap follows a [public consultation](#) held between April 23rd and May 22nd, 2018.

In July 2019, the MCA published an amended decision making available the entire 1427-1517 MHz band for terrestrial systems capable of providing electronic communications services in Malta. The decision follows a public consultation procedure undertaken between 27 December 2018 and 8 February 2019.

The MCA published, in July 2019, the latest edition of the National Frequency Plan. The key developments in the Plan include the harmonization of radio spectrum in the 874-876 and 915-921 MHz and the 1427-1517 MHz frequency bands for terrestrial systems capable of providing electronic communications services.

The regulator also published, in the same month, a draft of its five-year Radio Spectrum Policy Programme. The MCA opened a consultation for this paper until the 5th August 2019.

The MCA is in the process to consult on the assignment mechanism applicable for the 5G pioneer bands by Q1 2020.

3.1.20. Netherlands

Connectivity Action Plan, July 2018.

In December 2018, the Netherlands Authority for Consumers and Markets (ACM) published a 5G paper “5G and the Netherlands Authority for Consumers and Markets”.

In June 2019, the ACM released an updated spectrum plan for 5G. The telecom regulator intends to auction 700, 1400, 2100 and 3500 MHz. The 700/1400 MHz spectrum is expected to become available from 2020, the 2100 MHz spectrum from 2021, the 3500 MHz (3400-3450 MHz) from September 2022 (3400-3450 and 3750-3800 MHz from 2026). The multi-band spectrum auction is scheduled for Q1 2020. The 3500 MHz auction is planned for 2022 as the band is currently used for satellite communications. Spectrum at 3400-3450 MHz and 3750-3800 MHz is intended to be made available for local use.

The use of the 26 GHz band is under consultation use of spectrum either for shared use or local authorisations from 2020.

In December 2019, a public consultation was opened potential spectrum caps for 700/1500/2100 MHz spectrum and a reserve price that would raise at least 0.9 billion EUR. Licences will include coverage obligations of 98% geographic coverage of all domestic municipalities. The auction itself is scheduled for Spring 2020.

3.1.21. Poland

Main points

- 5G Strategy for Poland, January 2018.
- 5G spectrum consultation, July 2018.
- A few trials to date.
- 3.6-3.8 GHz auction expected in June or July 2020
- 700 MHz auction expected in 2022

In January 2018, the Ministry of Digital Affairs opened a public consultation on the “[5G strategy for Poland](#)” until 11 February 2018. According to the document, Poland will launch 5G in 2020 with 700 MHz frequencies in at least one Polish city by year-end and transport paths will be covered by 2025. Frequencies in the 3.4-3.8 GHz and 26 GHz bands will be assigned in 2021. The 5G strategy for Poland steered by the Ministry of Digital Affairs will be funded by public and community funds until 2023. The

Ministry of Digital Affairs will allocated PLN 10-15 million to digitalization until 2023. The Ministry aims at easing permission for installing parts of the networks (e.g. masts) and restrictions on electromagnetic emissions.

Between July and August 2018, The Polish Office of Electronic Communications (UKE) issued a consultation on frequencies for 5G covering 700 MHz, 3.4-3.6 GHz, 3.6-3.8 GHz and 26 GHz bands. It proposes the sale of spectrum in these bands. Parts of the bands are currently used for telecom and TV services. UKE considers reorganization and reallocation in all bands.

In December 2018, UKE asked if 700 MHz spectrum could be opened up in 2020 to 2022.

In April 2019, the UKE announced that 3.6-3.8 GHz spectrum could be awarded by June or July 2020. The income of the Polish state budget from the auction is expected to amount to PLN 3.5-5 billion.

The UKE decided, in late August 2019, to allocate 5G-capable spectrum in the 3.4GHz-3.8 GHz range via a competitive auction rather than a tender process.

In December 2019, UKE opened a consultation into its planned auction of four licences in the 3.4-3.8 GHz band. The NRA indicated it wants to award the four licences by mid-2020. Four lots will be auctioned: concessions A (3480MHz-3560MHz) and B (3560MHz-3640MHz) will offer full nationwide coverage, licences C (3640MHz-3720MHz) and D (3720MHz-3800MHz) will have certain geographic restrictions where spectrum has not yet been freed up.

3.1.22. Portugal

A public consultation on spectrum for 5G was released between March and April 2018. Frequencies studied included 450/700/900/1500/1800/2100/2600/3600 MHz and 26 GHz frequencies.

In July 2018, the Portuguese regulatory authority ANACOM approved the 700 MHz band plan for 5G services. The 700 MHz band will be freed up by June 2020. The release of the band will start in Q4 2019.

At the end of 2018, Portugal indicated that it was establishing a working group to work on the development of the Portuguese national 5G action plan. On the first half 2019, it worked on a public consultation on a proposed multiband spectrum auction (450/700/900/1500/1800 MHz, 2.1/2.6/3.6/26 GHz).

In October 2019, telecommunications market regulator Anacom announced plans to hold an auction for six frequency bands including the 700 MHz band, between April and June 2020.

3.1.23. Romania

The National Authority for Management and Regulation in Communications (ANCOM) launched a public consultation on 5G spectrum between May and June 2018.

ANCOM launched a public consultation on the [“National Strategy for the Implementation of 5G in Romania”](#) between November 20th and December 21st, 2018.

In December 2018, the Romanian regulator, ANCOM, has issued a consultation about its action plan for 2019. ANCOM's President, Sorin Grindeanu, said in a press release that its main project will be the auction of the 700 MHz, 800 MHz, 1500 MHz, 2.6 GHz, and 3.4 – 3.6 GHz bands for 5G services.

700 MHz/1500 MHz/2600 MHz/3400-3800 MHz

In June 2019, ANCOM published plans to auction spectrum in 700 (703-733/758-788 MHz and 738-753 MHz SDL), 800 (2x5 MHz FDD), 1500 (40 MHz SDL), 2600 (2x40 MHz FDD), and 3400-3800 MHz (90 MHz TDD valid in the 2020-2025 period, and 400 MHz TDD valid from 2026) frequencies by the end of October 2019. In July 2019, a consultation was issued to discuss technical details of the auction process. Licences should be valid as from June 20th, 2020.

Romanian regulator released the draft terms of its 5G contest in August 2019. The procedure will include a first stage, in which operators can obtain frequency blocks for optional commitments, before a second stage (auction), which will allow candidates to obtain additional frequencies.

In November 2019, the auction was rescheduled in H1 2020.

26.5-27.5 GHz

At least 1 GHz will be made available in the upper parts of the 26 GHz frequencies. The auction is expected in 2021.

3.1.24. Slovakia

In April 2017, the Slovakian regulator launched a public consultation on 26 GHz frequencies. As a result, 26 GHz frequencies are expected to be assigned after July 7, 2021.

At the end of 2018, the NRA indicated that 5G strategy is being prepared in Slovak Republic. At the same time, strategy on digital transformation of Slovakia is preparing where the part about infrastructure is also included.

In April 2019, the Slovakian regulator adopted a plan to use 700 MHz frequencies for 5G. It issued trial licences in this band. 700 MHz is expected to be used commercially after July 2020.

In June 2019, Slovakia launched a consultation on spectrum auctions methods for 700/800/900/1500 and 1800 MHz frequencies. 700 and 1500 MHz spectrum is primarily reserved for 5G services.

700 MHz (primarily for 5G)

Slovakia announced it plans to auction 700 MHz spectrum in the second half 2019. The spectrum will be available by June 2020. A consultation on the planned award of the 700, 900 and 1800 MHz bands was issued in December 2019.

3.6 GHz band

(Source: ec.europa.eu/newsroom/document.cfm?doc_id=44456)

This frequency band has been assigned for fixed wireless broadband access so it is likely to be used for 4G and not for 5G.

RÚ completed the assignment of the 3.5 GHz frequency band (3.4-3.6 GHz) in 2016. Frequency licences were assigned through electronic auction to three operators for the whole country (O2 Slovakia, SWAN and Slovanet). These run until August 2025.

However, the assignment procedure for the 3.7 GHz frequency band (3.6-3.8 GHz) is still ongoing. RÚ has started the assignment process for the remaining frequencies in this band concerning two segments: the 3600-3640 MHz and the 3760-3800 MHz bands. Licences for these frequencies are granted locally at district level. The first tenders were published in August 2016 and November 2016; calls continue to be published and new licences to be issued for use of the 3.7 GHz (3.6-3.8 GHz) band throughout Slovakia. The assignment procedure is expected to be finished in 2017. The planned use of frequencies assigned in 3.4-3.8 GHz band is for fixed wireless broadband access.

3.1.25. Slovenia

In January 2017, the Slovenian Government and AKOS called for project applications for testing 5G. In the call, trial licences in 3.4-3.8 GHz frequencies were proposed. In October 2018, a controversy emerged regarding the allocation of 5G testing frequencies in the 700 MHz and 3.5 GHz spectrum. The 700 MHz frequency band was granted until January 2019. The 3.4 to 3.8 GHz band was granted until May 2021.

In July 2017, a consortium on PPDR issues (5G PPDR) was created. The following organizations are participating in the initiative: Telekom Slovenije, Faculty of Electrical Engineering, Iskratel, Ericsson, Ministry of Internal Affairs – Police, the Ministry of Defence, Administration for Civil Protection and Disaster Relief, The Information Society Directorate of the Ministry of Public Administration, and AKOS.

Slovenia launched a public consultation for the assignment of spectrum in the 700 MHz band and in the 26 GHz for 4G and 5G services in 2017. Two blocks (56 MHz and 112 MHz) in the 26 GHz frequencies were awarded in January 2018. However they cannot be used for 5G services.

In May 2019, AKOS issued a consultation on its spectrum management strategy for the next few years. It wants to make a decision by June 2020 with respect to awarding the 700 MHz, 1400 MHz, 2.1 GHz, 2.3 GHz, 3.4-3.8 GHz, and 26 GHz bands. The document also discusses the potentially making spectrum available for local wireless broadband networks in a portion of the 3.4-3.8 GHz band, as well as critical M2M services in a 2 x 3 MHz block of spectrum within the 700 MHz band.

AKOS awarded trial licences in 5G pioneer bands until the public tender for auction:

- until in the band 3400-3800 MHz until 31 December 2020,
- in the 700 MHz band until 30 June 2020,
- in the 26 GHz band until the award is due, until 31 December 2019

In December 2019, AKOS delayed the launch of the planned multi-band auction to the second half 2020. The delay is due to a delay in adopting a, updated Radio Spectrum Management Strategy. The auction is scheduled for YE 2020.

3.1.26. Spain

Main points

- Early spectrum assignment process in the 3.4-3.6 GHz range took place in 2016. It is likely to be used for 4G.
- The 3.6-3.8 GHz auction ended in July 2018 and will be used by 5G networks:
 - Vodafone has eighteen 5 MHz blocks (€198.1m)
 - Orange has twelve 5 MHz blocks (€132.1m)
 - Telefonica has ten 5 MHz blocks (€107.4m)
- The 700 MHz auction will be held in the first months of 2020.
- 5G National Plan 2018-2020 – 5G Observatory in Barcelona, July 2017 consultation, release in 2018
- The 5G process in Spain started in July 2017 when the Government opened a public consultation about the 5G National Plan consisting of 25 questions.
- The [5G National plan 2018-2020](#) aims at “promoting the development and deployment of 5G technology” via the auction of spectrum in the 1.5 GHz and the 3.6 GHz bands in early 2018, and at “developing their infrastructures and telecommunications networks with a 5G platform”.
- 5G launch by Vodafone on June 15

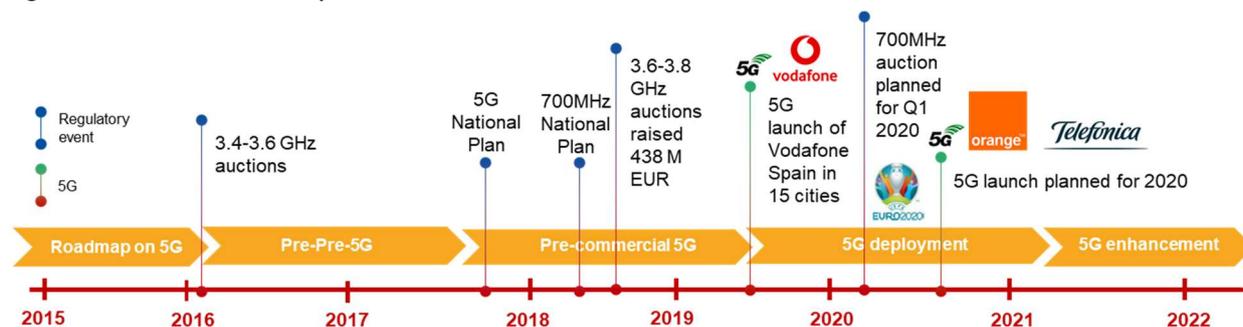
The Spanish government has allocated 1 MEUR to create a national 5G observatory in Barcelona, part of a project designed to boost the candidature of Barcelona as the European capital of 5G technological innovation. The observatory is part of the “5GBarcelona” joint initiative of the regional government of Catalonia with Barcelona City Hall, the Mobile World Capital Barcelona Foundation, the i2CAT Foundation, the CTTC (Centre Tecnològic de Telecomunicacions de Catalunya), Atos and the UPC (Universitat Politècnica de Catalunya).

5GBarcelona will develop a European 5G digital hub based on an open experimental infrastructure in the metropolitan area for validating 5G technologies and services. It will be an open innovation environment based on the collaboration between public and private institutions that will harmonize the ecosystem generated by the Mobile World Congress (MWC) and other technology fairs held in Barcelona. For this R&D&I programme, 500 kEUR were allocated during April-September 2017 to define the KPIs and challenges towards becoming an international digital hub.

The 3.6-3.8 GHz spectrum auction raised 438 MEUR in the end of July 2018.

The 700 MHz auction initially scheduled for spring 2019 was postponed late November 2018 to the first months of 2020.

Figure 19: 5G timeline in Spain



Source: IDATE DigiWorld, 5G markets in Europe, November 2019

3.1.27. Sweden

Main points

- Broadband strategy paper.
- Nordic cooperation on 5G.
- Upcoming 5G spectrum auctions: preliminary study on 3.4-3.8 GHz and 24.25-27.5 GHz, May 2018.
- The 5G strategy in Sweden is based on the paper released in March 2017 entitled [“A Completely Connected Sweden by 2025 – a Broadband Strategy”](#).
- Trial licences have been granted on a first-come first served basis, valid from 2017 until 31st December 2019. 200 MHz of spectrum was made available in the 3.4-3.6 GHz band and 1000 MHz in the 24.25-27.5 GHz band.
- The Nordic countries signed a letter of intent in May 2018 to deepen cooperation on 5G.
- The 700 MHz auction took place in December 2018.
- 2.3 and 3.5 GHz auction initially scheduled for March 2020 but could be postponed later in 2020.

In February 2019, a public consultation on upcoming award of the 2.3 and 3.5 GHz bands in Sweden was published. PTS intends to award national licences for 80 MHz in the 2.3 GHz band and 320 MHz at 3400 – 3720 MHz. Each 10 MHz block in the 2.3 GHz band would have a minimum price of SEK 20 million, and each 20 MHz block at 3.5 GHz would be sold for at least SEK 100 million. It also proposes to make the 3720 – 3800 MHz band available on a local basis. The auction was initially scheduled for March 2020 and could be postponed later in 2020.

3.1.28. UK

Main points

- 5G strategy for the UK, 2016.
- Strategy paper “Next Generation Mobile Technologies: A 5G Strategy for the UK”, March 2017.
- Group of 5G research centers.
- 3.4-3.6 GHz spectrum auctioned in April 2018.
- “5G Testbeds and Trials”, April 2018-March 2019.
- Statement on the review of spectrum used by fixed wireless services published in July 2018.
- Launch of EE 5G service on May 30, 2019.

- Launch of Vodafone 5G service on July 3, 2019.
- Launch of Three 5G service on August 19, 2019.
- Plans to auction parts of 700 MHz and 3.6-3.8 GHz spectrum late in 2019 or early 2020.

5G was initiated in 2016 when the Government announced its National Productivity Investment Fund (NPIF) worth in total of 23 BGBP, of which 740 MGBP funded by the government aiming at 5G trials and full fiber deployment across the UK by 2020-2021. Projects must complete all grant-funded activities by 31 March 2019.

In July 2018, Ofcom decided to change the authorization approach for fixed wireless systems in the 64-66 GHz band to licence exempt and to implement common technical conditions across the 57-71 GHz band for short range wideband data transmission systems and fixed wireless systems as follows:

- 1) For short range wideband data transmission
 - a) Extension of the licence exemption and technical conditions (from 57-66 GHz) up to 71 GHz
 - b) Introduce new technical conditions to allow licence exempt use of lower power equipment operation in a fixed outdoor installation in the extended 57 - 71 GHz band.
- 2) For fixed wireless systems
 - a) Extend the current licence exemption (from 57.1-63.9 GHz) up to 70.875 GHz.
 - b) Extend the current technical conditions (from 57.1-63.9 GHz) up to 70.875 GHz

In November 2018, the UK Government published the [“National Infrastructure and Construction Pipeline”](#) report for 2018. It gives an overview of investment (both public and private) that is underway or expected to be put toward 5G and full fibre (FTTP) between 2018/19 and 2020/21 (financial years). 6.85 billion GBP should be devoted to full fibre and 5G upgrades by 2021.

In June 2019, Ofcom issued a consultation on its proposals to allow defragmentation of the 3.4 – 3.8 GHz band. Portions of the 3.4 – 3.6 GHz band were awarded in 2018, and the regulator plans to award the 3.6 – 3.8 GHz band in 2020.

In August 2019, the UK government issued a consultation on how it should implement the European Electronic Communications Code (EECC). The consultation was closed on September 10.

In November 2019, OFCOM has issued a consultation til December 3, 2019 on draft statutory instruments that would support its local spectrum access and spectrum sharing policies.

700 MHz

In December 2018, OfCom announced plans to auction 700 MHz (80 MHz) and 3.6-3.8 GHz (120 MHz) spectrum in late 2019 or early 2020. The related public consultation ended in March 2019.

In December 2019, OFCOM asked for comments on its revised proposals for the auction design without coverage obligations.

3.4-3.8 GHz band

3400-3600 MHz auctioned in April 2018.

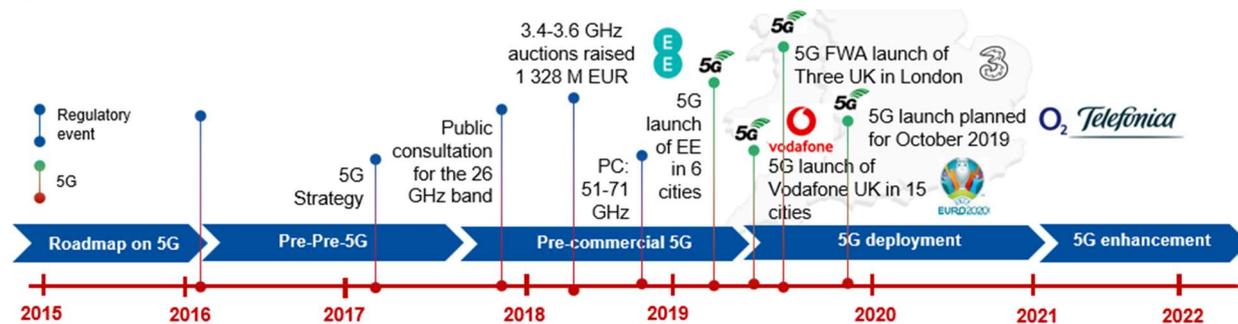
The Government plans to auction 3600-3800 MHz frequencies in 2020. A consultation on defragmenting the 3.4-3.8 GHz band was issued in June 2019. As a result, it plans to introduce spectrum sharing and open up spectrum (3800-4200/1800/2300 MHz) to private network operators and vertical industry players on a first-come first-serve basis. Spectrum sharing will also be introduced in the 26

GHz frequencies, but only for indoor services. In December 2019, OFCOM asked for comments on its revised proposals for the auction design without coverage obligations.

26 GHz band

In July 2019, Ofcom published a document «Draft UK Interface Requirement (IR) 2105» defining the technical conditions for “Shared Access Indoor 26 GHz”.

Figure 20: 5G timeline in the UK



Source: IDATE DigiWorld, 5G markets in Europe, November 2019

3.2. 5G strategy and pioneer bands follow-up

Table 15: 5G strategy and pioneer bands follow-up for EU-28 countries – December 2019

Country	Frequency band	5G strategy published	Spectrum assigned	Availability for 5G use	Channel width	Coverage obligations	Licence duration
Austria	700 MHz	✓	✗	✗	5 MHz	N/A	20 years
	3.4-3.8 GHz	✓	✓	✓	5 MHz	✓	20 years
	26 GHz	✓	✗	✗	N/A	N/A	31 December 2039
Belgium	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
	26 GHz	✓	✗	✗	200 MHz	N/A	N/A
Bulgaria	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Croatia	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Cyprus	700 MHz	✓	✗	✗	N/A	Likely	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	Likely	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Czech Republic	700 MHz	✓	✗	✗	5 and 10 MHz	N/A	N/A
	3.4-3.8 GHz	✓	✓	✓	40 MHz for 3.7 GHz	✓	15 years for 3.7 GHz
	26 GHz	✗	✗	✗	N/A	N/A	N/A
Denmark	700 MHz	✓	✓	✓	5 MHz	✓	20 years
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Estonia	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A

Country	Frequency band	5G strategy published	Spectrum assigned	Availability for 5G use	Channel width	Coverage obligations	Licence duration
Finland	700 MHz	✓	✓	✓	60 MHz in 2x5 MHz+4x5 MHz SDL	✓	17 years
	3.4-3.8 GHz	✓	✓	January 2019	10 MHz?	✗	15 years
	26 GHz	✓	✗		N/A		
France	700 MHz	✓	✓	✓	5 and 10 MHz duplex	✓	15 years
	3.4-3.8 GHz	✓	✗ 2020	✗	10 MHz and 50 MHz	✓	15 years
	26 GHz	✓	✗ 2020	✗	N/A	✗	15 years?
Germany	700 MHz	✓	✓	✓	5 MHz	✓	15 years
	3.4-3.7 GHz	✓	✓	✓	10 MHz	✓	31/12/2040
	26 GHz	✓	✗	?	N/A	N/A	N/A
Greece	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Hungary	700 MHz	✗	✗	✗	N/A	N/A	15+5 years
	3.4-3.8 GHz	✗	✓		5 MHz	N/A	15+5 years
	26 GHz	✗	✗	✗	N/A	N/A	N/A
Ireland	700 MHz	✗	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✗	✓	✓	5 MHz	N/A	15 years
	26 GHz	✗	✗	✗	N/A	N/A	N/A
Italy	700 MHz	✗	✓	✗ July 2022	5 MHz duplex	✓	15.5 years
	3.4-3.8 GHz	✗	✓ 200 MHz (3.6-3.8 GHz)	✓	20 MHz	✓	19 years
	26 GHz	✗	✓ 1 GHz (26.5-27.5 GHz)	✓	200 MHz	✗	19 years
Latvia	700 MHz	✗	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✗	✓	✓	50 MHz	N/A	10 years
	26 GHz	✗	✗	✗	N/A	N/A	N/A
Lithuania	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Luxembourg	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Malta	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Netherlands	700 MHz	✓	✗	✗	N/A	✓	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Poland	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	80 MHz	✓	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Portugal	700 MHz	✓	✗	✗	5 MHz	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	20 MHz	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Romania	700 MHz	✓	✗	✗	5 MHz	N/A	N/A

Country	Frequency band	5G strategy published	Spectrum assigned	Availability for 5G use	Channel width	Coverage obligations	Licence duration
	3.4-3.8 GHz	✓	?	?	N/A	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Slovakia	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	10 and 20 MHz	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Slovenia	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Spain	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✓	✓	5 MHz	✗	20 years
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Sweden	700 MHz	✓	✓	✓	5 and 10 MHz duplex	✓	21 years
	3.4-3.8 GHz	✓	✗	✗	20 MHz	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
United Kingdom	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.6 GHz	✓	✓	✓	20, 40 and 50 MHz	✗	Indefinite term
	26 GHz	✓	✗	✗	N/A	N/A	N/A

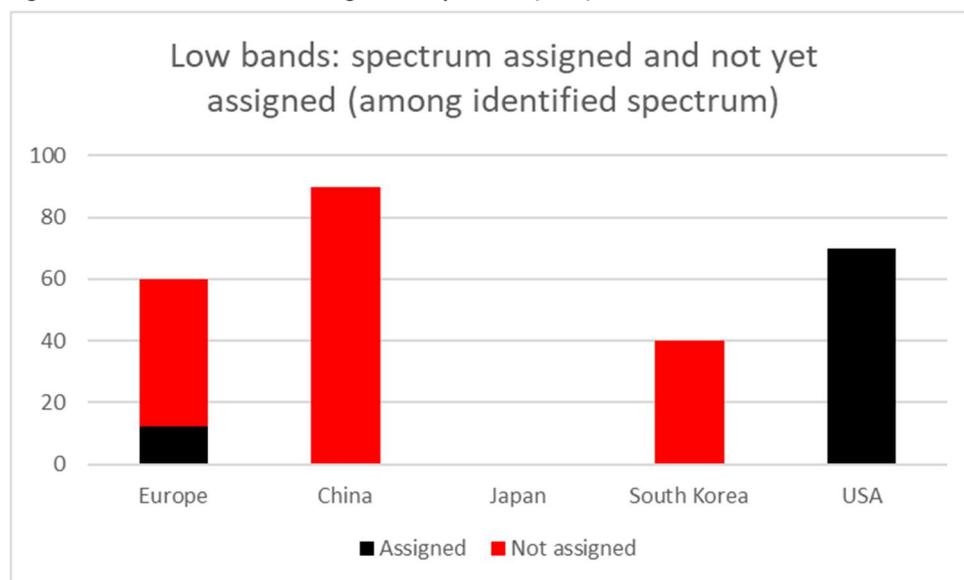
Source: IDATE DigiWorld

3.3. 5G Spectrum comparison

We compared spectrum in low, mid and high bands in the USA, China, Japan, South Korea with the EU. Bearing in mind non-European countries do not have specific pioneer bands for 5G, we assessed spectrum identified and spectrum assigned and took into account national discrepancies.

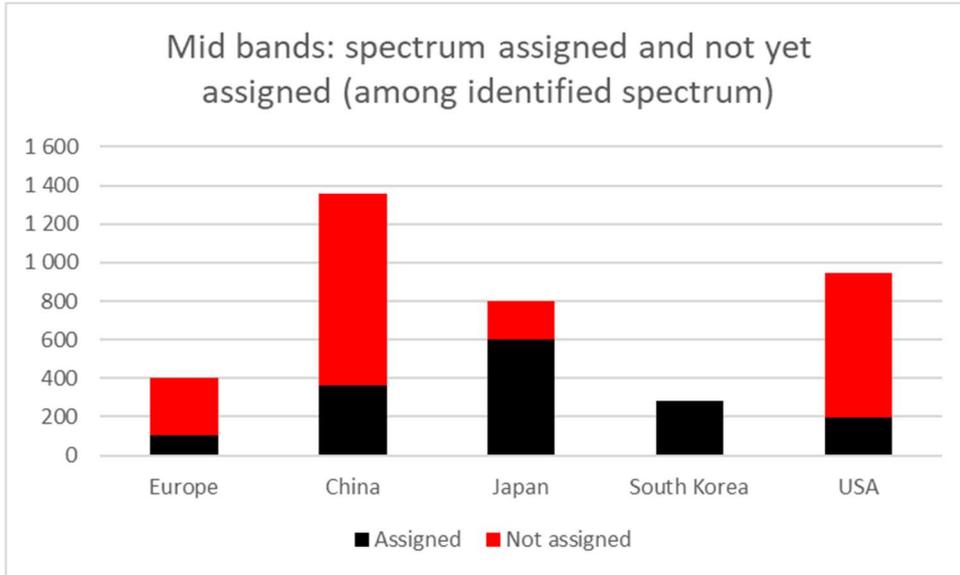
The graphs below show amounts of spectrum identified and assigned in low bands, mid-bands or high bands for each country or region.

Figure 21: Identified and assigned 5G spectrum (MHz) – Low bands



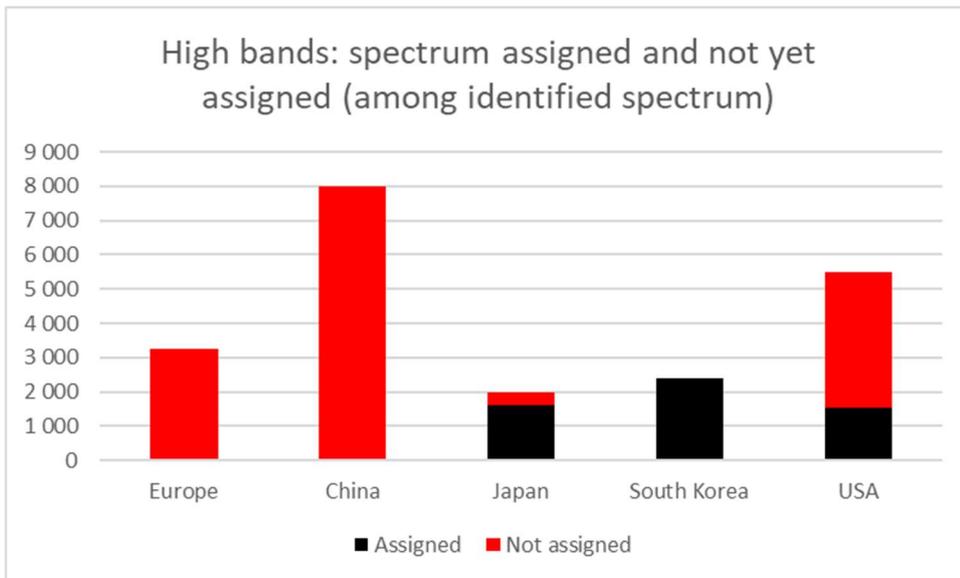
Source: IDATE DigiWorld

Figure 22: Identified and assigned 5G spectrum (MHz) – Mid bands



Source: IDATE DigiWorld

Figure 23 : Identified and assigned 5G spectrum (MHz) – High bands



Source: IDATE DigiWorld

In order to compare identified/assigned 5G spectrum in South Korea, Japan, China and the United States, we listed hereafter frequency bands considered in the low-bands (< 1GHz), mid-bands (>1 GHz and <6 GHz) and high-bands (> 6 GHz):

In the USA:

- Low bands: 600 MHz
- Mid-bands: 2500 MHz, 3550-3700 (CBRS), 3700-4200 and 3450-3550 MHz.
- High-bands considered are: 24250-24450, 24750-25250, 25250-27250, 26500-29500, 37600-38600, 38600-40000, 47200-48200, 42000-42500 and 31800-33000 MHz.

In South Korea:

- Low bands: 700 MHz
- Mid-bands: 3420-3700 MHz
- High bands: 26500-28900 MHz

China:

- Low bands: 700 MHz
- Mid-bands: 2600, 3300-3400, 3400-3600, 3600-4200; 4400-4500, 4800-5000 MHz
- High bands: 24750-27500, 37000-42500 MHz

Japan:

- Low bands: no band identified below 1 GHz
- Mid-bands: 3600-4200, 4400-4900 MHz
- High bands: 27500-29500 MHz

The figure indicated for Europe corresponds to the % of spectrum assigned by Member States for each one of the pioneer bands.

3.5. International developments/trials

USA, Japan, South Korea and China are the leading countries in terms of 5G readiness. A number of Gulf countries claim to be the firsts to have launched 5G:

- **China:** Commercial launches for the three mobile players are scheduled for 2020. Commercial launches in Autumn 2019.
- **USA:** AT&T and Verizon launched mobile commercial services in early 2019. Sprint launched in May 2019 and T-Mobile USA in June 2019.
- **Japan:** KDDI, Softbank and NTT DoCoMo are targeting commercial launch by 2020 (Tokyo Summer Olympics).
- **South Korea:** 5G services for business users were launched in December 2018. Full commercial launch took place in April 2019.
- **Gulf Countries:** Qatar and UAE both claim to be the world firsts to have launched 5G. Without any 5G device available, it appears to be a 5G infrastructure green light rather than a full commercial launch. Kuwait also claims to have launched 5G.

3.5.1. USA

The four main players have already launched 5G.

Spectrum for 5G was identified in July 2016 by the FCC (10.85 GHz in the 28 GHz (27.5-28.35 GHz), 37 GHz (37-38.6 GHz) and 39 GHz (38.6-40 GHz) bands, and in an unlicensed band at 64-71 GHz). 24 and 28 GHz spectrum was auctioned in the first half 2019. The FCC plans to auction upper bands by year-end 2019.

A specific fund for 5G was opened in 2016.

Spectrum issues

The FCC voted in 2016 for the release and development of nearly 11 GHz of high-frequency spectrum intended to be used for fixed and mobile broadband bandwidth uses: 3.85 GHz to be assigned under licences in the bands 27.5-28.35 GHz and 37-40 GHz and 7 GHz, under general authorization, in the band 64-71 GHz.

- July 2016: the FCC made available a total of 10.85 GHz in the 28 GHz (27.5-28.35 GHz), 37 GHz (37-38.6 GHz) and 39 GHz (38.6-40 GHz) bands, and in an unlicensed band at 64-71 GHz.
- November 2017: the FCC made available an additional 1700 MHz of high band spectrum for flexible terrestrial wireless use in the 24 GHz (24.25-24.45/24.74-25.25 GHz) and 47 GHz (47.2-48.2 GHz) bands.
- March 2018: the FCC announced that it would like to hold auctions of the 28 GHz and 24 GHz bands by the end of the year (November 2018 for the 28 GHz auction).
- June 2018: the FCC voted to proceed with making the upper 26 GHz (25.25–27.5 GHz) and 42 GHz (42–42.5 GHz) bands available for 5G services, while examining further aspects of the bands already in the 5G pipeline. The auction for the 28 GHz spectrum (27.5-28.35 GHz) and 24 GHz spectrum (24.25-24.45-24.75-25.25 GHz) is scheduled to begin on November 14, 2018.

- July 2018: the FCC is considering options for up to 500 MHz of spectrum in the 3.7-4.2 GHz frequencies. Satellite companies currently use the frequencies.
- 28 GHz auctions results:
 - The FCC's auction of residual 28 GHz¹⁰ (27.5-28.35 GHz) frequencies began on November 14th, 2018. The auction closed on January 24th, 2019 when a round ended without bids placed.
 - According to the FCC Auction Bidding System Public Reporting System (PRS), winning bids reached 702.6 MUSD on Jan. 24th, 2019, after 38 days of bidding and 176 rounds completed. The residual licences were sold on a county basis. Two blocks of 425 MHz were available.
- 24 GHz spectrum (24.25–24.45 GHz + 24.75–25.25 GHz) auctions started in March 2019 and ended on May 28, 2019. 24 GHz frequencies were auctioned in 100 MHz blocks and sold by partial economic areas (PEAs, PEAs are larger than counties). In total, the auction raised 2.02 billion USD.
- A public notice with public results for 24 and 28 GHz auctions is expected soon.
- The FCC is already looking ahead to its upcoming December auction of spectrum in the upper 37 GHz, 39 GHz, and 47 GHz bands.

3.5.2. China

5G deployment in China is strongly backed by the government. 5G ranks among the strategic priorities for the whole country (13th 5-year plan 2015-2020 and “Made In China” 2025 Initiative launched in 2013). In January 2017, the Ministry of Industry and Information Technology (MIIT) of the Chinese government published a report on “Development Planning for Information and Communication Industry (2016-2020) in which it sets the objective of becoming one of the global leaders of 5G.

The “Made in China 2025” initiative aims for a commercial 5G launch by 2020. As part of the country plan and initiative, the authorities awarded grants to local 5G oriented companies including ZTE and Huawei. ZTE and Huawei received 72 million USD for 5G.

In October 2017, the Chinese government kicked off the 3rd phase of 5G technology research and development tests. This phase aimed to get pre-commercial products ready for when the first version of 5G standard came out in June 2019.

According to the China Academy of Information and Communications Technology (CAICT), China is expected to invest CNY900 billion - 1.5 trillion (USD134 – 223 billion) in 5G networks during the 2020-2025 period.

China awarded four 5G licences to China Mobile, China Unicom, China Telecom and China Broadcasting Network early June 2019, faster than anticipated.

China Mobile, China Telecom and China Unicom have launched 5G services on November 1st, 2019. The operators unveiled their monthly 5G packages. Price plans are quite similar among the three MNOs. Entry-level plans cost 129 CNY (16 EUR) per month and offer 30GB data with 300 Mbps of download speeds and 500 minutes of voice and. Most expensive plans cost 599 CNY (76 EUR) and offer 300GB of data with download speeds of up to 1Gbps. Only high-end price plans offer 5G-like speeds.

¹⁰ The 28 GHz band had already been assigned. This auction is to assign residual spectrum.

Spectrum issues

MIIT (Ministry of Industry and Information Technology) has approved/reserved a number of bands for 5G:

- The 3.3-3.6 GHz is officially reserved. Trials were approved in the band in January 2016. The 3.3-3.4 GHz part is limited to indoor use.
- The 4.8-5 GHz is also reserved for 5G service, China has also solicited opinions on the 24.75-27.5 GHz) and 37-42.5 GHz bands. Trials were approved in the mm-wave frequencies in July 2017.

MIIT identified other bands for 5G:

- MIIT will likely free up the 3.6-4.2 GHz
- Lower frequencies (below 3 GHz were also mentioned for 5G, notably the 700 MHz band which has the largest spectrum band available. However, the 700 MHz spectrum is not available to China Unicom. MIIT might make available spectrum at 1 GHz or 2.5 GHz to Unicom. China Mobile will receive spectrum in the 4.8 GHz-5.0 GHz frequencies.
- Mobile operators have to give back 2.6 GHz spectrum currently used for 4G.

In December 2018, the Chinese government allocated spectrum to players for 5G national trials until June 2020. China Telecom and China Unicom received 100 MHz of spectrum in 3.5 GHz frequencies (3.4-3.5 GHz for China Telecom, 3.5-3.6 GHz for China Unicom). China Mobile obtained 260 MHz in 2.6 GHz (2515-2675 MHz) and 4.8 GHz (4800-4900 MHz) frequencies. Under the arrangement, China Telecom and China Unicom will stop using 2.6 GHz frequencies by end March 2019.

MIIT (Ministry of Industry and Information Technology) issued four 5G licences to China Mobile, China Unicom, China Telecom and China Broadcasting Network at the beginning of June 2019.

China Mobile

China Mobile started to conduct 5G trials during the second half of 2016. China Mobile plans to start offering 5G services in September 2019 in 40 cities, which is a year earlier than originally planned (2020). China Mobile was issued a 5G licence by the Chinese Government early June 2019.

In 2018, China Mobile announced large-scale trials in five cities including Shanghai and Hangzhou by the third quarter of 2018 with about 500 base stations (100 first base stations by end June 2018). Trials will be extended to 20 cities early 2019 with another 500 base stations, to test out business applications. The trial network will use 3.5 GHz spectrum and some of the 4.9 GHz band.

China Mobile appears to be the fastest player in China towards 5G. In November 2018, China Mobile presented its '5G Terminal Pioneer Programme', through which it plans to launch 5G-compatible devices by 2019. The company announced that first 5G devices will be launched by H1 2019. Under the government's current plans for 5G development, the new technology will see pre-commercial use in 2019 while full commercial launch will occur by 2020.

In February 2019, China Mobile announced it plans to deploy 5G at scale in four cities this year in non-standalone (NSA) mode. The operator is collaborating on developing equipment running on the 2.6 GHz and 4.9 GHz bands to increase capacity and reduce power consumption of 5G base stations.

China Unicom

China Unicom announced in August 2018 that 300 5G base stations will be implemented in Beijing this year, via its 'Next 5G' initiative. China Unicom has been trialling 5G in 600 labs of 16 cities including Beijing, Tianjin, Qingdao, Hangzhou, Nanjing, Wuhan, Guiyang, Chengdu, Shenzhen, Fuzhou, Zhengzhou, and Shenyang. In 2019, application experiments and large-scale trials are scheduled.

In January 2019, China Unicom announced it completed a 5G call with a ZTE 5G prototype smartphone in a commercial field trial in Shenzhen.

China Unicom received a 5G licence from the Chinese Government early June 2019. It plans to launch 5G services in 40 cities by the end of September 2019.

China Telecom

China Telecom started testing 5G in six cities including Xiong'an, Shenzhen, Shanghai, Suzhou, Chengdu and Lanzhou in a view to test 5G in 12 cities in the end.

3.5.3. South Korea

In South Korea, the Korean Government (Ministry of Science, ICT and Future Planning) and the public-private partnership, 5G Forum, itself established in Seoul on 30 May 2013, defined the 5G mobile strategy as early as January 2014. For that purpose, the Government allocated 1.5 billion USD.

The program of the 5G Forum (www.5gforum.org) runs over the seven-year period of 2014-2020 with a joint investment of 1.6 trillion KRW by both the Government and the private sector. Some 26 companies/institutions are part of the project comprised of private companies (operators, equipment vendors), research institutes and universities.

The South Korean carriers agreed mid-2018 to build single 5G network to save money and time. 5G services were jointly launched by the three MNOs on April 3rd, 2019.

Spectrum issues

The government assigned 280 MHz of the 3.4-3.7 GHz spectrum in June 2018 at 3.3 trillion KRW (2.4 billion EUR). Prices raised very high levels (more than 16 EUR per MHz per pop for 10 years).

At the same time, the South Korean government assigned 2400 MHz (800 MHz for each player) of 28 GHz spectrum. Each player paid 160 million EUR for the 28 GHz spectrum.

3.5.4. Japan

The Radio Policy Vision Council of the MIC (Ministry of Internal Affairs and Communications) held in 2014 presented the roadmap for 5G. Following this report, the 5GMF (5G Mobile Forum) was established late in September 2014. Around 300 million USD have been dedicated by the Japanese authorities to promote the Industrial IoT and related technologies such as big data, artificial intelligence, and robotics. Japanese operators target the roll out 5G in time for hosting the Summer Olympic and Paralympic Games in August 2020.

Spectrum issues

In April 2019, The Ministry of Internal Affairs and Communications (MIC) has assigned spectrum in the 3.7 GHz, 4.5 GHz and 28 GHz bands through a beauty contest to the four mobile operators in Japan. Spectrum has been assigned as follows:

- NTT Docomo: 3.6-3.7 GHz, 4.5-4.6 GHz and 27.4-27.8 GHz
- KDDI: 3.7-3.8 GHz, 4.0-4.1 GHz and 27.8-28.2 GHz
- Softbank: 3.9-4.0 GHz and 29.1-29.5 GHz
- Rakuten: 3.8-3.9 GHz and 27.0-27.4 GHz

NTT DoCoMo

As early as 2017, NTT DoCoMo executives indicated that the Tokyo Summer Olympics were a target for 5G launch. NTT DoCoMo sticks to that target date; it could however pre-launch 5G services in Autumn 2019.

NTT DoCoMo carried out a number of 5G trials with multiple vendors. For example, they cooperated with Tobu Railway to trial a 5G system at Tokyo Skytree Town using 28 GHz spectrum in March 2018. Earlier in November 2016, they carried out a large-scale field trial using 200 MHz of spectrum in the 4.5 GHz band in Yokohama, Japan. This trial, aimed at testing Ultra Reliable and Low Latency Communications (URLLC), resulted in network speeds up to 11.29 Gbps total and less than half-a-millisecond latency. NTT DoCoMo also completed 5G integrated access backhaul trials using the 39 GHz frequencies. With Nokia, NTT DoCoMo tested 5G on the 90 GHz band.

In May 2018, NTT DoCoMo achieved a 5G field trial at 28 GHz, involving a 5G base station and a car travelling at around 293 km/h. In November 2018, NTT DoCoMo and Mitsubishi Electric achieved peak data speeds of up to 27 Gbps during 5G trials, using a single mobile terminal and 500 MHz of spectrum in the 28 GHz band.

NTT DoCoMo, in partnership with Metawave Corp, demonstrated 5G technology in December 2018 using the 28 GHz band. The trial took place in Koto-ku, Tokyo and achieved data transmission speeds of 560 Mbps with Metawave's meta-structures reflect-array in place, compared to 60 Mbps with no reflector.

In December 2018, NTT DoCoMo and Mitsubishi ran 5G trials in Kanagawa. Tests used a single terminal and 500 MHz of 28 GHz spectrum. By using a 16-beam spatial multiplexing in LOS (line of Sight) conditions with massive MIMO antennas, tests hit a peak speed of 27 Gbps at a distance of 10 metres. At a distance of 100 metres, tests achieved 25 Gbps.

Softbank

SoftBank has been performing many 5G trials with Huawei or Ericsson since 2017, notably using 4.5 GHz frequencies. SoftBank is working with Huawei to demonstrate 5G. A demonstration included real-time UHD video transmission (throughput of over 800 Mbps) using ultra-high throughput, remote control of a robotic arm and ultra-low latency transmission as well as remote rendering via a GPU server using edge computing. With ZTE, Softbank achieved DL speeds of 956 Mbps in Nagasaki in October 2017. Commercial launch of 5G service is expected in 2020.

KDDI

In December 2017, KDDI and Samsung completed a successful 5G demo on a train moving at over 100 km/h. The distance between two stations was approximately 1.5 km. Companies achieved a successful DL and UL handover as well as a peak speed of 1.7 Gbps.

KDDI has also performed 5G trials, mainly with Ericsson and Samsung Electronics. Between September 2017 and March 2018, KDDI and Ericsson tested a PoC in the 4.5 GHz frequency band in many cities across Japan.

In November 2018, KDDI outlined plans to start offering 5G services in selected areas by 2019, with full-scale development coming in 2020. It reportedly aims to implement its 5G core in 2021, planning to launch various services using network slicing.

Rakuten Mobile

Rakuten Mobile is the fourth mobile operator in Japan, planning to launch its service in 2019 starting with 4G, with 5G following a few months later. The operator intends to launch a fully virtualized cloud-native mobile network.

3.5.5. India

The Indian government is strongly backing 5G deployment. Indian authorities established a 5G forum with a budget of approximately 76 million USD dedicated to 5G research and development.

The government launched two strategic initiatives to address these challenges: India's Smart Cities Mission and Digital India. 5G will be central in achieving these government-backed initiatives that focus on easing the stress of urban population growth and closing the digital divide among the citizens from different social backgrounds.

India has significant infrastructure challenges that will limit 5G deployment, such as the lack of a robust network to connect cellular sub-networks to a core networks. The majority of mobile subscriptions are still 2G, and MNOs have already begun considering to leapfrog from 2G/3G directly to 5G.

A reasonable target for 5G launch is 2022.

The Department of Telecom (DoT) is harmonizing spectrum in the 3.3-3.6 GHz band and 26 GHz band, along with the 71-76 GHz, the 81-86 GHz and the 57-64 GHz frequencies as 5G candidate bands.

The DoT ordered operators to vacate spectrum in the 3.3-3.4 GHz range by the end of September 2018. In August 2018, the government and the regulator TRAI suggested a reserve price of 30% of 1800 MHz FDD band for the 3.3-3.6 GHz spectrum i.e. 985 INR per MHz (12.4 EUR) considering the 1800 MHz reserve price of 3285 INR. Mid-frequencies should be put for sale in 20 MHz blocks with a spectrum cap of 100 MHz per bidder.

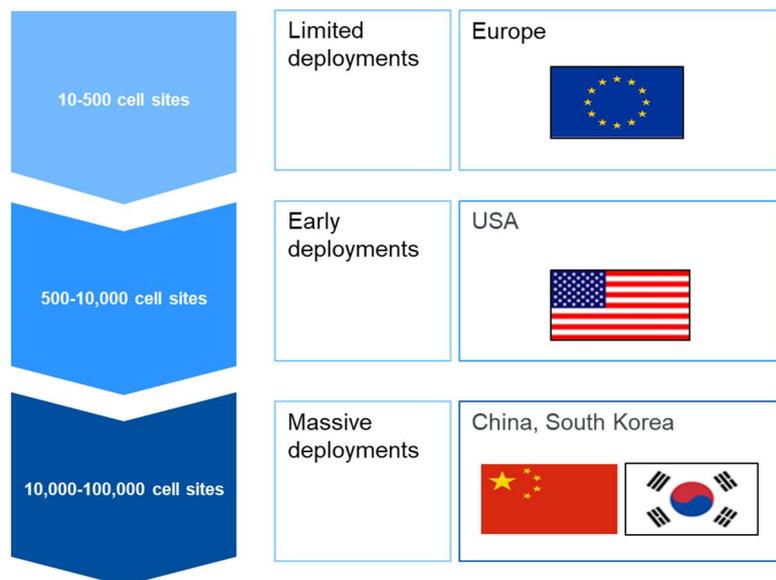
3.6. 5G commercial launch dates

Country	Operator	5G commercial launch	Expected 5G commercial launch
Austria	T-Mobile Austria	03/2019	
	A1 Telekom Austria	01/2020	
	Hutchison 3G Austria		H2 2019
Belgium	Proximus		2020
	Orange Belgium		Q4 2020/H1 2021
	Telenet Belgium		2021
Bulgaria	A1		2020
	Telenor		2020
	Vivacom		Q4 2020/H1 2021
Croatia	A1 Croatia		2020
	T-Hrvatski Telekom		2020
	Tele2 Croatia		n/a
Cyprus	MTN		2020
	CYTA		2020
	PrimeTel		2020
Denmark	TDC		Q4 2020
	Telenor Denmark		2020
	Telia Denmark		n/a
	3 (Hi3G)		n/a
Estonia	Telia Estonia		H2 2019
	Tele2 Estonia		2020
	Elisa Estonia		2020
Finland	Elisa Finland	June 2018	
	DNA	December 2019	
	Telia Finland	November 2019	
France	Orange France		2020
	SFR		2020
	Bouygues Telecom		2020
	Free Mobile		2020
Germany	Deutsche Telekom	July 2019	
	Telefonica Germany		n/a
	Vodafone Germany	July 2019	
Greece	Vodafone Greece		n/a
	Cosmote		n/a
	WIND Hellas		2020/2021
Hungary	Magyar (Deutsche Telekom)		2020
	Telenor Hungary		n/a
	Vodafone Hungary	October 2019	
Ireland	Vodafone Ireland	July 2019	
	EIR	December 2019	
	Three Ireland		H2 2019
	Virgin Mobile		n/a
Italy	TIM	June 2019	
	Wind Tre		H2 2019
	Vodafone Italy	June 2019	
	Iliad		n/a
Latvia	Tele2 Latvia		Autumn 2019
	Bite		n/a
	LMT	July 2019	
Lithuania	Bite		n/a
	Tele2		n/a
	Telia (Omnitel)		H2 2019

Country	Operator	5G commercial launch	Expected 5G commercial launch
Luxembourg	POST		n/a
	Tango		Mid-2020
	Orange		2020
Malta	Melita		H2 2019
	Vodafone Malta		n/a
	GO		n/a
Netherlands	T-Mobile		2020
	VodafoneZiggo		2020
	KPN		2020
Poland	T-Mobile Polska		2020
	Orange Poland		2020/2021
	Plus		n/a
	Play		n/a
Portugal	Altice (MEO)		H2 2019
	NOS		2020
	Vodafone		End 2019
Romania	Orange	November 2019	
	Telekom		2020
	Vodafone	June 2019	
	RCS&RDS (DIGI)	June 2019	
Slovakia	Orange		n/a
	T-Mobile		n/a
	O2		n/a
Slovenia	Telekom Slovenije		2020-2022
	A1		n/a
	Telemach		n/a
Spain	Orange Spain		H2 2019
	Telefonica (Movistar)		2020
	Vodafone Spain	June 2019	
	Yoigo		n/a
Sweden	Telia		H2 2019
	Tele2		2020
	Telenor		2020
Switzerland	Sunrise	March 2019	
	Salt		Q4 2019
	Swisscom	April 2019	
United Kingdom	EE	May 2019	
	Telefonica UK	October 2019	
	Vodafone UK	July 2019	
	Three UK	August 2019 (FWA)	

3.7. Number of cell sites for 5G trials and commercial deployments

A number of mobile operators have already announced the number of 5G cell sites they are using or planning to use for their 5G trials and commercial deployments.

Figure 24: 5G deployments – number of cell sites

Source: IDATE DigiWorld – December 2019

Large scale deployments are observed in China and South Korea with massive numbers (over 10,000) of 5G cell sites. Small scale deployments took place with tactical rollouts of pockets (100s) of 5G cell sites (Australia, UK, Germany, Saudi Arabia, Switzerland, UAE). Medium scale deployment is taking place in the USA with thousands of 5G cell sites.

Table 16: Number of cell sites/base stations for 5G trials and networks

Country	Operator	Number of 5G cell sites	Announcement date
Austria	T-Mobile	Commercial launch with friendly customers. 25 base stations installed in rural areas.	May 2019
Austria	Drei	100 5G base stations by the end of 2019. The 6000 cell sites the MNO operates should be 5G equipped within 2 years	December 2019
Australia	Optus	Signed a partnership with Ericsson to deploy 50 5G sites across the cities of Sydney and Melbourne	February 2019
China	China Mobile	China Mobile announced plans to deploy more than 50,000 5G base stations in 2019. This figure was confirmed in November 2019.	June 2019
China	China Unicom	500 5G stations in Shanghai. Plans to construct 10,000 5G base stations by the end of 2019 and 30,000 by 2021.	April 2019
China	China Telecom	China Telecom announced plans to deploy 40,000 5G base stations by YE2019	Early 2019
China	Three operators	China's deployment plans: more than 80,000 5G base stations in November 2019, and about 130,000 expected by year-end	November 2019
Europe	Vodafone	Setting up trial areas in seven cities and plans to expand to 1,000 sites by 2020	September 2018
France	Orange	Orange announced the installation of 80 5G antennas in Marseille, 40 of which should be installed by spring 2019, and the rest before the end of 2019.	January 2019
France	Orange	263 authorized 5G sites in Metropolitan France	September 2019
France	Bouygues Telecom	63 authorised sites in Metropolitan France	September 2019
France	SFR	25 authorized 5G sites in Metropolitan France	September 2019

Country	Operator	Number of 5G cell sites	Announcement date
Germany	Deutsche Telekom	Deutsche Telekom currently maintains about 28,000 towers across Germany, but the operator has formerly suggested that figure could even double with the rollout of 5G technology in the 2020s	February 2018
Germany	Deutsche Telekom	Wants to build over 2,000 new mobile sites every year along with 10,000 smaller radio cells to improve coverage at high-demand locations or inside buildings Signed an agreement to build 14,000 new masts in Germany (with competitors)	October 2018 September 2019
Germany	Deutsche Telekom	Announced it plans to build 300 5G antennas in 6 cities in Germany by YE-2019	March 2019
Germany	Deutsche Telekom	Announced 129 5G antennas at 5G launch (66 antennas in Berlin)	September 2019
Germany	Vodafone	25 5G base stations in 20 cities Already operates 60 5G sites and 140 antennas in 40 German cities. Will add 150 5G antennas before year end.	July 2019 November 2019
Italy	Vodafone	The 5G network in Milan covers 80% of the city's population via 120 active sites	December 2018
Kuwait	Viva	Viva is rolling out a nationwide 5G network with over 1,000 5G NR-based radio sites in 2019	March 2019
New Zealand	Vodafone	Plans to have at least 100 5G cell sites by YE-2019. Tested 5 5G sites as from September 2019	August 2019
South Korea	KT	Around 1500 5G base stations deployed in January 2019. 30,000 base stations by April 5, 2019 (including 15,000 in Seoul)	January 2019 March 2019
South Korea	LG Uplus	5,500 5G base stations deployed in January 2019 18,000 base stations deployed in March 2019. The operator plans to install 50,000 base stations within the first half of the year. 80,000 5G base stations planned for end 2019	January 2019 March 2019
South Korea	SK Telecom	Around 1500 5G base stations deployed in January 2019 34,000 5G base stations 54,202 5G base stations	January 2019 April 2019 May 2019
UAE	Du	Plans 700 5G base stations by year-end 2019	February 2019
UK	Vodafone	In 2018, tested 5G at more than 40 sites in Birmingham, Bristol, Cardiff, Glasgow, Liverpool, London and Manchester Extension to 1,000 sites by 2020 Operates 200 5G sites and plans 500 additional sites by YE2019	June 2018 December 2018 July 2019
UK	EE/BT	Nine 5G trial sites are now live across East London. 1500 cell sites will be operating in 2019 covering 15% of the population (25% of total traffic)	November 2018

Source: IDATE DigiWorld

3.8. 5G network equipment – main manufacturers

3.8.1. Ericsson

Ericsson as well claim to offer the “Market first global 5G access and transport portfolio”, having created its Radio System as the basis for its future 5G offering including a transport and access solution. Ericsson put the stress on the smooth transition from 4G to 5G that its solution enables with notably a support for spectrum sharing between 4G and 5G. This solution brings increased flexibility for spectrum asset usage since it enables to deploy both 4G and 5G in the same spectrum, something particularly interesting at the beginning when 4G devices still account for the majority of the data

traffic. With its 5G radio dot offering, Ericsson also emphasize the importance of indoor coverage and how its tiny base station fulfils the challenge of bringing 5G capacity indoor. A street macro solution and RAN compute portfolio that should be launched in the second half of 2019.

Figure 25: Presentation of Ericsson 5G solution



Source: Ericsson

Table 17: Ericsson 5G portfolio

5G product	Comments
Base stations	
5G radio dot	For indoor coverage, support 5G mid bands between 3 and 6 GHz for speeds up to 2 Gbps
Hardened Radio Dot	for outdoor and stadium deployments
5G Indoor Radio Unit	Used to aggregate 5G radio dots
5G Street Macro	increase capacity in urban areas across mmWave spectrum bands
RAN Compute portfolio	enable the easy distribution of RAN functions (centralized or distributed)
baseband	Baseband processing supporting 10 modes from 4G LTE to 5G NR through massive MIMO
Radio Processor	For deployment close to the radio site, software upgradable
Core network	
Cloud packet core	5G EPC for NSA operation and 5G Core for SA operation, to be deployed in data center, support for centralized and distributed network function, network slicing
Cloud UDM and Policy	Support for dynamic network slice selection

Source: IDATE DigiWorld

3.8.2. Huawei

In February 2018 at MWC in Barcelona, Huawei presented its end-to-end 5G solution including a 5G baseband for devices. Huawei claimed to be the only vendor to offer an end-to-end 5G solution at that time, covering sub 3 GHz frequency bands, C band as well as mm-wave band. Those products have been adapted to the different types of deployment likely to be used for 5G, with tower sites, pole sites and small cells and are accompanied by Active Antenna Units with up to 64T64R antenna elements to further increase capacity.

These Active Antenna Units are particularly important for 5G network to leverage new frequency bands and face the new challenges associated with new network topologies, where beamforming and Multi User MIMO brings new capacity and flexibility in the coverage of users. In the C-Band (3,5 GHz), Huawei Massive MIMO AAUs support the aggregation of up to 200MHz total bandwidth and also support 3D beamforming. Huawei mmWave products support up to 1GHz of bandwidth.

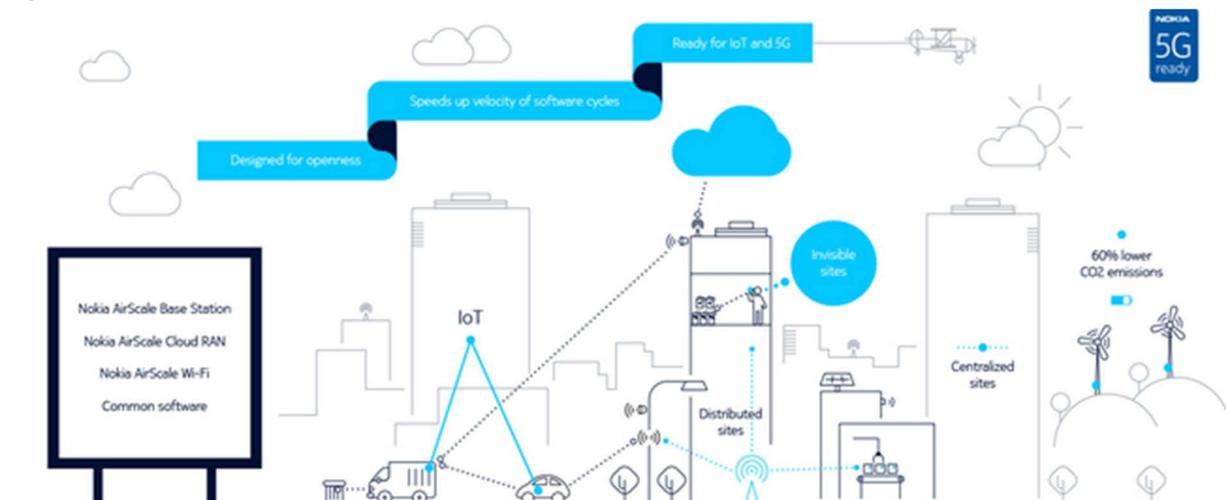
As for baseband units (BBU) they have been designed to support both centralized and distributed RAN

Recently, Huawei has been facing a sale ban in the US from the government over security concerns. This sale ban is accompanied with pressure on other countries to rethink their relation with Huawei, especially in the core market. As an example of collateral effect, Softbank in Japan decided to select Nokia and Ericsson instead of Huawei, with which it had been working in the past for 4G and in 5G trials.

3.8.3. Nokia

The AirScale Radio Access solution is the RAN equipment proposed by Nokia for 5G networks. It uses the ReefShark chipsets which decrease the size of massive MIMO antennas by 50%, and allow a 64% reduction in the power consumption of baseband units.

Figure 26: Nokia AirScale Radio Access for 5G



Source: Nokia

The Finnish manufacturer also proposes a cloud-native 5G core, the AirFrame data center solution, and mobile transport solutions.

Table 18 : Nokia 5G portfolio

Nokia 5G product	Description
RAN (AirScale Radio Access)	
<i>AirScale base stations</i>	
<i>AirScale Active Antennas</i>	support Massive MIMO
<i>Airframe</i>	Nokia AirFrame Cloud infrastructure
<i>AirScale WiFi</i>	
Transport (Nokia 5G Anyhaul)	
<i>Microwave Anyhaul</i>	microwave solution up to 170 GHz, support network slicing
<i>IP Anyhaul</i>	
<i>Optical Anyhaul</i>	Enable deployment of centralized and distributed RAN architectures
<i>Broadband Anyhaul</i>	
Core network	Cloud native 5G Core network
AAA	Authentication, authorization and Accounting solution
<i>Cloud Packet core</i>	Cloud native and multi access packet core
<i>Cloud Signaling Director</i>	
<i>Shared Data Layer</i>	
<i>Smart Plan Suite</i>	
<i>Subscriber Data Management</i>	
<i>Telecom Application Server</i>	

Source: IDATE DigiWorld based on Nokia

3.8.4. Samsung

Figure 27: Samsung 5G products evolution



Source: Samsung

With 5G, Samsung has been much more vocal about its technological prowess than with 4G, touting a host of first with notably the first mm-wave Proof of Concept as early as in 2013 and the first field deployed 5G product in 2017. Samsung was notably involved in several demonstrations over the capabilities of mm-wave propagations in different environment (static, urban, different mobility scenario...).

If we exclude transport offering (microwave, optic fiber ...) Samsung has a complete 5G portfolio. It has notably developed a Fixed Wireless Access solution for the South Korean and American (Verizon) market.

Figure 28: Displaying of Samsung 5G FWA solution for the American market



Source: Samsung

3.8.5. ZTE

ZTE is seen as one of the leader in terms of 5G technology development, having received several awards for its pre-5G solutions notable. ZTE is notably known for working on applying 5G concepts on 4G commercial networks. This pre-5G solution support technologies such as Massive MIMO and Ultra Dense Network 5G technologies and combine them with LTE-Advanced Pro technologies such as Massive Carrier Aggregation, 256QAM, LAA, LWA and NB-IoT. This solution is also aimed at facilitating the future transition from 4G to 5G.

ZTE pre-5G solution was commercially deployed in China, in Japan but also in Japan with Softbank. Softbank became the first operator to launch commercial Massive MIMO, a solution based on 8T8R antenna system enabling the reach of 1 Gbps throughput with two Carrier Components carrier aggregation. It was followed by Telkomsel in Indonesia. Massive MIMO trials with ZTE solutions were also carried out by Telefonica, H3G in Spain and Austria.

According to ZTE, the use of Massive MIMO with 4G network enables an increase of spectral efficiency up to 8 times.

ZTE has also developed a solution for massive Machine Type Communication with MUSA.

3.9. Electromagnetic Fields (EMF) in the EU-28 Member States

As regards wireless services in general and mobile services in particular, there have been long-standing public concerns over possible health effects due to exposure to electromagnetic fields (EMF).

In Europe, EMF guidelines for non-ionising¹¹ EMF are primarily based on the guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The current ICNIRP guidelines are reflected in a 1999 Council Recommendation¹² on the permissible level of emissions for equipment to be deployed. Article 58 of the newly enacted European Electronic Communications Code (EECC) effectively requires Member States to notify the Commission of draft measures where the Member State intends to deviate from the Council Recommendation, and empowers the Commission or other Member States to propose amendments to the draft measure in order to remove or reduce barriers this might create to the free movement of goods.

Table 19 : Adoption of ICNIRP limits in the EU-28 Member States

EU-28	Details on EMF	
Austria	Yes	
Belgium	No	More restrictive than ICNIRP. Each region has its own limits. Current limits do not allow 5G deployment in the city of Brussels.
Bulgaria	No	Public exposure limit of 0.1 W/m ² (300 MHz to 30 GHz)
Croatia	No	Exposure limits for power density are 16% of the ICNIRP guidelines
Cyprus	Yes	ICNIRP limits adopted in 2004

¹¹ Non-ionizing radiation is the term given to radiation in the part of the electromagnetic spectrum where there is insufficient energy to cause ionization. It includes electric and magnetic fields, radio waves, microwaves, infrared, ultraviolet, and visible radiation (see https://www.who.int/topics/radiation_non_ionizing/en/).

¹² European Council (1999), Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz), (1999/519/EC).

EU-28		Details on EMF
Czech Republic	Yes	ICNIRP limits adopted in 2000
Denmark	Yes	
Estonia	Yes	ICNIRP limits adopted in 2002. No permit for ERP power <100W
Finland	Yes	
France	Yes	ICNIRP limits adopted in 2002
Germany	Yes	
Greece	No	60% of ICNIRP guidelines for base stations located less than 300 m from schools, hospitals... 70% of ICNIRP guidelines in other areas
Hungary	Yes	ICNIRP limits adopted in 2004
Italy	No	20 V/m as a general limit in open areas. 6 V/m inside buildings used for more than four hours a day
Ireland	Yes	
Latvia	Yes	
Lithuania	No	Public limits for power density set at 10% of ICNIRP limits
Luxembourg	No	Limit at 3 V/m per operator and per antenna system. About 0.2% of ICNIRP limit above 2 GHz
Malta	Yes	
Netherlands	Yes	
Poland	No	0.1 W/m ² between 300 MHz and 3 GHz. 1% of ICNIRP limits above 2 GHz
Portugal	Yes	ICNIRP limits adopted in 2004
Romania	Yes	
Slovakia	Yes	ICNIRP limits adopted in 2007
Slovenia	Yes	
Spain	Yes	ICNIRP limits adopted in 2001
Sweden	Yes	
UK	Yes	ICNIRP limits adopted in 2000

3.10. TDD synchronisation in the EU-28 Member States

TDD synchronisation status in the EU-28

Up to now, all 2G and 3G networks and the vast majority of 4G networks were deployed in FDD mode in Europe. 5G networks are going to use the TDD mode in the 3.4-3.8 GHz band. ECC report 296, “National synchronization regulatory framework options in 3400-3800 MHz: a toolbox for coexistence of MFCNs in synchronised, unsynchronised and semi-synchronised operation in 3400-3800 MHz” addresses the question of Time Division Duplex (TDD) synchronisation between mobile (4G and 5G) networks. Annex 1 “synchronisation frameworks in recent C-Band award procedures” provides some information on national conditions in Austria, Ireland, Italy and the United Kingdom.

In Europe, the majority of legacy TDD networks deployment can be grouped in two categories (source ECC report 296):

- Based on synchronised operation when operators run their networks without relying on sufficient isolation (e.g. this is the case of LTE-TDD networks, comprising thousands of BS, in Italy operating in the 3400- 3600 MHz band);

- Based on unsynchronised operation when there is sufficient isolation between operators running their networks on adjacent frequency blocks (e.g. one operator per region is often assumed).

Going forward, recent advances for newer TDD systems in a multi-operator context encourage synchronisation more strongly, therefore this situation is expected to evolve in the coming years.

TDD synchronisation frameworks in the EU-Member States

ECC Report 296 section 3.3 describes some potential situations where inter-operator agreement relying solely on the market may be challenging in a multi-operator context (either at the time of auction, or later in time). Therefore regulators may get involved at some point in the process in order to ensure an efficient spectrum usage. This has already been done in the past, and ECC Report 216 Annex 3 already describes a few of them: Austria, Ireland, Italy and the United Kingdom. France and Sweden have also recently addressed this question.

3.10.1. Austria

(source ECC report 296)

The Austrian Administration is planning to start the assignment procedure for the 3410-3800 MHz range in Q1 '19. The following provisions are described in the tender document from the Telekom-ControlKommission.

The "LTE compatible" NR frame structure (DSUDDDSUDD) is defined as the "default frame structure" for which the ECC baseline out of block power limit applies. "Licence holders are responsible for ensuring that frames are based on a uniform reference time (+/- 1.5 µs), so that all of any licence holder's frames are aligned equally and transmissions are consequently synchronised". "...Small cells inside buildings are exempt from synchronisation. The default BEM can be used for such small cells in buildings, provided that no damaging interference occurs to other licence holders".

According to the tender document: "... the synchronisation frame specified here can be altered by the TTK to reflect technical and economic conditions when 5G reaches market maturity, in accordance with Art. 57 TKG 2003. If such modifications are indeed made, consideration will nonetheless have to be given in each case to the proportionality of the measure and the economic impact on the parties affected. Even if any such change is made, the spectrum holders will have the option of stipulating under private law a synchronisation frame".

The tender document also provides conditions associated with the use of the restrictive BEM when "other frame structures" are adopted.

3.10.2. France

On August 1st, 2019, ARCEP published Decision n° 2019-0862 on synchronisation of terrestrial networks in the 3.4-3.8 GHz band in France. This decision requires that terrestrial networks operating in the 3.4-3.8 GHz band will have to use the same synchronisation frame from July 1st 2020.

However, terrestrial networks in the 3.4-3.8 GHz band will be allowed to use another synchronisation frame as long as they do not generate harmful interferences to other networks.

3.10.3. Ireland

(source ECC report 296)

In its June 2017 Spectrum 3600 MHz band spectrum award [1] Ireland mandated the LTE-TDD frame configuration #2 with special sub-frame configuration #6 (or equivalent frame structures whose transmit and receive periods are aligned with this configuration) as the default frame structure which an operator must comply with in order to be allowed to comply with the "permissive Block Edge Mask". The operator must also ensure compliance with a common reference time of +/- 1.5µs.

3.10.4. Italy

(source ECC report 296)

In September 2018, a multiband 5G spectrum auction in Italy followed a light touch approach with respect to the definition of the synchronisation framework for the 3600-3800 MHz band. The auction rules [12] did not include specific provisions in relation to the synchronisation framework, leaving to operators the task to agree on the most suitable framework. Soon after the frequency assignment, the Italian Ministry has announced that it will facilitate the process by setting up a specific working group among operators that acquired licences in the band.

3.10.5. Sweden

Source: PTS

PTS issued a consultation covering synchronisation of TDD networks in the 2.3 GHz and 3.5 GHz in 2018. PTS is proposing licensing conditions enabling co-existence without geographical separation, implemented by a "relaxed" BEM and a common frame structure, in case the licencees cannot reach an agreement themselves, and it should be re-considered every 5 years in order to follow technology development.

3.10.6. United Kingdom

(source ECC report 296)

In its May 2015 statement on the award of the 3.4 GHz spectrum band [14], the UK decided on the LTE-TDD frame configuration #2 with special sub-frame configuration #6 (or equivalent frame structures whose transmit and receive periods are aligned with this configuration) as the "preferred frame structure" which an operator must comply with in order to be allowed to comply with the "permissive transmission mask. An operator unwilling to adopt the "preferred frame structure" must comply with the "restrictive transmission mask" and the "compatible frame structure", i.e. must comply with semi-synchronised operation.

Licencees are required to synchronise their networks in order to avoid interference to one another, so traffic alignment and the "preferred frame structure" for transmission with the limits of the "permissive transmission mask" are mandated to implement the synchronisation. Timeslots must have a duration of 1ms. LTE-TDD frame configuration #2 (3:1) is compatible with this frame structure.

Indoor base stations with a transmit power level below 24 dBm are exempt from synchronisation requirements unless they cause interference to the macro-cellular network, in which case they are required to synchronise.

In April 2018, Ofcom conducted the auction, and the 3.4 GHz band plan based on final auction results as below, as announced by Ofcom. Ofcom will auction 3600-3800 MHz in second half of 2019.

European Commission

5G Observatory – Quarterly report 6

Luxembourg, Publications Office of the European Union

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