

# **5G Observatory**

## **Quarterly Report 10**

### **Up to December 2020**



European 5G Observatory

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# 1. Executive summary

This is the tenth quarterly report of the European 5G Observatory for the fourth quarter of 2020.

At the end of 2020, 5G commercial services were available in twenty-three EU-27 states.

Spectrum assignment in the pioneer bands has not reached the 5G Action Plan objectives with assignment of the three pioneer bands in all Member States. At the end of 2020, only three Member States had assigned spectrum in all three pioneer bands.

Beyond the dramatic health and socio-economic impact of the COVID-19 pandemic affecting all of us, there are also many impacts on the 5G ecosystem today. During the lockdown, cellular networks have coped with increased traffic requirements and been proven reliable. First 5G networks in Europe have only a limited number of users, so there have been no congestion issues yet.

During 2020, many 5G auctions were delayed in Europe due to the pandemic situation. Most of these delayed processes took place in the latest months of 2020.

In the medium to longer term, it is likely that this crisis will increase the awareness of the need for digital solutions, e.g. in telehealth, increased teleworking (which also calls for higher network capacity and bit rates), fixed wireless access and many features supported by 5G networks.

## 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-27 plus the United Kingdom, 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 more than two years with equipment manufacturers and vertical industry players on various trials and pilots in order to validate 5G's capabilities. At end-December 2020, it was clear that they are heavily involved in 5G testing with 199 trials reported at that time (up from 138 in Q4/2018) in EU-27 countries plus the UK.

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 large number of cities throughout Europe. Deployments are on-going with generally tens to hundreds of base stations to be switched on in many European cities. Germany already has more than 10,000 5G base stations in operation.



At the end of December 2020, 24 countries (EU Member States plus the UK) enjoy 5G services (Austria, Belgium, Bulgaria, Croatia, Czech Republic, Estonia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Romania, Slovakia, Slovenia, Spain, Sweden and the UK), and in several countries there are more than one 5G service provider: all four mobile operators in France (Bouygues Telecom, Free Mobile, Orange and SFR), Italy (TIM, Illiad, WindTre and Vodafone Spain (Orange, Masmovil, Telefonica and Vodafone), Spain (Orange, Masmovil, Telefonica, Vodafone). Sweden (Tele2, Telenor, Tre and Telia) and in the United Kingdom (EE, Vodafone, O2, Three: FWA) offer commercial 5G services. Many commercial service launches took place at the end of 2020: Free Mobile in France, Slovak Telekom in Slovak Republic, HT in Croatia and Telenor in Sweden. Three players provide 5G services (mobile and/or FWA) in Austria (T-Mobile, A1 and Hutchison), Czech Republic (Telefonica, T-Mobile and Vodafone), in Finland (DNA, Elisa and Telia), Germany (T-Mobile, Telefonica and Vodafone), Ireland (Eir, Three and Vodafone), Netherlands (KPN, T-Mobile and VodafoneZiggo), Poland (Orange, Polkomtel and T-Mobile Poland) and Romania (Digi, Vodafone and Orange).

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 December 2020, 5G commercial services had been deployed in 24 countries (EU-27 plus the UK). 5G commercial launches in Europe: Austria (3 operators with 5G commercial service), Belgium (1), Bulgaria (2), Croatia (1), Czech Republic (3), Denmark (2), Estonia (1), Finland (3), France (4), Germany (2), Greece (2), Hungary (2), Ireland (3), Italy (4), Latvia (2), Luxembourg (2), Netherlands (3), Poland (3), Romania (3), Slovakia (1), Slovenia (1), Spain (4), Sweden (4) and the UK (4).</p> <p>5G commercial launches in the USA: Verizon (October 2018 for FWA and April 2019 for mobile services), AT&amp;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 were launched in South Korea in December 2018 for enterprise customers, and in April 2019 for residential customers. 5G commercial services in China were launched in November 2019. 5G commercial services available in Japan since April 2020.</p>
Promote early deployment in major urban areas and along major transport paths	<p>199 trials announced in EU-27 plus the UK. 46 trials identified in Russia, Turkey, San Marino, Switzerland and Norway.</p> <p>Twelve "digital cross-border corridors" established inter alia accommodating live tests of 5G for Cooperative Connected and Automated Mobility.</p> <p>Three large-scale projects have been selected on these corridors (5G-CARMEN, 5GCroCo, 5G-MOBIX).</p> <p>In June 2020, three new projects (5GMed, 5G-Routes and 5G-Blueprint) were launched and will provide applications in cross-border connected and automated mobility.</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, 5G-GROWTH, 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> <p>Eleven new Horizon 2020 projects under the European 5G Public-Private Partnership (5G PPP), kicked off in September 2020 with the objective to seize opportunities in 5G hardware innovation and to validate 5G ecosystems for connected and automated mobility (CAM) along three new European cross-border corridors.</p>

Source: IDATE DigiWorld – December 2020

## 1.2. 5G deployment outside Europe

In other regions of the world, 5G has been progressing at a rapid pace as well. We estimate that there are close to 140 operators providing commercial 5G services worldwide at the end of December 2020. It should be noted that mobile 5G-ready devices were available quite early in 2019, and that in the end of December 2020, more than 500 5G devices had been announced.

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

service was restricted to friendly<sup>1</sup> customers until the first quarter of 2019, and it 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 5G service at 2.5 GHz in May 2019, and T-Mobile USA did the same two months later in July 2019.

After the announcement of limited commercial services 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 has been massive with more than 115,000 live 5G base stations at mid-2020.

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

Japan is already very active in the 5G field, and three operators (NTT Docomo, KDDI and Softbank) launched commercial 5G services in March 2020. The newcomer, Rakuten, launched 5G in September 2020.

Other commercial 5G launches were also reported in many countries, mainly using the 3.5 GHz band (non-exhaustive list): Australia (Telstra in 2018, Optus in January 2019), Bahrain (Viva in February 2019), Brazil (Telefonica in July 2020), Canada (Rogers, Bell Canada and Telus in early 2020), Hong Kong (HKT, Hutchison 3 and China Mobile Hong Kong in April 2020), Kuwait (Viva, Zain and Ooredoo in June 2019), Lesotho (Vodacom in August 2018), New Zealand (Vodafone New Zealand in December 2019), Oman (Omantel in December 2019), Philippines (Globe Telecom), Qatar (Ooredoo in May 2018 and Vodafone in August 2018), Saudi Arabia (STC and Zain in June 2019), South Africa (Vodacom in May 2020), Taiwan (Taiwan Star in August 2020), Thailand (Advanced Info Service in March 2020), UAE (Etisalat in September 2018, Du in June 2019). Other recent launches took place in EMEA (Monaco, San Marino), APAC (Maldives) and South America (Suriname, Trinidad & Tobago and Uruguay).

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

Public authorities in the EU have taken measures to facilitate the introduction of 5G since the past three years. This has been ranging 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, the EU 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 three pioneer spectrum bands identified by RSPG). The second target was the identification of

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<sup>1</sup> Friendly customers are employees of the mobile operator or people using the service for no charge in exchange for reports on the service

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 2020, the most tested frequency band in Europe has been by far the 3.6 GHz band (70% of the tests). The 26 GHz band is starting to gain traction very slowly.

**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>Thirteen countries (12 EU MS plus the UK) have published fully-fledged national 5G roadmaps including spectrum strategies (Austria, Czechia, Denmark, Estonia, Finland, France, Germany, Luxembourg, Portugal, Spain, Sweden, The Netherlands, and the UK).</p> <p>All EU-27 Member States and the UK 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"> <li>The 700 MHz band has been assigned in fourteen EU-27 countries: Austria, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Luxembourg, Netherlands, Slovakia and Sweden.</li> <li>Spectrum in the 3.4-3.8 GHz band has been assigned in accordance with 5G technical conditions<sup>2</sup> in 16 countries (EU-27 countries and the UK): Austria, Cyprus, Czech Republic, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Romania, Slovakia, Spain and United Kingdom.</li> <li>The 26 GHz band has been assigned in Italy, Greece and in Finland. It has not been assigned in the UK but local licences are available.</li> </ul> <p>In 19 Member States plus the UK, at least one spectrum auction has been completed. The latest spectrum auction ended in December 2020 in Cyprus in the 700 MHz and 3.6 GHz bands.</p> <p>In 26 countries (EU-27 plus the UK) at least one spectrum auction has been done or scheduled in 2020. Of the two remaining countries, Italy has already auctioned the three pioneer bands and Germany still has to assign spectrum in the 26 GHz band, even though it has been made available.</p>
Spectrum: usage of 5G pioneer bands and/or of other bands identified by the RSPG	Usage: commercial usage of 5G spectrum in EU-27 plus the UK: 5G compatible devices appeared in the European market in March 2019 and 5G infrastructure building started early 2019 in many countries.
Service verticals: feasibility of vertical use cases based on deals inked with key vertical players	<p>Media &amp; Entertainment: 39 trials</p> <p>Transport: 33 trials</p> <p>Automotive: 23 trials</p> <p>Other verticals: Industry 4.0, Agriculture, Smart cities, smart buildings, eHealth, Public Safety...</p>
Top 10 countries (EU-27 plus the UK) in terms of 5G trials organised	Spain, Germany, Italy, France, UK, Finland, Netherlands, Portugal, Estonia, Poland

<sup>2</sup> 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

5G AP analysis criteria	Assessment
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 have been tested in the first trials in Europe. The media and entertainment vertical has been the most popular one amongst the reported trials.

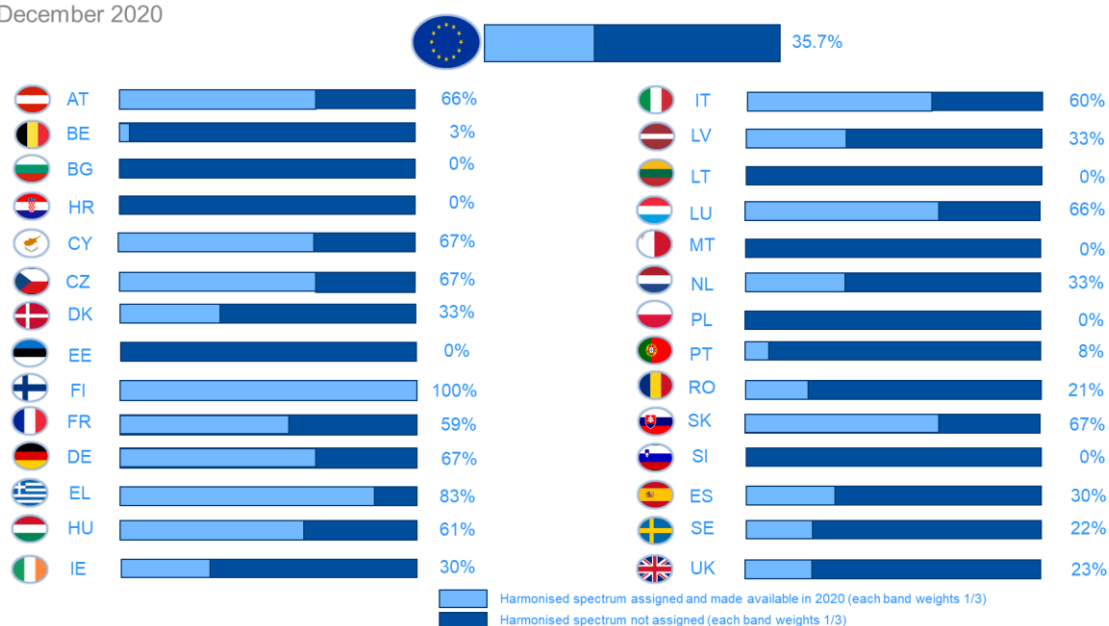
Source: IDATE DigiWorld – December 2020

The Digital Economy and Society Index (DESI) score for each Member State for the three pioneer bands is presented in Figure 1.

**Figure 1: DESI score for the three pioneer bands**

### All pioneer bands: DESI Score

December 2020

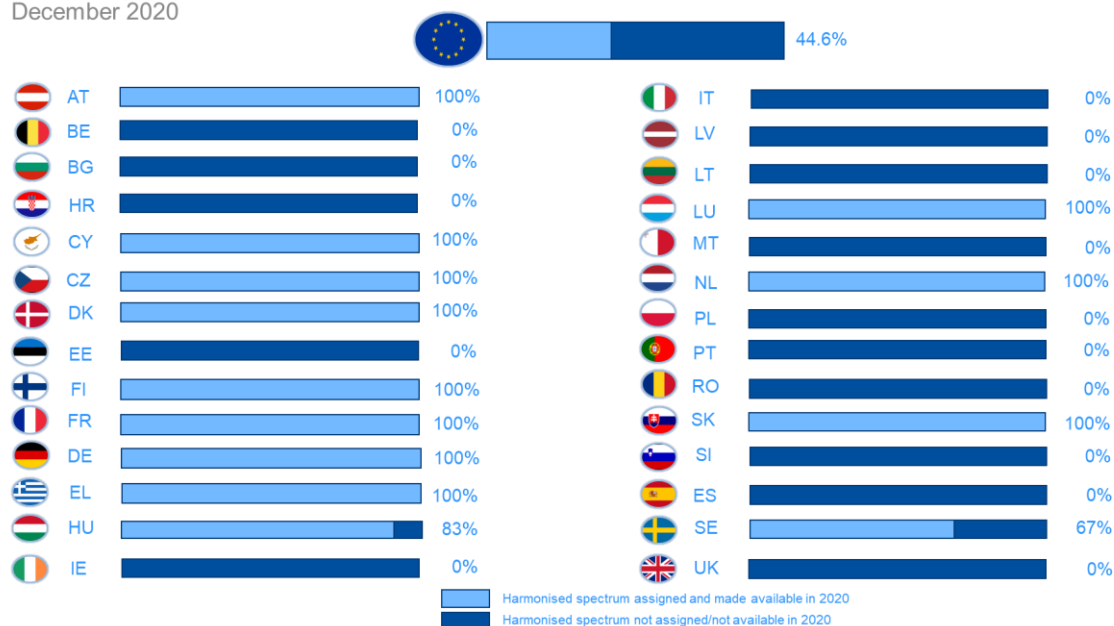


Source: IDATE DigiWorld – December 2020

The Digital Economy and Society Index (DESI) score for each Member State for the 700 MHz band is presented in Figure 2.

**Figure 2: DESI score for the 700 MHz band****700 MHz band: DESI Score**

December 2020

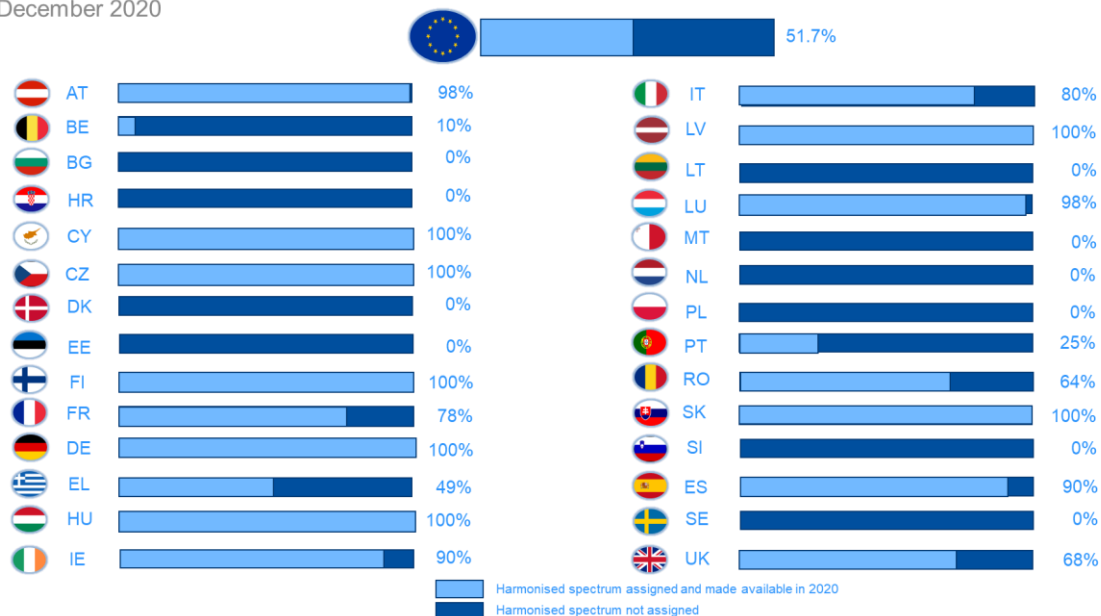


Source: IDATE DigiWorld – December 2020

The Digital Economy and Society Index (DESI) score for each Member State for the 3.6 GHz band is presented in Figure 3.

**Figure 3: DESI score for the 3.6 GHz band****3.6 GHz band: DESI Score**

December 2020



Source: IDATE DigiWorld – December 2020

## 2. Recent major developments

### 2.1. Latest developments at EU level

5G keeps progressing well in Europe, and the process has significantly accelerated during the past year. 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 having uninterrupted 5G coverage in all urban areas and major terrestrial transport paths by 2025.

The European Union regulatory framework for electronic communications has 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 2017 ((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 the RSPG and to be tackled in the coming months.

In the last quarter of 2019, the Electronic Communications Committee (ECC) of the CEPT 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 on 1 June 2019, closely 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.

In June 2020, the European Commission has adopted the Implementing Regulation<sup>3</sup> on small-area wireless access points, or small antennas. It aims to help simplify and accelerate 5G network installations, which should be facilitated through a permit-exempt deployment regime, while ensuring that national authorities keep oversight.

Eleven new Horizon 2020 projects under the European 5G Public-Private Partnership (5G PPP), will have kicked off in September 2020 with the objective to seize opportunities in 5G hardware innovation and to validate 5G ecosystems for connected and automated mobility (CAM) along three new European cross-border corridors.

## 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. These strategies are being extended or renewed for the 2021-2023 period.

In order to facilitate a consistent approach across Europe, the European Commission has published in November 2018 a Report<sup>4</sup> 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: all MSs have launched public consultations on 5G

By end December 2020, all the MSs plus the UK had finalised public consultations on 5G spectrum/strategy: Austria (2017, 2019), Belgium (2018, January 2020), Bulgaria (December 2018), Croatia (2019, September 2020), Cyprus (September 2019), Czech Republic (early 2019, July 2019,

<sup>3</sup> [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L\\_.2020.234.01.0011.01.ENG&toc=OJ:L:2020:234:TOC](https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2020.234.01.0011.01.ENG&toc=OJ:L:2020:234:TOC)

<sup>4</sup> <https://circabc.europa.eu/ui/group/7da1d333-3dda-4a40-9d7c-0013e0c51c98/library/3179b0e0-061d-4eac-9742-e391d63b5cc6/details>



February 2020, August 2020), Denmark (March 2018), Estonia (October 2019, May 2020) Finland (2018), France (December 2017, October 2018, May 2019, July 2019, September 2019, December 2019, October 2020), Germany (2018), Greece (2018, 2019, February 2020, July 2020), Hungary (2019), Ireland (2019, June 2020, July 2020, September 2020), Italy (2017), Latvia (April 2020, July 2020), Lithuania (2018), Luxembourg (2018, May 2019, March 2020), Malta (2018), Netherlands (first half 2019, January 2020), Poland (2018, 2019, January 2020, August 2020), Portugal (2018, 2019, February-May 2020), Romania (December 2018, July 2019, December 2020), Slovakia (2017, August and December 2019), Slovenia (2017, 2019, August 2020, December 2020), Spain (2018), Sweden (2017, June 2019, December 2019, February 2020, August 2020) and the UK (2017, 2019, February 2020 on EMF, May 2020 on modelling and technical matters for the 700 MHz and 3.6-3.8 GHz bands).

5G strategies and plans by Member States are detailed in section Erreur ! Source du renvoi introuvable. of 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. Thirteen MSs (in EU27 plus the UK) published fully-fledged national 5G roadmaps including spectrum strategies (Austria, Czechia, Denmark, Estonia, Finland, France, Germany, Luxembourg, Portugal, Spain, Sweden, The Netherlands, and the UK). Portugal adopted its strategy and calendar for 5G rollout in February 2020. In March 2019, Croatia adopted a new plan with 5G as a priority and started consultations on spectrum auction processes. They also published a document as a result of consultation. In May 2020, Ireland revised its national roadmap on the use of 700 MHz frequencies initially published in March 2019.

In 2019, six Member States had planned to publish their 5G strategies: Cyprus (planned 1/19, not published yet but 5G spectrum auction delayed to year-end 2020), 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 was completed in March 2020<sup>5</sup>), Portugal (planned 7/19, but the multi-band spectrum auction initially planned for June 2020 at the latest was rescheduled for October 2020). In Romania, following the public consultation on 5G strategy late in 2018, ANCOM initially scheduled the multi-band spectrum auction for year-end 2019 and postponed it to year-end 2020 or early 2021. Slovenia asked for comments on its spectrum strategy published in May 2019, but the topic was removed from the government's agenda. Nevertheless, they announced that the multi-band auction for 700/1500/2100/2300/3600 MHz bands and the 26 GHz band should take place before year-end 2020 and consulted on a draft Information Memorandum in August 2020.

<sup>5</sup> 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 and auctioned 700 MHz and 3.4-3.8 GHz spectrum in March 2020.

In 2019, three Member States had 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 2020, 5G auction plans were significantly impacted by the pandemic. A number of Member States decided to postpone spectrum auction processes. The majority of countries that had to postpone auctions due to the covid-19 pandemic have already completed their auctions or scheduled dates. Other processes were delayed de facto.

- In Austria, the multi-band auction for 700 MHz/1500 MHz/2100 MHz spectrum ended in August 2020.
- In Czech Republic, spectrum auctions in the 700 MHz and 3.5 GHz frequencies were postponed later in 2020 (initially scheduled for January 2020).
- In France, the 3.4-3.8 GHz auction which was initially planned for end April 2020 started late in September 2020. It ended on October 1<sup>st</sup>, 2020. The positioning auction will follow in October 2020.
- In the Netherlands, the multi-band auction ended in July 2020.
- In Luxembourg, the multi-band 700 MHz/3.4-3.8 GHz auction was completed in July 2020.
- In Poland, the 3.4-3.8 GHz auction is expected likely in the first quarter 2021
- In Portugal, the multi-band auction (700/900/1800/2100/2600/3600 MHz) was postponed in March 2020 due to covid-19 and rescheduled for October 2020.
- In Spain, the 700 MHz auction initially scheduled for March and then for May 2020 was further postponed likely to the first quarter 2021.
- In Sweden, the 2.3 and 3.5 GHz auction initially scheduled for March 2020 was postponed to 10 November 2020, with applications invited until 30 June 2020.

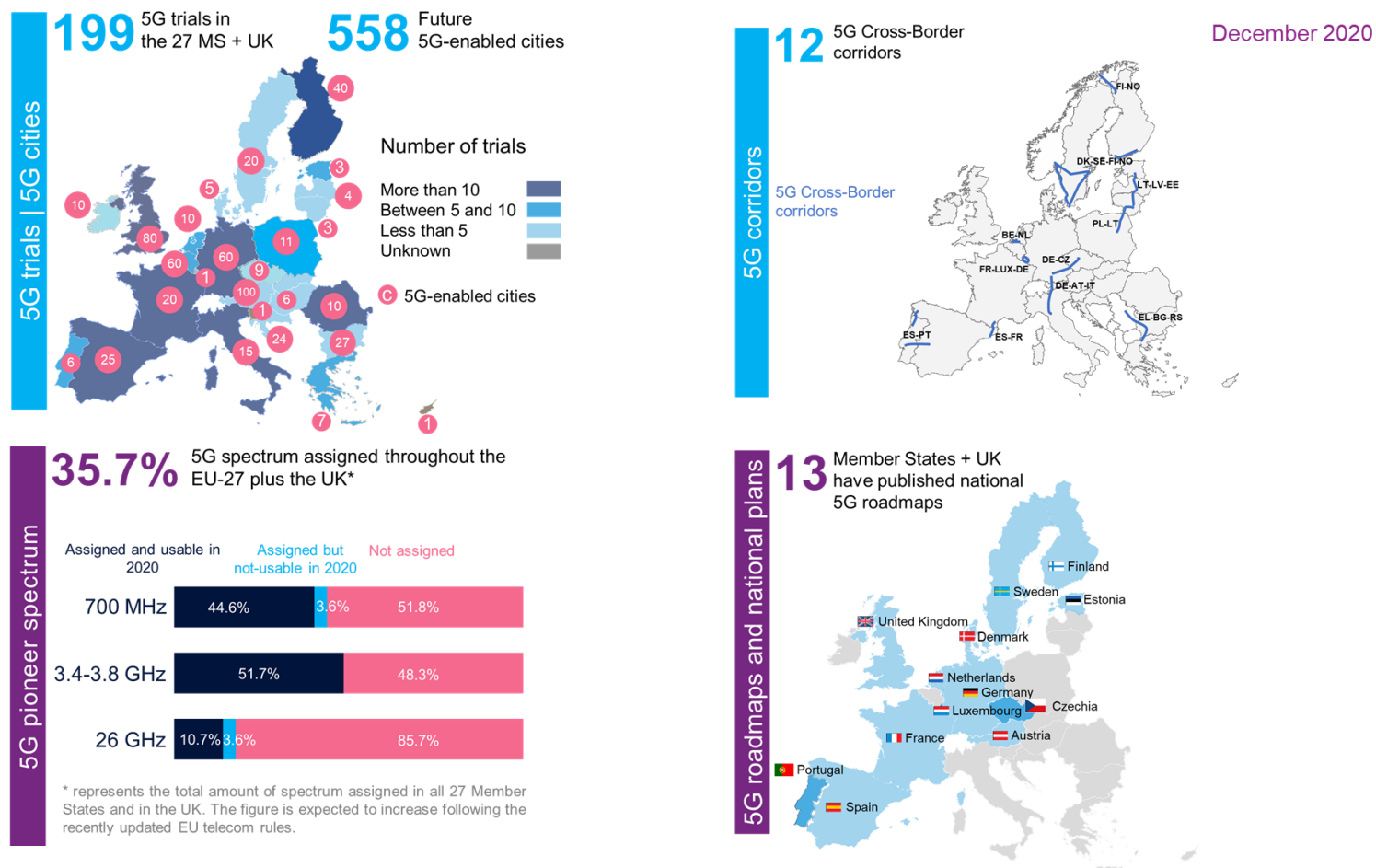
The Hungarian 5G spectrum auction was, on the contrary, upheld due to heavy market interest. The auction took place one time one day before tight restrictions on movements and activities were imposed. In Finland, the 26 GHz auction was not disrupted either by the pandemic, and it took place in June 2020.

## 2.3. 5G scoreboard

### 2.3.1. 5G scoreboard – EU-27 plus the UK

The 5G scoreboard summarizes the status of 5G trials, spectrum assignments, and measures on coverage, roadmaps and national plans in EU-27 plus the UK.

Figure 4: 5G scoreboard – EU-27 plus the UK (December 2020)

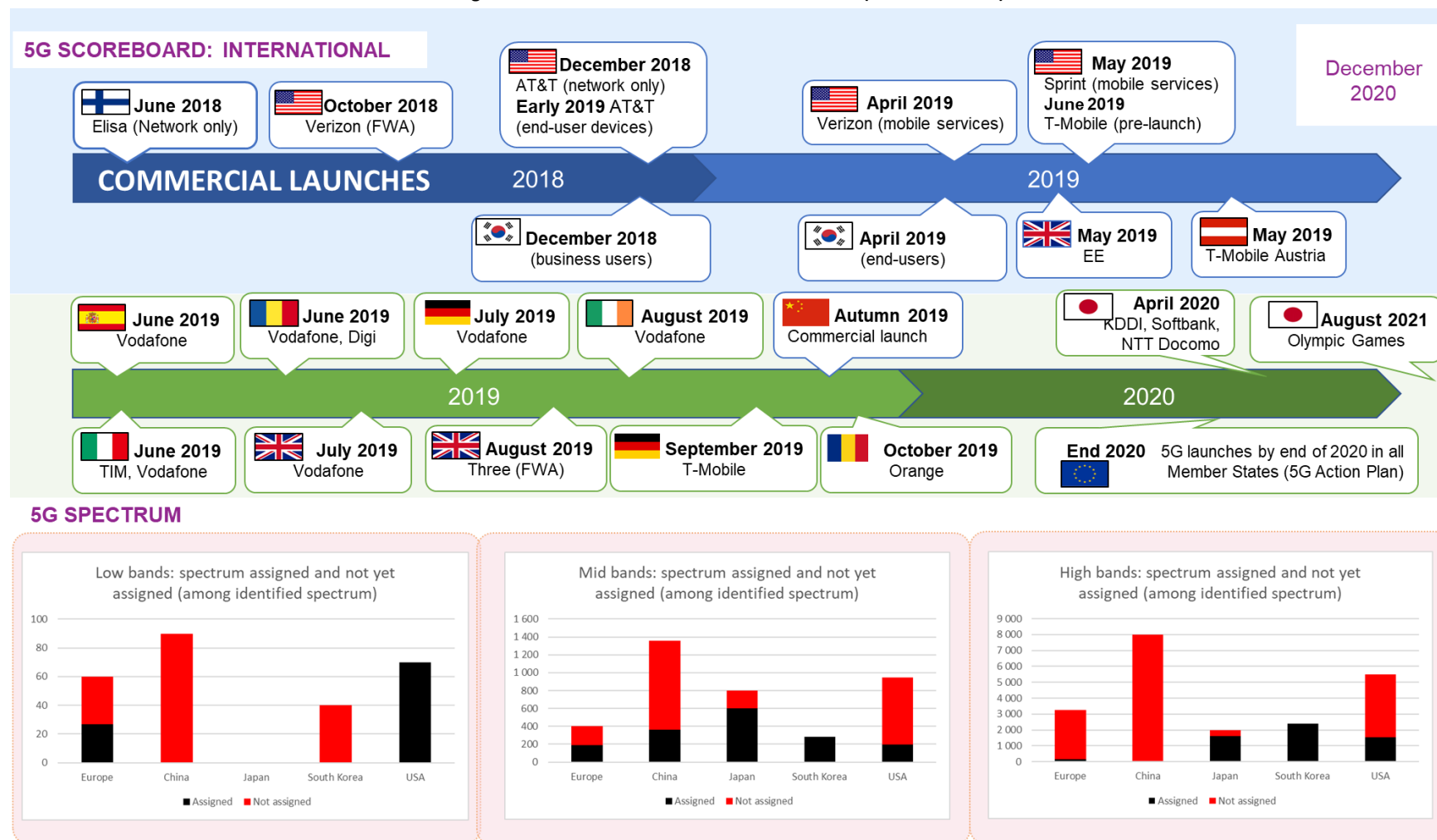


Source: IDATE DigiWorld

### 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 5: 5G Scoreboard – International markets (December 2020)



Source: IDATE DigiWorld

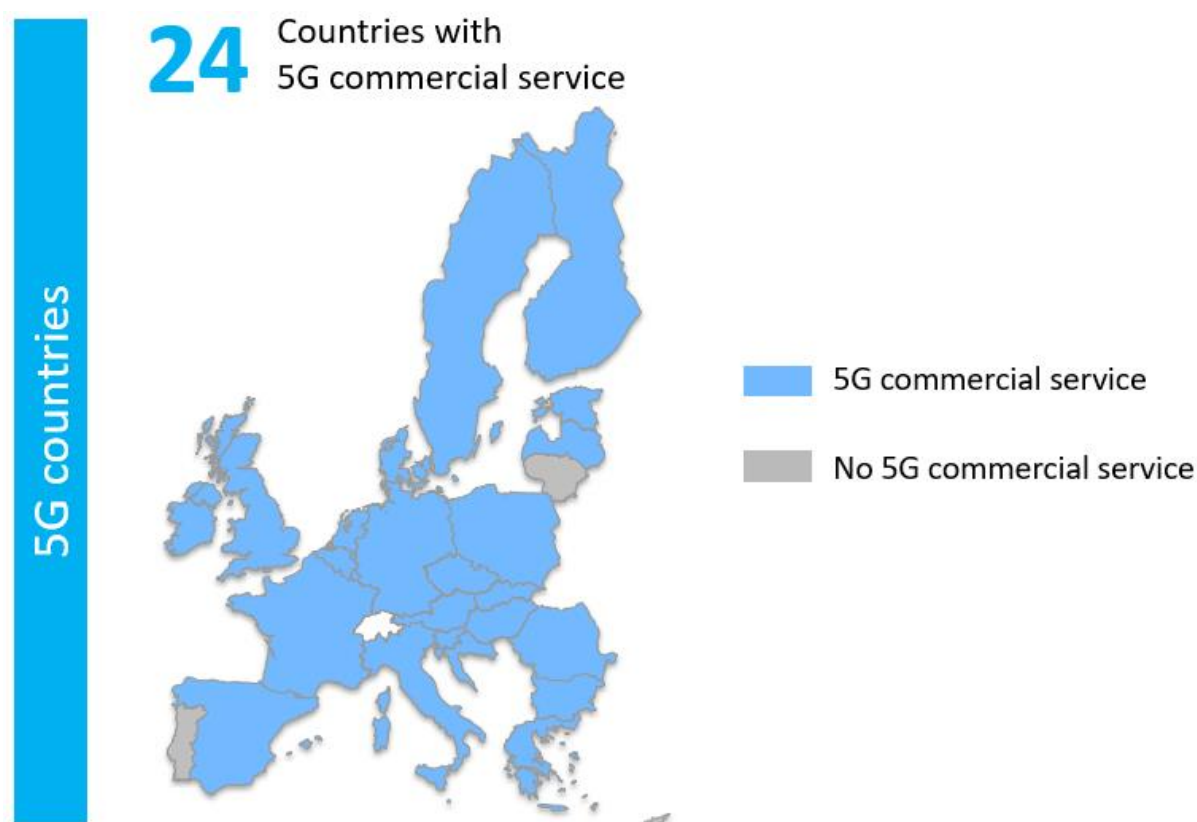
## 2.4. Announcements of commercial launches

Global 5G race is heating up. The number of live 5G networks increased significantly in Europe and outside Europe since the beginning of 2019. Only Cyprus, Lithuania, Malta and Portugal have not launched 5G services in the EU as at the end of December 2020.

### 2.4.1. Europe

At the end of December 2020, 5G commercial services had been deployed in 24 (EU-27 plus the UK) countries: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Estonia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Romania, Slovakia, Slovenia, Spain, Sweden and the UK.

Figure 6: EU-27 plus the UK countries with 5G commercial service – December 2020



Source: IDATE DigiWorld

#### Austria

##### *T-Mobile*

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 were available at the end of 2019.

The operator announced in July 2020 that its 5G network was active at 600 locations across the country, covering 25% of Austrian homes and businesses. By the end of 2020, the total coverage was

foreseen to increase to 1,200 locations, representing almost 40% of homes and businesses. The company noted that it is implementing Dynamic Spectrum Sharing technology.

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.

In September 2020, T-Mobile Austria paid 87 million EUR for 2x20 MHz of 700 MHz spectrum, 20 MHz in the 1500 MHz band and 2x15 MHz of 2100 MHz spectrum in the second 5G auction in the country.

### *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 and started offering 5G tariffs and devices. In December 2019, the company revealed that around 100 5G locations were going to be live across the country by the end of 2019.

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

### *A1 Telekom*

A1 launched its 5G network in January 2020 using the 3.5 GHz band. The “A1 5Giganetwork” covers 350 locations across 129 municipalities in Austria spanning 54,000 square kilometres. The operator paid 64.3 million EUR for nationwide 5G spectrum in the 3.5 GHz range in March 2019.

## **Belgium**

Proximus launched Belgium’s first commercial 5G services on April 1, 2020, using spectrum in its existing spectrum holdings (2.1 GHz), deployed on existing antennas and within current EMF norms. Coverage was available in about 30 cities and towns. In June 2020, the operator expanded the network coverage to an additional 26 locations in Flanders, including central areas of Ghent and Antwerp. The network was not deployed in the Brussels region due to its stricter radiation standards. Customers can access the network with the “Mobilus 5G unlimited” tariff priced 49.99 EUR and can expect speeds of up to 30% faster than LTE-A.

## **Bulgaria**

### *Vivacom*

In September 2020, Vivacom launched the first Bulgaria 5G network in all 27 district centers of the country. The operator is giving free of charge 30 GB per month to its customers to test the new technology until the end of 2020. Vivacom is using Dynamic Spectrum Sharing (DSS) in the 1800 MHz and 2.1 GHz bands.

### *A1*

A1 Bulgaria switched on its 3.6 GHz 5G network in capital city Sofia in November 2020. The operator said that the network supports coverage of Sofia's main residential and business districts and is capable of delivering 1 Gbps download speeds.

## **Croatia**

### *Hrvatski Telekom*

Hrvatski Telekom (HT) switched on Croatia's first commercial 5G network in late October in parts of six major cities: Zagreb, Rijeka, Split, Osijek, Samobor and Sveta Nedelja. At launch, 18% of the Croatian population was covered with the 5G network, with plans to increase coverage up to 25% of the population, meaning 1 million people, by the end of 2020. Customers on selected tariffs and with a 5G-capable device can access 5G services at no extra charge until June 2021.

The Hrvatski Telekom's 5G network is based on Dynamic Spectrum Sharing (DSS) technology, which enables the current use of existing frequencies for 5G. Hrvatski Telekom has launched on 2100MHz bands while awaiting the upcoming 3.5 GHz auction rescheduled for 2021.

## **Czech Republic**

### *Telefonica*

O2 (Telefonica) Czech Republic launched 5G services in July 2020 in selected parts of Prague. The network is also available in the city of Koline.

### *Vodafone*

Vodafone Czech Republic announced in early October 2020 the launch of its NSA 5G network in the cities of Prague, Brno, Usti nad Labem, Jesenik, and Karlovy Vary, using Dynamic Spectrum Sharing technology.

Operators count on the coming 5G auction for a truly nationwide expansion of the network.

### *T-Mobile*

T-Mobile launched 5G commercial services in November 2020 in the cities of Prague and Brno. The operator said that by the end 2020, more than a quarter of the population in both cities will be covered by its 5G network, targeting having around 360 base transceiver stations online.

## **Denmark**

### *TDC*

TDC launched commercial 5G services in the 3.5 GHz band in Copenhagen, Odense, Aarhus and Helsingør on 7 September 2020. The company claims that almost 3,000 base stations have been equipped with Ericsson's 5G technology throughout Denmark, with plans to increase the footprint to 80% by end of September 2020 and by 90% by year-end 2020.

The company is offering two 5G plans: the "Professional" with 30 GB of data allowance costs 399 DKK (54 EUR) per month and the "Premium" with 100 GB of data allowance costs 499 DKK (67 EUR) per

month. These two 5G price plans complete 4G cheaper plans with lower data allowances (3 GB at 199 DKK/month or 27 EUR and 10 GB at 299 DKK/month or 40 EUR).

#### *Telenor*

Telenor Denmark activated its 5G network in November 2020 using the 3.5 GHz band, covering around 600,000 potential customers in Copenhagen and Aalborg. Cities of Aarhus and Odense are next in line for rollouts.

#### *Hi3G Access*

Danish mobile network operator Hi3G Access (3) announced the official switch-on of its new 5G network in Copenhagen and Roskilde in mid-December 2020. The operator launched 5G using frequencies in the 700 MHz and 1.800 GHz. In March 2021 it is expected that the Danish Energy Agency will hold an auction to award spectrum in the 3.5 GHz band. That additional spectrum and further 5G development will enable speeds of around 1 Gbps, 3 Denmark said. The operator announced that it expects to cover one-third of its network by mid-2021 and to complete its nationwide network by mid-2022.

### **Estonia**

#### *Telia*

Telia Eesti switched on Estonia's first commercial 5G network in November 2020 in the centres of the country's three largest cities, Tallinn, Tartu and Pärnu. The network uses Ericsson Spectrum Sharing technology, enabling Telia to utilise its existing frequencies since the government has not yet auctioned off 3.5 GHz licences for 5G.

### **Finland**

#### *Elisa*

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. The operator started offering 5G mobile devices and plans in June 2019 in Tampere, Jyväskylä, Turku and Helsinki. At the moment their 5G subscriptions are being offered with unlimited data (up to 30 GB per month in the EU) plans including data speed options of 1 Gbps at 49.90 EUR per month, 600 Mbps for 36.90 EUR per month and 300 Mbps for 31.90 EUR per month.

Elisa revealed in June 2020, that its 5G network had been switched on in a total of 30 cities and towns across the country, with more than one million people within its service area.

#### *Telia*

Telia Finland launched 5G services in seven cities at the end of 2019. The operator also promotes Fixed Wireless Access for homes, besides normal mobile subscriptions. For consumers, their 5G mobile service offering includes subscriptions with unlimited monthly data (up to 25 GB within the EU) and speeds ranging from 300 Mbps (31.90 EUR per month) to 1 Gbps (49.90 EUR per month).



*DNA.*

DNA started selling mobile 5G subscriptions in January 2020, having previously launched its 'DNA Home 5G' offering in December 2019. In summer 2020, they were going to provide 5G services in more than 20 Finnish cities and towns, with data speeds and prices of their mobile subscriptions ranging from 400 to 1000 Mbps and from 34.90 to 44.90 EUR per month, all with unlimited data usage in Finland and up to 27 GB within the EU.

**France***Orange*

Orange France launched its commercial 5G mobile network on 3 December 2020 in 15 municipalities including Nice, Marseille, Le Mans, Angers, and Clermont Ferrand. By the end of 2020, more than 160 municipalities will be covered with the 3.5GHz 5G network, providing data speeds up to three-to-four times faster than 4G LTE. According to Orange, each municipality will be added to the official coverage list when its 5G outdoor population coverage rate reaches 80% or more.

*Bouygues Telecom*

Bouygues Telecom switched on its 5G network in 20 major cities the 1st of December. The network is available in Lyon, Nice, Montpellier, Reims, Le Havre, Toulon, Dijon, Villeurbanne, Le Mans, Aix-en-Provence, Boulogne-Billancourt, Metz, Saint-Denis, Argenteuil, Rouen, Versailles, Montreuil, Nancy, Avignon, and Cannes. The French operator has also confirmed the goal of achieving nationwide coverage by the end of 2021. The current roll-out phase will rely on the 3.5 GHz and 2.1 GHz bands.

*SFR*

SFR announced in late November the availability of its 5G service in the city of Nice. 50% of the population of Nice is covered by 5G, and within several weeks, 80% will be covered. The company confirmed plans to extend its coverage to more than 120 municipalities throughout December. The rollouts will take place at selected locations in the agglomerations of Bordeaux, Marseille-Aix-en-Provence, Montpellier, Nantes, Nice, and Paris-Ile-de-France.

*Free*

Free Mobile became on 15 December the fourth French operator to launch commercial 5G services. New customers with a 5G compatible smartphone can subscribe to the 5G package at 20 EUR per month with 150 GB of data. For the same data volume, consumers must pay more than three times more at Orange or at SFR. Even Bouygues Telecom, the lowest price with its entry-level brand B & You, offers 130 GB of 5G data at 25 EUR per month. For existing subscribers, 5G services are available at no additional cost and with unlimited 5G data. The price drops to 16 EUR per month for Freebox subscribers and even 10 EUR per month for the owners of the Freebox Pop.

The 5G network covers about 40% of the population and has good indoor reception thanks to the 5,255 active 700 MHz cell sites. Free Mobile also activated 220 cell sites equipped with 3.6 GHz frequencies to offer ultra-fast speeds in selected locations.

## Germany

### *Deutsche Telekom*

Deutsche Telekom switched on its 5G network on September 5th, 2019, in five German cities: Berlin, Bonn, Cologne, Darmstadt, and Munich. Hamburg, Frankfurt, and Leipzig followed.

In July 2020, the operator announced that its 5G network covered 40 million Germans, representing half of the population. Services are available in over 3,000 towns and municipalities, after a further 18,000 antennas were upgraded for 5G and integrated into the live network. The company announced that it plans to cover two thirds of the population by the end of 2020.

Telekom uses spectrum in the 2100 MHz band to provide customers with 5G coverage in less densely populated areas, while the 3600 MHz band is being used in large cities. Dynamic Spectrum Sharing is also being deployed.

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 per month, the MagentaMobil L with 24 Go at 59.95 EUR/month, and the MagentaMobil XL with unlimited data at 84.95 EUR per month. The new plans are all 5G-enabled.

### *Vodafone Germany*

Vodafone Germany started its 5G network in July 2019. At launch, customers were able to access 5G plans at 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 offered two 5G-suitable smartphones: The Huawei Mate 20 X 5G and Samsung's Galaxy S10 5G. The Gigacube 5G home router from Huawei was also available.

In November 2020, Vodafone Germany announced that its 5G network was covering ten million people thanks to the rollout of around 3,000 antennas at more than 1,000 locations across the country. Around 300 towns, cities and municipalities gained access to Vodafone's 5G services ahead of target. By the end of 2020, coverage was set to increase to 15 million Germans, before reaching 30 million by the end of 2021 – ten million more than previously planned.

### *Telefonica*

Telefonica became Germany's third mobile network operator to introduce 5G services on 3 October 2020, when the network was activated in ten cities: Berlin, Hamburg, Munich, Frankfurt, Cologne, Dusseldorf, Stuttgart, Essen and Potsdam. Telefonica's 5G network in the 3.6 GHz band will have grown from 450 antennas to over 6,000 to cover more than 30% of the population by the end of 2021. The operator expects to reach around 50% by the end of 2022 and the whole country by 2025. In rural areas, the company will use Dynamic Spectrum Sharing.

## Greece

### *Wind Hellas*

Greek mobile operator Wind Hellas announced in December 2020 that it switched on its 5G mobile network a few days after winning frequencies in the country's multi-band 5G spectrum auction. The network was initially covering Athens and Thessaloniki, while coverage of other major cities is expected in 2021. The operator said that 5G population coverage is expected to exceed 60% within three years.

#### *Cosmote*

Cosmote launched its commercial 5G services in December 2020 in Athens, Thessaloniki and other Greek cities, with speeds exceeding 1 Gbps in certain areas. The company is aiming to increase coverage to over 50% of the population by the end of 2021

### **Hungary**

#### *Vodafone Hungary*

In October 2019, Vodafone Hungary launched a commercial 5G service limited to Budapest, using its existing 3500 MHz spectrum and ahead of Hungary's March 2020 licence auction where it won additional 3500 MHz frequencies plus a 700 MHz licence.

In late June 2020, the operator announced plans to roll-out 5G services in the following cities: Miskolc, Gyor, Debrecen, Szekesfehervar, Pecs, Szeged and Eger, focusing on the busiest parts of inner cities and around universities. The rollouts will increase the number of Vodafone 5G base stations to about 300.

#### *Magyar Telekom*

The operator launched commercial 5G mobile network services in April 2020 in partnership with Ericsson. The network was available in limited areas of Budapest and Puskas Ferenc stadium. By September 2020, the network was available in parts 18 cities and towns including Zalaegerszeg, Szombathely, Debrecen, Szeged and Kecskemét.

### **Ireland**

#### *Vodafone*

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

#### *Eir*

In early December 2019, Eir launched its 5G service in 10 towns and cities. By January 2020, 5G services were available in 20 towns and cities. In September 2020, Eir confirmed that its 5G network covered 29% of the population, with infrastructure now available in 21 towns and cities.

#### *Three Ireland*

In late September 2020, Three Ireland started offering 5G commercial services with Ericsson's equipment in a total of 315 sites across Ireland, reaching 35% of population coverage. The operator expects to add a further 500 5G-capable sites in 2021. Ericsson announced that the 5G network is

powered by the vendor's fully virtualised 5G Core and the latest products and solutions from its Radio System portfolio.

## **Italy**

### *Vodafone*

Vodafone Italy 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 the end of 2019 and to 100 by 2021. Vodafone offered 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, Naples followed in July 2019. TIM offered 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, 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 were offered by the company: The Samsung Galaxy S10 5G and the Xiaomi MIX 3 5G from Xiaomi. The Oppo Reno 5G will follow shortly.

As of late March 2020, 5G services were available in Bologna, Brescia, Florence, Genoa, Milan, Naples, Turin, and Rome.

### *Windtre*

Wind Tre launched its 5G network in around ten regional capitals in October 2020. The operator announced plans to extend services to 70 cities by end-2021.

### *Free*

Free Italy switched on 5G in 27 Italian cities in December 2020. Free launched what it could be a highly disruptive offer in Italia, a 5G called Flash 70 for under 10 EUR for a limited period only, until January 21, 2021. The operator did not say what the price will be after the offer period. The offer package includes 70GB of combined 4G and 5G data, plus unlimited phone calls and text messages.

## **Latvia**

### *LMT*

Latvian Mobile Telephone launched 5G network in July 2019, with limited availability. In January 2020, commercial 5G services were extended to the cities of Jelgava and Daugavpils.

### *Tele2*

Tele2 Latvia commercially launched 5G services in Daugavpils and Jelgava in January 2020. The operator said any customer with a compatible device could use the 5G network. Nevertheless, availability was very limited; each city has only two live 5G base stations. By September 2020, the network was available in Riga, Jurmala, and Valmiera.

## **Luxembourg**

### *Orange*

The operator confirmed the network was activated in November 2020 covering Luxembourg City and surrounding areas, such as Bertrange, Strassen, Kirchberg and the airport. Orange subscribers can access 5G services at no extra charge as part of their existing mobile plans.

### *Tango*

Luxembourg mobile network operator Tango launched 5G services in November 2020. The 5G network was initially available in Luxembourg City before being deployed in other larger towns from early 2021. All customers are able to benefit from the new 5G network with their current mobile subscription, reaching speeds of up to 1 Gbps.

## **Netherlands**

### *VodafoneZiggo*

The operator activated its 5G network in late April 2020 across more than half of the Netherlands. They said that 5G coverage will reach all the Netherlands by late July. In partnership with Ericsson, the operator implemented 5G services via its existing antennas and Dynamic Spectrum Sharing technology which allows operators to dynamically allocate some of their existing 4G LTE spectrum to 5G.

Customers with a Red (consumer) or Red Pro (business) subscription will have 5G access at no extra cost. Currently, four 5G devices are available: Samsung Galaxy S20 5G, S20 +, S20 Ultra and Oppo Find X2 Pro.

The company notes that the mobile data download speeds that 5G can offer using its existing spectrum reach a maximum of 1 Gbps, although it adds that in practice the 5G data rates experienced by initial customers will be on average 10% higher than the 4G speeds (maximum of 350 Mbps) they were previously getting.

### *T-Mobile*

In late July 2020, T-Mobile Netherlands launched its 5G mobile network in The Hague and ‘most of the Netherlands’. The operator confirmed that its initial 5G network is based on its new 700 MHz spectrum, with existing subscribers to its Unlimited and Unlimited Plus subscriptions automatically receiving 5G access on suitable devices. The company plans to provide nationwide 5G coverage by the end of 2020.

### *KPN*

KPN launched commercial 5G services the same day than T-Mobile, in late July 2020. The network covers over 90% 5G coverage in the top five Dutch cities, Amsterdam, Rotterdam, The Hague, Utrecht,

and Eindhoven, reaching approximately half of the Netherlands' population. The operator plans to offer nationwide 5G coverage by the end of 2021. KPN announced that B2B customers will be able to purchase special 5G-only services including coverage-on-demand, application priority and guaranteed bandwidth.

## **Poland**

### *Polkomtel (Plus)*

Polish operator launched the country's first commercial 5G mobile network in May 2020. The network uses 100 base stations in the 2.6 GHz band, providing 5G services in seven cities and to about 900 000 people: Warsaw, Gdansk, Katowice, Lodz, Poznan, Szczecin and Wroclaw.

### *T-Mobile Poland*

The operator launched 5G services via 1,600 base stations, using the 2100 MHz band and covering up to six million people in June 2020. T-Mobile aimed to cover by the end of June 2020, Warsaw, Lodz, Krakow, Poznan, Wroclaw, Plock, Opole, Czestochowa, Rzeszow, Bielsko-Biala and Kielce. The network uses the 2100 MHz band.

### *Orange*

Orange Polska launched 5G commercial services on 1 July 2020. The operator said that around six million people were covered by its 5G networks, via 1,600 base stations in cities including Warsaw, Lodz, Krakow and Katowice. The network uses the 2100 MHz band while it awaits the planned auction of spectrum in the 3.5 GHz band.

## **Romania**

### *Vodafone*

Vodafone launched 5G services in Romania on 26 June 2019 in areas of three cities. Customers could 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. The operator announced in January 2020 the expansion of its 5G network to Brasov and Poiana Brasov.

In late August 2020, Orange Romania announced its 5G network in Bucharest has now been expanded to cover the entire city, enabling 100% of its population to access download speeds of up to 1.2 Gbps. The network has been expanded to Mamaia and Timisoara.

## **Slovakia**

### *Slovak Telekom*

Slovak Telekom became the country's first operator to launch commercial 5G services in December 2020. Services were available in eight districts of Bratislava. ST announced that customers can expect download speeds of between 300 Mbps and 600 Mbps, and between 60 Mbps and 80 Mbps for upload. The operator is utilizing 15 MHz of frequencies in the 2100 MHz band, in combination with LTE spectrum.

## **Slovenia**

Telekom Slovenije launched the first commercial 5G network in Slovenia in July 2020. The mobile operator has upgraded 150 4G base stations to support 5G and announces that it provides approximately 25% coverage of the population. By the end of 2020, Telekom Slovenije expects to surpass 33% coverage.

Ericsson announced that Telekom Slovenije is using its Radio Access Network (RAN) and Cloud Core solutions for its 5G commercial rollout. Ericsson also assisted with a software installation to existing Ericsson Radio System and packet core equipment, which enables spectrum sharing between 4G and 5G on 2600 MHz FDD spectrum.

## **Spain**

### *Vodafone*

Vodafone Spain launched its commercial 5G services at 3.7 GHz in 15 cities on June 15, 2020 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.

Vodafone Spain activated in May 2020 its 5G network in a total of 21 cities. 5G services are now available in Alicante, Murcia, Palma de Mallorca, Valladolid, Benidorm and Badajoz. The company had previously said that it was working with Huawei and Ericsson in the deployment of the 5G network.

### *Telefonica*

Telefonica announced on September 1st 2020 that it has switched on its Non-Standalone 5G network in unspecified Spanish locations. The network utilises 3.5 GHz spectrum, alongside with refarmed 1800 MHz and 2100 MHz frequencies. Telefonica also announced it has awarded Finnish vendor Nokia the contract to increase 5G coverage up to 75% of the Spanish population by year-end 2020. This means that Nokia is the only vendor to supply 5G radio technology to all of Telefonica's 5G operations across Europe.

In the meantime, Telefonica announced it will shut down both mobile (2G and 3G) and fixed (copper) networks.

### *Orange*

In September 2020, Orange Spain has launched 5G mobile services in selected parts of five cities, namely: Madrid, Barcelona, Valencia, Seville and Malaga, predominantly in central areas. Orange covers around 30% of each city and plans to expand rapidly to other cities. Orange customers can access the network free of charge with 5G-capable handsets.

The Ericsson Radio System, delivering Massive MIMO, powers the 3.6 GHz 5G network in Madrid and Barcelona. Ericsson also supplies Orange Spain with a 5G Evolved Packet Core to support the 5G New Radio non-standalone 5G network.

#### *MASMOVIL*

In September 2020, Grupo MASMOVIL has become the fourth Spanish operator to launch 5G services, after switching on connectivity in 15 cities. The 5G network is available in parts of Alicante, Alcobendas, Almeria, Avila, Barcelona, Hospitalet de Llobregat, Huesca, Jaen, Madrid, Malaga, Melilla, Orense, Salamanca, Seville and Valencia. Customers with a 5G-capable handset can access the network at no extra cost.

The carrier said that the 5G service is being offered via a combination of own infrastructure and an agreement with rival operator Orange. The deal gives MASMOVIL access to Orange Spain's entire 5G network thanks to a "virtual active sharing mode" agreement, enabling it to deploy 5G in 4,500 locations that cover 35% of the Spanish population in 40 main cities. Orange will deploy 1,500 new sites through the end of 2021 throughout the country.

In a future phase, MASMOVIL announced it aims to launch its own 5G SA network with 80 megahertz of spectrum in the 3.4-3.8 GHz band.

### **Sweden**

#### *Tele2*

Tele2 switched on 5G networks in Stockholm, Gothenburg and Malmo on May 24, using 80 MHz of the 3.6 GHz spectrum band. The operator said that customers with a Tele2 Unlimited subscription and a 5G compatible mobile phone from Samsung's Galaxy S20 series will get free access to the new network from 24 June 2020. Tele2 added that customers can expect speeds surpassing 1 Gbit/s from start.

#### *Telia Sweden*

Telia Sweden announced its 5G network is active through 15 base stations in Stockholm, using its existing 700 MHz spectrum, boosted by LTE and New Radio carrier aggregation. Telia added that by the end of the year, it expects to expand coverage to a further twelve cities, including Gothenburg and Malmo. The operator is working with local partner Ericsson, which confirmed it is providing radio access network products and solutions. Certified by the Swedish Society for Nature Conservation, the 5G network is powered by 100 % renewable energy.

#### *Tre*

In late June 2020, Tre Sweden announced the commercial launch of 5G services in Malmo, Lund, Uppsala, Helsingborg, Vasteras and large parts of Stockholm. The operator activated 385 5G masts,



200 of which are in Stockholm, and expects to cover most of the centre of the capital by the end of August.

#### *Telenor*

Telenor Sweden launched commercial 5G services in central Stockholm in October 2020, becoming the fourth 5G network in the country. The operator said its network will provide internet access at 1 Gbps to customers with a compatible handset and a Telenor 5G-ready 30 GB, 75 GB, or Unlimited subscription. 5G network coverage is available in at least half of the city centre. The operator intends to widen its footprint in the capital while also adding connectivity in Malmö and Gothenburg before expanding the rollout to towns with a population of over 50,000. Telenor also said that it expects its 5G network to cover 99% of Sweden's population by 2023.

### **2.4.2. Rest of Europe**

#### **Norway**

Telenor Norge begun offering a commercial 5G service in March 2020, becoming the first operator in the country to do so. The 5G network initially available in nine locations across the country: Kongsberg, Elverum, Bodo, Askvoll, Fornebu, Kvitfjell, Spikersuppa, Oslo and Trondheim. In November 2020, Telenor launched a FWA 5G service.

In May 2020, Telia launched 5G for customers in Lillestrøm and parts of Groruddalen in Oslo, with plans to expand to other areas during 2020. In November 2020, Telia launched a FWA 5G service.

#### **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.

#### **United Kingdom**

##### *EE*

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 launched 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. The network had targeted to bring 5G connectivity in 45 cities and large towns by the end of 2019.

As of June 2020, EE's 5G service was live in 80 towns and cities across the country, announced the UK carrier. The company is using a Non-standalone 5G New Radio deployment focused on using the combined power of 4G and 5G technologies. In a second phase from 2022, it will introduce the full 5G core network, enhanced device chipset capabilities, and increased availability of 5G-ready spectrum. A third phase, beginning in 2023, will introduce Ultra-Reliable Low Latency Communications (URLLC), network slicing and multi-gigabit-per-second speeds.

EE's 5G tariffs were upgraded recently. Customers can access the 5G network with the following plans: 60 GB data at 24 GBP (27 EUR) per month, 100 GB data at 27 GBP (30 EUR) per month, 200 GB data at 31 GBP (35 EUR) per month and unlimited data at 35 GBP (40 EUR) per month. Compared to November 2019, prices for the same quantity of data have been divided by two! Prices for EE's 5G plans in November 2019, started at GBP 41 (48 EUR) a month for 10 GB of data, rising to GBP 69 (81 EUR) a month for unlimited data.

#### *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 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 2 Mbps 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. As of June 2020, the 5G network was live across parts of 60 towns and cities in the country, up from 20 at the start of 2020. The company targeted to be live in 50 locations by summer 2020.

### **2.4.3. 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. SK Telecom, LGU+ and KT launched 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.

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 2020, South Korean telecom operator KT revealed in its earnings statement that the company ended 2019 with a total of 1.42 million 5G subscribers. SK Telecom announced it ended 2019 with 2.08

million 5G subscribers. The country's larger operator by subscribers count expects to reach between 6 and 7 million 5G subscribers by the end of 2020. LG U+ reported that it closed last year with a total of 1.16 million 5G subscribers.

More than six million South Koreans had subscribed to 5G mobile networks as of April 2020, a year after local operators had commercially launched this technology. There was an increase of 8% compared to the previous month, announced the Ministry of Science and ICT.

*SK Telecom's* 5G customers accounted for 45% of total 5G subscribers, followed by *KT* with 30% and *LGUplus* with 25%, the Ministry published. 5G subscribers represent just about 10% of the country's total mobile base.

The Korean government announced that operators had already deployed a total of 115,000 5G base stations across the country.

In July 2020, South Korea's 5G users reached 8.65 million subscribers at late August according to the data published by the country's Ministry of Science and ICT.

#### 2.4.4. Australia

*Telstra Australia* launched its 5G service on the 3.6 GHz band at the end of May 2019 as it had switched on over 200 5G sites since August 2018. The 5G service was available in over 10 cities, including parts of Melbourne, Sydney, Canberra, Brisbane, Adelaide, Perth, Hobart, Launceston, Toowoomba, and the Gold Coast. Twenty-five additional cities should be covered before end-June 2020 including the major regional cities in Australia. However, the operator announced it is ahead of its target and 5G services are now available in 47 cities across the country.

Telstra added it has seen a massive expansion in the number of potential customers, growing from 4 to 8 million. Swedish vendor Ericsson has announced collaboration agreements with the operator to provide 5G equipment and upgrade Telstra's network.

The operator announced in September 2020 that it now has more than 1,500 5G sites in operation across selected areas of 53 cities and towns covering around ten million people.

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

Rival mobile network operator *Optus* announced the commercial launch of 5G mobile and 5G residential fixed broadband services covering selected areas in November 2019. 290 5G network sites went live and 1,200 sites were planned by March 2020. Recently, the company announced that by the end of May 2020 customers in parts of the western Sydney suburbs of Bonnyrigg and Minchinbury, Niagara Park on the NSW Central Coast, Cook in the ACT and the Brisbane suburb of Kenmore will be able to order 5G services. The telco is using equipment from both Ericsson and Nokia in its rollout of 5G.

Optus secured spectrum in the 3.6 GHz spectrum auction for AUD 185 million (EUR 110 million) in late 2018.

Also *Vodafone Australia* has switched on its first 5G sites in some areas of Sydney, Melbourne, Brisbane, Adelaide, Canberra and Perth.

#### 2.4.5. Japan

Historically, Japan has been at the forefront of mobile technology. Japan originally targeted the Tokyo summer Olympic Games, which have now been postponed due to COVID-19 pandemic from 2020 to 2021, 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. After a few months of pre-commercial service, Rakuten Mobile launched its 4G commercial service in April 2020.

In April 2019, The Ministry of Internal Affairs and Communications (MIC) 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.

##### *NTT DOCOMO*

NTT DOCOMO launched Japan's first 5G smartphone service on March 25, 2020. The network is live in 150 areas in Japan covering 29 of the nation's 47 prefectures. Customers can get 100 GB of data for 7 650 JPY (62 EUR) per month, excluding taxes.

##### *KDDI*

KDDI launched 5G mobile services in 15 of Japan's 47 prefectures on March 26, 2020. The operator said it aims to install 10,000 base transceiver stations by 31 March 2021 and another 10,000 BTS by the end of March 2022. Customers can access the 5G network with an unlimited data plan costing 8, 650 JPY (USD 78.1) per month and the option of Netflix and Apply Music streaming.

##### *SoftBank*

SoftBank turned on its 5G network in March 27, 2020. 5G mobile services are available in selected areas in seven prefectures across Japan for an additional charge of 1 000 JPY (8 EUR) per month. The operator aims to install over 10,000 5G base stations by the end of March 2023 and expects 90% of the Japanese population to have access to 5G by the end of 2021.

SoftBank and KDDI are teaming together to speed up 5G rollout in rural areas. To this end, they announced on April 1st, 2020 the setup of a joint venture, 5G JAPAN. The joint venture's goal is to promote infrastructure sharing based on the mutual use of base station assets held by the two companies. The initial capital of the joint venture will be 500 million JPY (4.24 million EUR) and each operator will own 50% of the stakes.

##### *Rakuten*

Greenfield operator Rakuten launched commercial 5G services in late September 2020 in certain areas across six prefectures of the country. The service, initially offered via Non-Stand Alone (NSA) 5G architecture, is already available in parts of Tokyo, Kanagawa, Saitama, Hokkaido, Osaka and Hyogo. Rakuten Mobile's President Yoshihisa Yamada said that the operator is expecting the 5G to be available in Japan's all 47 prefectures by end-March 2021. Rakuten Mobile expects to launch a Stand-Alone 5G network in the second quarter of 2021.

The Ministry of Internal Affairs and Communications plans to start allowing certain 4G frequencies to be converted to 5G this summer, which would let providers use existing base stations to power 5G networks.

#### 2.4.6. 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 reached an agreement to jointly build a 5G network and share network infrastructure.

*China Mobile, China Telecom and China Unicom* 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 30 GB data with 300 Mbps of download speeds and 500 minutes of voice and. Most expensive plans cost 599 CNY (76 EUR) and offer 300 GB of data with download speeds of up to 1 Gbps. Only high-end price plans offer 5G-like speeds. As of December 2020, many plans are being sold at 100 CNY (13 EUR) or less.

Each player activated their network in 50 cities at launch, including Beijing, Shanghai, Guangzhou, Shenzhen, Hangzhou, Nanjing, Tianjin, Wuhan, Jinan, and Zhengzhou. Authorities said they planned to install over 50,000 5G base stations across the country by the end of 2019. Shanghai had activated 11,859 5G base stations by mid-October 2019, in key outdoor areas. In early October 2019, the three major mobile operators had already registered almost 9 million 5G users before the official launch. China Mobile announced 5.32 million subscribers, China Telecom hit 1.76 million subs, and China Unicom was right in line with 1.75 million users.

China Mobile announced it ended November 2020 with a total of 147.4 million 5G subscribers, compared to 6.7 million 5G customers in January 2020. Rival operator China Telecom added 7.6 million subscribers in November 2020 to take its total 5G subscribers base to 79.5 million. China Unicom has not revealed its 5G numbers. Not all "5G package subscribers" announced by the players are in possession of a 5G-capable handset. This overstates the actual 5G user numbers.

The Ministry of Industry and Information Technology announced that by April 2020, telecommunications companies have built more than 250,000 5G base stations across the country. By September 2020, the number of base stations built was 500,000. China expects to build more than 600,000 5G base stations by the end of the year, covering cities above the prefecture level in the

country, in addition to about 100,000 5G base stations built in 2019. The tech hub, often referred to as China's answer to Silicon Valley, was home to about 46,000 5G cell sites as of September 2020.

According to estimates from the Chinese Academy of Engineering, the total number of 5G base stations in China could reach more than 1.7 million by the end of 2021.

#### **2.4.7. USA: all major players have launched 5G services**

Auctions for 28 and 24 GHz spectrum ended in January 2019 and May 2019, respectively. The upper 37 GHz, the 39 GHz and the 47 GHz auction began on time on December 10th, 2019. The bidding phase, or clock phase, ended on 5 March 2020 with gross bids totalling 7.6 billion USD.

##### *Verizon*

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

##### *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). The service is 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). The telco notes that the platform can deliver peak speeds of up to 1Gbps, although users should expect 'typical' speeds of around 300Mbps.

In early October 2020, the service was also available in Chicago, Detroit, Saint Paul and Minneapolis and by the end of 2020, the technology will be available in ten cities nationwide.

##### *Verizon 5G mobile service*

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. The 5G mobile network was available in about 35 U.S. cities as of September 2020. The operator offers three different 5G plans: the Get More unlimited enables customers to have both high data allowance and high-quality content; the Do More unlimited enables the customers to have higher data allowance and lower quality content; finally the Play More unlimited enables the customer to have higher quality content and lower data allowance.

##### *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. The company launched its '5G E' mobile services in certain parts of selected cities in December 2018, using the 39GHz frequencies. In April 2020, the company had rollout out its 5G network in the 850 MHz band in over 190 markets, covering about 120 million people. AT&T's faster mm-wave network branded '5G+' was launched for consumer access in March 2020, offering coverage in parts of 35 cities.

In late July 2020, AT&T announced that its 5G network using the 850 MHz band was available to 205 million consumers in 395 markets across the US.

The operator offers two different 5G mobile plans: the AT&T Unlimited Extra at 75 USD per month with 50 GB of data allowance, Standard-definition streaming and 15 GB of data sharing; and the AT&T Unlimited Elite at 85 USD per month with 100 GB of data allowance, High-definition streaming, 30 GB of data sharing, and HBO MAX.

#### *T-Mobile USA*

T-Mobile USA signed in August 2018 two USD 3.5bn 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.

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.

On December 2, 2019 T-Mobile switched on its 5G network using the 600 MHz frequency band. The deployment is country's first nationwide 5G network, covering more than 200 million people and more than 5 000 cities and towns across the country. It should however be noted that data rates available with the 600 MHz spectrum alone is lower than the data rates provided by 4G services.

In late September 2020, T-Mobile US covered a total of 210 towns and cities using its 2.5 GHz band, the former Sprint spectrum.

T-Mobile partnered with Cisco and Nokia to build its 5G core, and Ericsson and Nokia for its 5G radio infrastructure.

#### *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 and Sprint Merger*

Sprint and T-Mobile officially merged into one company in April 2020. T-Mobile started to expand its network with spectrum from Sprint in the 2.5 GHz band and opened nationwide 5G access for Sprint customers network in the 600 MHz and mm-wave bands. Customers in New York are the first to have access to 5G in the low-, mid- and mm-wave bands.

### **2.4.8. Other countries**

#### **Bahrain**

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



## Brazil

### *Telefonica*

In July 2020, Telefonica launched its 5G network in selected parts of eight state capitals, namely: Sao Paulo, Salvador, Brasilia, Rio de Janeiro, Porto Alegre, Goiania, Curitiba, and Belo Horizonte. Rival Claro also launched 5G services in selected zones of in Sao Paulo and Rio de Janeiro in July 2020.

### *Claro*

Claro launched its 5G network in July 2020 using a combination of 700 MHz, 1800 MHz and 2.5 GHz spectrum in areas in Sao Paulo and Rio de Janeiro. The operator announced plans to expand its 5G service in 12 additional cities before the end of 2020.

## Canada

*Rogers Communications* started offering 5G services in March 2020 in parts of Vancouver, Toronto, Ottawa, and Montreal using equipment from Ericsson. The operator announced it will eventually expand over 20 more markets by the end of 2020. Consumer and B2B subscribers to the ‘Infinite plans’ can enjoy 5G access at no extra charge until March 2021, starting at 75 CAD (49 EUR) per month for 10 GB of data. The network initially uses 2.5 GHz spectrum, with 600 MHz spectrum to be added later in 2020. The telco also expects to deploy dynamic spectrum sharing (DSS), which will allow 4G frequencies to be used for 5G.

*Bell Canada* started the construction of its 5G network in February 2020, using equipment from Finnish vendor Nokia. The carrier also selected Ericsson 5G Radio Access Network (RAN) technology to support its nationwide 5G mobile and fixed wireless access deployment. The operator launched commercial 5G services in Montreal, The Greater Toronto Area, Calgary, Edmonton, and Vancouver. Bell announced on the same day a partnership with Western University in London, Ontario to create a 5G research centre including a campus-wide 5G network to support development of Canada’s 5G innovation ecosystem.

Third largest operator by mobile subscribers, *Telus*, announced in June 2020, the selection of European vendors Ericsson and Nokia to build its 5G network. In June 2020, the operator announced the roll-out of its 5G network in Vancouver, Montreal, Calgary, Edmonton, and the Greater Toronto Area. The company will continue to expand to an additional 26 markets across Canada throughout the remainder of the year. Telus 5G will be available at no additional cost on Telus Peace of Mind plans with endless data and no overage fees. The mobile operator also revealed that it selected South Korea’s Samsung as a network infrastructure partner to provide ‘transformational 5G mobile services’.

## Hong Kong

*HKT*, *Hutchison 3* and *China Mobile Hong Kong* (CMHK) launched 5G services on April 1, 2020. CMHK announced its 5G network covers over 90% of the main areas of Hong Kong Island. HKT said coverage will initially reach 11 of the territory’s 18 districts.

## 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 and 26 GHz bands, 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.

### **Israel**

*Pelephone* announced the launch of its commercial 5G services in 150 locations October 2020, including Tel Aviv, Haifa, Ra'anana, Dimona and Kiryat Shmona.

### **Kuwait**

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

### **New Zealand**

*Vodafone New Zealand* launched 5G services in parts of Auckland, Wellington, Christchurch, and Queenstown in December 2019.

*Spark* launched 5G service in July 2020 in Palmerston North and promised four more locations will be added before the end of the year.

### **Oman**

*Omantel* launched 5G services in December 2019. The network covers parts of about 17 cities and towns. *Ooredoo* followed launch 5G services in over 6 cities and towns.

### **Philippines**

*Globe Telecom* launched 5G FWA services in June 2019 in parts of Bulacan, Cavite City, and Rizal. PLDT launched its 5G mobile network in the main business districts of Metropolitan Manila in late July 2020.

*Smart Communications* launches its 5G network in September 2020.

### **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 in the 3.5 GHz spectrum range domestically with the very few compatible devices available (25 devices according to Gulf times).

*Vodafone Qatar* has also launched 5G services in August 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.

## **Singapore**

*M1* announced that it switched on its 5G non-standalone network in Singapore in September 2020. Coverage was available in Singapore's central business district, and other selected areas. The operator announced plans to extend coverage to the rest of the country's key urban areas/towns by end-2020.

## **South Africa**

In May 2020, *Vodacom* turned on 5G in Johannesburg, Pretoria, and Cape Town. Wider coverage is expected throughout the year. *MTN* rolled out 5G services in areas of Bloemfontein, Cape Town, Edenvale, Johannesburg, Hopetown, Queenstown, Port Elizabeth, Port Alfred. *Rain* launched 5G services in areas of Cape Town, Johannesburg & Tshwane in July 2020.

## **Thailand**

In March 2020, *Advanced Info Service (AIS)* launched 5G services on the 2600 MHz range it acquired from auction concluded the same month. The company announced that 1 000 of its cells are compatible with frequency band and that it plans to spend 10-15 billion THB (290-430 thousand EUR) on 5G network expansion over one year.

## **Taiwan**

*Taiwan Star* launched its commercial 5G services in August 2020. 5G coverage in Taiwan's major metropolitan areas has reached 50% and are expected to top 80% by the end of 2020.

## **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 June 2019.

## **Uruguay**

*Antel* launched a commercial 5G network in April 2019, in Manantiales, though limited in reach.

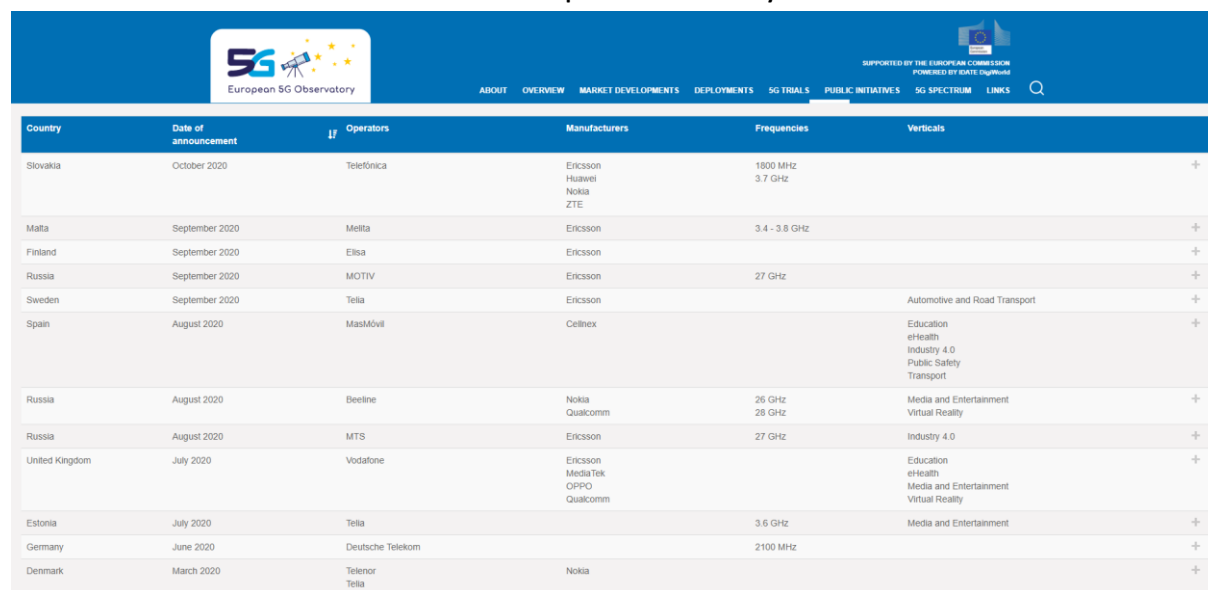
## 2.5. 5G pre-commercial trials

199 5G trials in the 27 MSs of the European Union plus the United Kingdom and 245 trials including Russia, San Marino, Norway, Turkey and Switzerland

### 2.5.1. Analysis of the 245 trials registered so far<sup>5</sup>

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	Operator	Manufacturers	Frequencies	Verticals
Slovakia	October 2020	Telefónica	Ericsson Huawei Nokia ZTE	1800 MHz 3.7 GHz	
Malta	September 2020	Meitla	Ericsson	3.4 - 3.8 GHz	
Finland	September 2020	Elisa	Ericsson		
Russia	September 2020	MOTIV	Ericsson	27 GHz	
Sweden	September 2020	Telia	Ericsson		Automotive and Road Transport
Spain	August 2020	MasMóvil	Celnex		Education eHealth Industry 4.0 Public Safety Transport
Russia	August 2020	Beeline	Nokia Qualcomm	26 GHz 28 GHz	Media and Entertainment Virtual Reality
Russia	August 2020	MTS	Ericsson	27 GHz	Industry 4.0
United Kingdom	July 2020	Vodafone	Ericsson MediaTek OPPO Qualcomm		Education eHealth Media and Entertainment Virtual Reality
Estonia	July 2020	Telia		3.6 GHz	Media and Entertainment
Germany	June 2020	Deutsche Telekom		2100 MHz	
Denmark	March 2020	Telenor Telia	Nokia		

Source: IDATE DigiWorld, December 2020

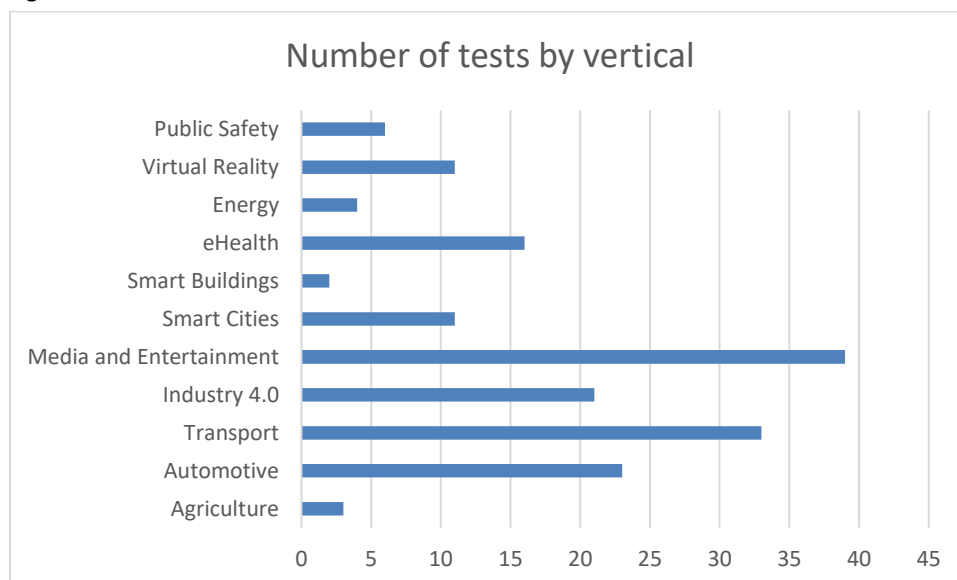
As many as 245 trials have been listed so far. The share of technical tests dropped significantly in the past year as several mobile operators have already launched 5G commercial services and others are planning 5G network deployment for the third quarter of 2020 and/or for 2021. Last trimester, pilots involving verticals and standalone architecture increased.

#### Media and automotive are the verticals majorly driving trials

The most trialled verticals are media and entertainment (39 trials) followed by transport (33 trials) and automotive (23 trials).

The 245 trials were conducted in 31 countries (199 trials in 27 of the 27 EU MSs and the UK and 46 in Russia, San Marino, Norway, Turkey, and Switzerland). No trials have been registered so far in the following Member States: Cyprus, and Slovenia.

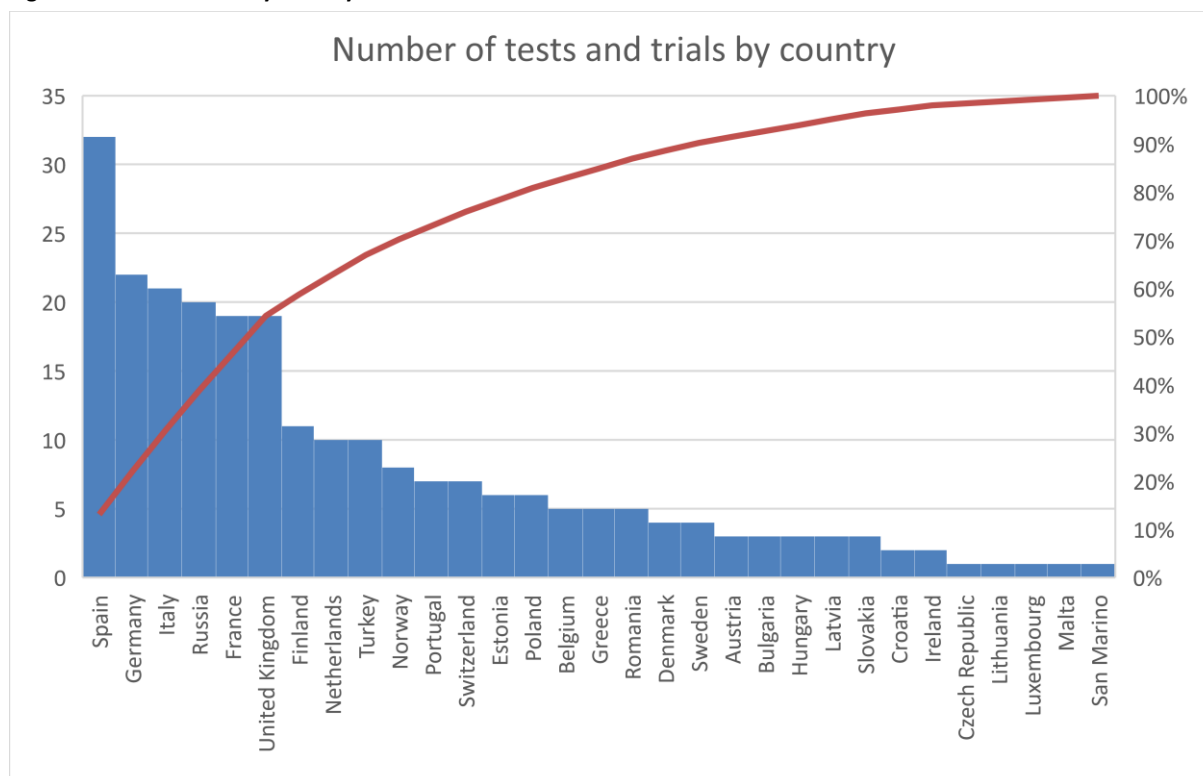
<sup>5</sup> The analysis was made with the data available on the 5G Observatory in December 2020

**Figure 7: Verticals tested in 5G trials**

Source: IDATE DigiWorld, September 2020

### The most numerous trials performed in Spain, Germany, Italy, and Russia

Trials have been the most numerous in Spain, Germany, Italy, and Russia. The top four biggest economies in the European Union (Germany, France, Italy, and Spain) are totalling 38% of trials, reaching 46% when the UK is included. Spain remains the countries with more trials and Germany ranks in second.

**Figure 8: 5G trials by country**

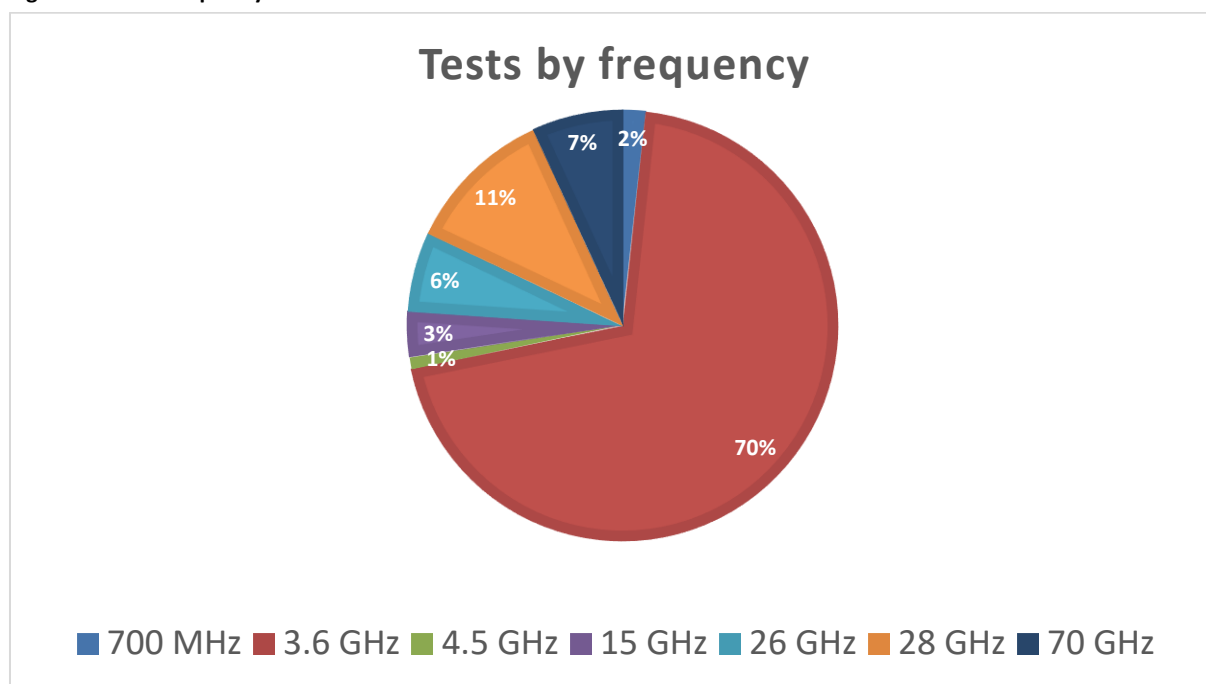
Source: IDATE DigiWorld, December 2020

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

### The 3.4-3.8 GHz band still is the most tested frequency band by far (70% of the trials)

When indicated (frequency bands tested are available only in selected trials, representing 48% of all trials listed), the most used frequency band for trials is by far the 3.4-3.8 GHz (82 trials tested the 3.4-3.8 GHz frequencies out of 117 trials mentioning which band was considered). The 28 GHz band is the second band with more tests, 13 tests in total. The 26 GHz band has been used in 7 tests.

Figure 9: Frequency bands tested



Source: IDATE DigiWorld, December 2020

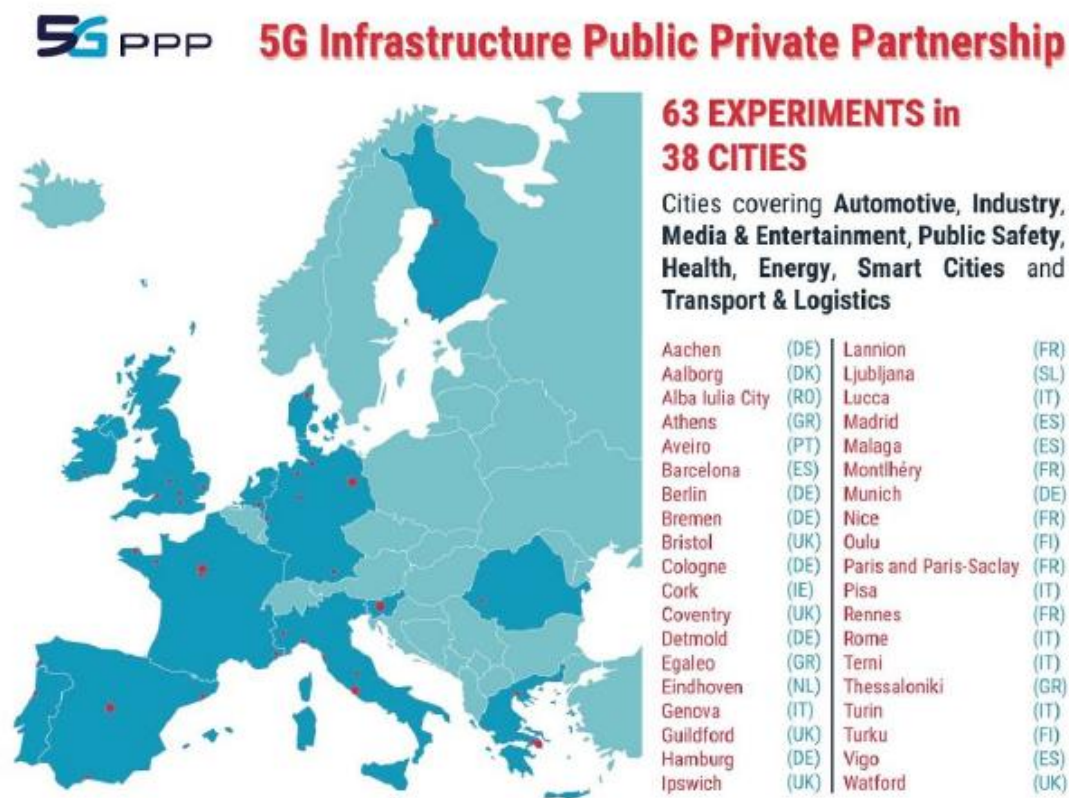
### Level of maturity of 5G trials

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, 59%, can be qualified as small tests or demonstrators (category 3), 27% of them can be considered as intermediate (category 2), and about 14% can be considered as 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.

In Portugal NOS launched in November 2019 the first 5G City in Portugal, Matosinhos, with 3.5 GHz coverage.

### 2.5.3. 5G corridors

Twelve "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, from road-safety or digital rail operations to high-value commercial services for road users and train passengers, e.g. mobile office or infotainment. 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 has been followed since then by a number of agreements between Spain and Portugal, between Bulgaria, Greece and Serbia, and between Estonia, Latvia, Lithuania and Poland over the "Via Baltica", with an extension between Lithuania and Poland. More recently, two agreements - between France and Spain and between the Netherlands and Flanders - were signed, respectively in September 2020 and in May 2020, in the form of MoU. The Netherlands-Flanders agreement concerns the Antwerpen-Rotterdam corridor encompassing road, harbours and inland waterways. The table below presents the situation regarding the on-going initiatives.

**Table 4: 5G CAM cross-border corridors**

5G Corridors	Political Commitment	H2020 cross-border corridor projects
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 testbed signed.	<b>5G CROCO:</b> €17.2M Budget (€12.9M H2020 funded). Coord: CTTC (ES). Consortium: DT, PTLU, Orange PSA, Renault, Volkswagen, Volvo + Bosch, SANEF (FR Highways) Ericsson, Huawei, Nokia, i2Cat
Rotterdam-Antwerpen: NL-BE	MoU signed in May 2020 by NL and Flemish authorities	<b>5G-Blueprint</b> will trial 5G for road, harbours and inland waterways between Antwerpen and Vlissingen, as of Sept. 2020, with a total budget of €13.6M
Porto-Vigo, Evora-Merida: PT-ES	LoI signed on Digital Day 2018, 10 April 2018	<b>5G Mobix:</b> a fraction of €27M budget (€21.4M H2020 funded)  Coord: ERTICO (BE). Consortium: Cosmote, KPN, Telefonica, Turkcell, Ford Otomotiv, National Electric Vehicle Sweden, Auto-Estradas Norte Litoral, Brisa, Ericsson, NSN, Nokia, Siemens, Fraunhofer, TNO, VTT
E8 "Aurora Borealis": NO-FI	C-ITS-TEN-T legacy. First 10km Aurora open in FI for testing	None

	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.	None
Brenner Corridor: IT-AT-DE	Ahead of DD2, Italy and the three presidents of Euroregion Tirol-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.	<b>5G-Carmen:</b> €18M budget (€ 15M H2020 funded). Consortium: DT, TIM, T-Mobile AT, BMW, FIAT Autostrade del Brennero (Brenner-Autobahn) NEC, Nokia, Qualcomm, CEA, IMEC. Support from IT Ministry of Transport, Euregio Tirol-Südtirol-Trentino, Bavarian Road Administration.
Thessaloniki, Sofia-Belgrade: EL-BG-RS	Letter of Intent signed in June 2018 during Digital Assembly in Sofia.	None
EE-LV-LT Via Baltica (E67) Tallinn (EE) – Riga (LV) – Kaunas (LT) – Lithuanian/Polish border	MoU signed on 28 Sept. 2018 in Riga at the 5G Techritory event. Although focused on C-V2X, elements of the Riga-Tallinn segment builds upon Smart E67 project (ITS).	<b>5G-Routes</b> will test 5G for road, rail and maritime over the Via Baltica-North through LV-EE-FI, including cross-border locations. The project, with a budget of €11.7M, will start in Sept. 2020, for a three year period.
LT-PL Via Baltica Kaunas-Warsaw, and further a national extension between Kaunas and Vilnius (LV)	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.  EE-LV-LT-PL consolidated MoU signed on 14 Sept. 2020.	
Barcelona (ES) - Perpignan (FR), Santander (ES) - Biarritz	MoU signed on 24 Sept. 2020 between ES and FR.	<b>5GMED</b> , will trials 5G-enabled use cases for road and rail across the border between FR and ES. The project, with a budget of €15.7M, will start in Sept. 2020, for three years.
CZ-Bavaria: Prague-Munich	MoU signed on 18 July 2019 in the perspective of CEF Digital.	
Greece-Turkey (8 km segment across the border)	The Greek Ministry of Transport and the Greek Ministry for Digital policies, and the Turkish ICT Authority (BTK) have expressed support to the	<b>5G Mobix:</b> a <i>small</i> fraction of €27M budget (€21.4M H2020 funded). Coord: ERTICO (BE). Consortium: Cosmote, KPN, Telefonica, Turkcell, Ford Otomotiv, National Electric Vehicle Sweden, Auto-Estradas Norte Litoral, Brisa,

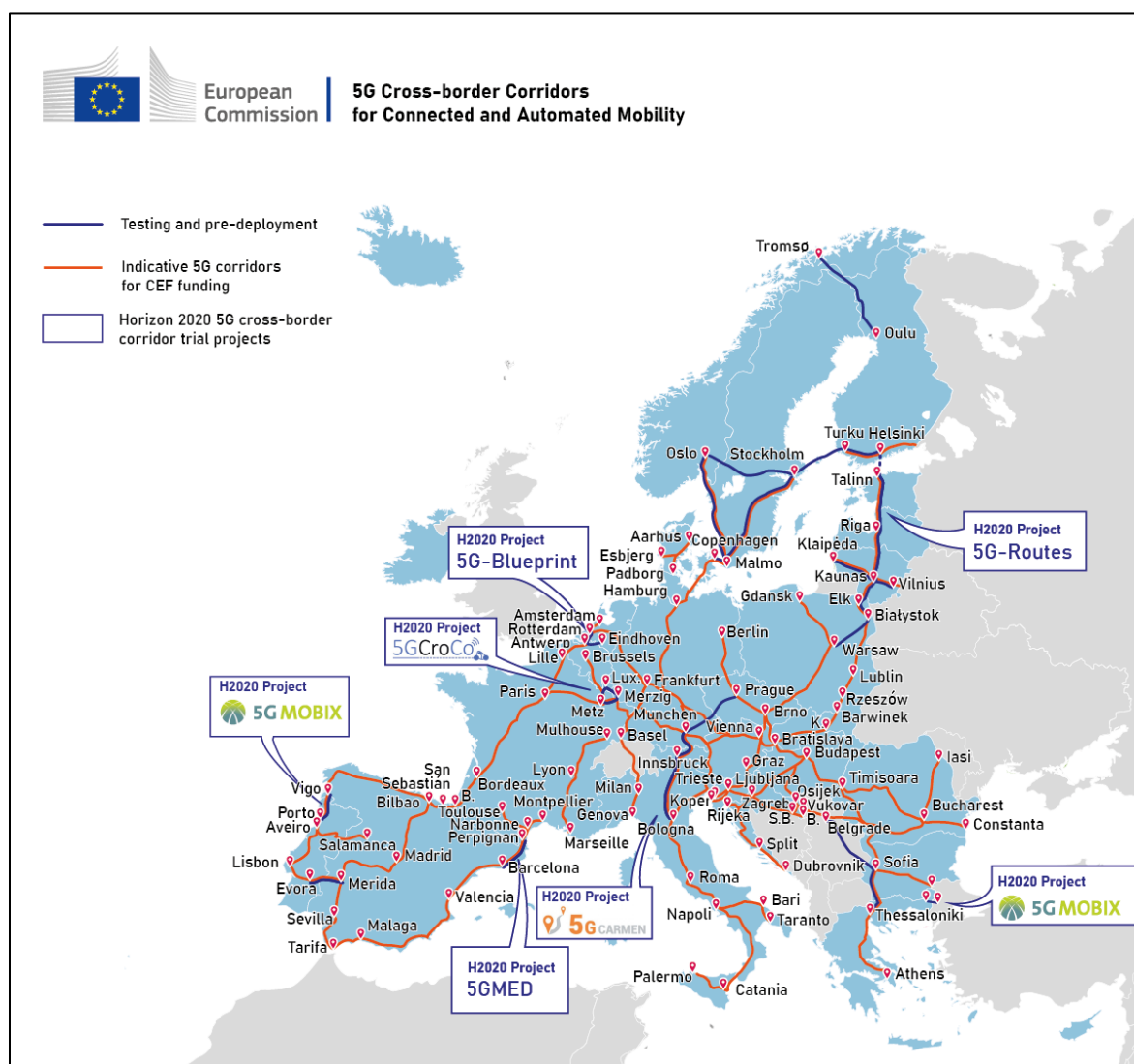


proposal from 5G-Mobix (see 3<sup>rd</sup> column)

Ericsson, NSN, Nokia, Siemens, Fraunhofer, TNO, VTT

Source: European Commission

The following map displays all the main public-private initiatives in Europe.



Source: European Commission, September 2020

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 (5G PPP). 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 (5G-CroCo), 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.

In September 2020, three new projects were launched and will provide applications in cross-border connected and automated mobility.

- 5GMed will test use cases for connected and automated mobility (CAM), including road and rail, on the basis of the same 5G network infrastructure along the Figueras-Perpignan cross-border corridor.
- 5G-Routes will test and validate over 150 km of the Via Baltica corridor, with a ferry extension to Helsinki, including ports and maritime routes.
- 5G-Blueprint will design and validate a technical architecture, business model and governance model for uninterrupted cross-border teleoperated transport for roads and maritime based on 5G connectivity between the ports of Antwerp (Belgium) and Vlissingen (Netherlands).
- Moreover, the forthcoming financial support to a large-scale deployment of 5G corridors under CEF Digital over the 2021-2027 period has further strengthened the momentum. The recent publication by the industry, on 2 October 2020, of [a 5G Strategic Deployment Agenda for CAM](#), with the support of leading European industry associations, and of a [5G SDA on 5G connectivity and spectrum for rail](#), in April 2020, by European rail associations, will contribute to provide strategic guidance to public and private investment projects in the field in the framework of the new European Partnership for Smart Networks and Services (SNS) that will be set up by the second half of 2021.

## 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 (Bordeaux, Nantes, Grenoble, Douai, Le Havre, Saint-Etienne, Lille, Montpellier and Lyon) in 2018. Tests took place and are still taking place in other cities (including Belfort, Le Vaudreuil/Rouen, Lannion/Rennes Marseille, Nantes, Nice/Sophia-Antipolis, Saint Etienne and 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. Barcelona contributes to the 5GMed project starting in September 2020. It will demonstrate advanced cross-border trials of 5G application scenarios in Cooperative Connected and Automated Mobility (CCAM) and Future Railway Mobile Communications System services (FRMCS) between Figueres (Spain) and Perpignan (France).

- The city of Berlin (<https://www.5g-berlin.org/?lang=en> ) 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. 5G was activated first in Berlin. The Innovation Cluster 5G Berlin has kept on testing 5G possibilities for private networks and for industrials in 2020.
- 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...
- Patras has been selected by the Greek Ministry of Digital Policy as a 5G pilot city. 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. Patras belongs to the three 5G-VINNI facility sites in Europe. The Patras 5G facility is operated by the Network and Management Architecture Group, of the Department of Electrical and Computer Engineering, at the University of Patras in Greece. It is part of the 5G PPP facilities ecosystem. The Patras area is seen as a playground for vertical industries.
- 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. In May 2020, the University of Bristol contributed to provide immersive media services to travellers arriving at Bristol and live streaming application. Earlier in March 2020, the city of Bristol showcased Virtual Reality a network of cameras able to detect faces. It also performed demonstrations in the Aston Gate Stadium related to programmable network, differentiation between slices, resilience using slices and Massive MIMO. In May 2020, the University of Bristol started to contribute to 5G-VICTORI' digital innovative mobility use case focusing the provision of immersive media services and live streaming applications.
- Telecom operators have announced additional trial cities.

5G has turned commercial in many EU countries since 2018. 2020 saw an acceleration in 5G deployment in European major cities as well as in smaller towns or municipalities.

We estimate that there were 558 at least partially-enabled 5G cities at the end of December 2020 (in EU-27 plus UK) 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 4.0<sup>6</sup>. Enabled cities include pilot 5G cities and 5G-live cities.

**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)	Key Cities
<b>Austria</b>	5G Private Trials & Pilots, 5G test Corridors, 5G-live cities	Innsbruck, Graz, Linz, Vienna, Worgl, Wortersee ~1000+ locations with commercial 5G services and ~100 cities with commercial 5G services (40% of population coverage)
<b>Belgium</b>	5G Private Trials & Pilots, 5G test Corridors, 5G-live cities	Antwerpen, Brussels, Ghent, Leuven ~60 municipalities with commercial 5G services
<b>Bulgaria</b>	5G Private Trials & Pilots, 5G test Corridors, 5G-live cities	27 city centers of district capitals including Sofia
<b>Croatia</b>	5G Private Trials & Pilots, 5G-live cities	24 parts of cities including Zagreb, Rijeka, Split, Osijek, Samobor and Sveta Nedelja
<b>Cyprus</b>	5G Infrastructure PPP	Limassol
<b>Czech Republic</b>	5G Private Trials & Pilots, 5G-live cities	Prague, Brno, Bílina, Jeseník, Karlovy Vary, Plzeň, Ústí, Kolin and Labem
<b>Denmark</b>	5G Private Trials & Pilots, 5G test Corridors, 5G Infrastructure PPP, 5G-live cities	Copenhagen, Aalborg, Odense, Aarhus, Helsingor
<b>Estonia</b>	5G Private Trials & Pilots, 5G test Corridors,	Tallinn, Tartu, Parnu
<b>Finland</b>	5G Private Trials & Pilots, 5G TNF, 5G Finland, 5G test Corridors, 5G Infrastructure PPP, 5G-live cities	Espoo, Helsinki, Muonio, Oulu, Sodankylä, Tampere, Turku, Ylivieska, Vantaa, Jyväskylä, Jarvenpää, Kerava, Tuusula, Kaarina and Naantali ~40 municipalities with commercial 5G services
<b>France</b>	5G Private Trials & Pilots, 5G test Corridors, 5G Infrastructure PPP, 5G-live cities	Over 50 parts of towns including Angers, Bordeaux, Chatillon, Clermont-Ferrand, Douai, Lannion, Le Mans, Lens, Lille, Lyon, Marseille, Metz, Montlhéry, Montpellier, Mulhouse, Nantes, Paris, Pau, Nice, Rennes, Toulouse ~20 commercial 5G cities
<b>Germany</b>	5G Private Trials & Pilots, 5G Berlin, 5G test Corridors, 5G Infrastructure PPP, 5G-live cities	Aachen, Berlin, Bremen, Cologne, Detmold, Dusseldorf, Hamburg, Ingolstadt, Merzig,

<sup>6</sup> 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). All the content is based on publicly available information and does not claim to be exhaustive.

European Countries	5G Activities (5G Private Trials and Pilots, 5G National Programmes (incl. Platforms), 5G test Corridors, 5G Infrastructure PPP (Vertical Trials and Pilots)	Key Cities
		Munich, Reutlingen, Bonn, Darmstadt, Leipzig ~60 commercial 5G cities
<b>Greece</b>	5G Private Trials & Pilots, Athens5Glink, 5G test Corridors, 5G Infrastructure PPP, 5G-live cities	Athens, Egaleo, Kalamata, Patras, Thessaloniki, Trikala, Zografou
<b>Hungary</b>	5G Private Trials & Pilots, 5G-live cities	Budapest and five county capitals
<b>Ireland</b>	5G Private Trials & Pilots, 5G Infrastructure PPP, 5G-live cities	Over 200 cities and towns including Dublin, Cork, Limerick, Galway, Waterford, Carlow, Castlebar, Dundalk, Drogheda and Kilkenny ~10 commercial 5G cities
<b>Italy</b>	5G Private Trials & Pilots, 5G MiSE, ROMA5G, 5G test Corridors, 5G Infrastructure PPP, 5G-live cities	Bari, Bologna, Genova, L'Aquila, Lucca, Matera, Milan, Naples, Pisa, Prato, Rome, Terni, Turin, Rimini ~15 commercial 5G cities
<b>Latvia</b>	5G Private Trials & Pilots	Riga, Talsi, Daugavpils, Jelgava
<b>Lithuania</b>	5G Private Trials & Pilots, 5G test Corridors, 5G-live cities	Kaunas, Riga, Vilnius
<b>Luxembourg</b>	5G test Corridors, 5G-live city	Luxembourg-City
<b>Netherlands</b>	5G Private Trials & Pilots, 5G Amsterdam, All main cities and towns including 5Groningen, 5G test Corridors, 5G Infrastructure PPP, 5G-live cities	Amsterdam, Eindhoven, Groningen, Rotterdam, Maastricht, Utrecht ~90% of population covered (~10 cities)
<b>Norway</b>	5G Private Trials & Pilots, 5G test Corridors, 5G Infrastructure PPP, 5G-live cities	Askvoll, Bodo, Elverum, Fornebu, Froya, Heroya, Kongsberg, Kvitfjell, Lillestrom, Spikersuppa (Oslo) and Trondheim
<b>Poland</b>	5G Private Trials & Pilots, 5G test Corridors, 5G-live cities	Gliwice, Krakow, Poznan, Warsaw, Katowice, Lodz, Gdansk, Gdynia, Sopot, Wroclaw, Szczecin
<b>Portugal</b>	5G Private Trials & Pilots, Aveiro5GCity, 5G test Corridors, 5G Infrastructure PPP, 5G-live cities	Parts of Aveiro, Cascais, Evora, Porto, Matosinhos, Lisbon
<b>Romania</b>	5G Private Trials & Pilots, 5G Infrastructure PPP, 5G-live cities	Full coverage in Bucharest, and parts of Cluj-Napoca, Iasi, Brasov, Poiana Timisoara, Otopeni, Ovidiu, Predeal, Constant, Mamaia, Club-Napoca, Oradea, Voluntari ~10 commercial 5G cities
<b>Serbia</b>	5G test Corridors	Belgrade
<b>Slovenia</b>	5G Infrastructure PPP, 5G-live cities	Ljubljana
<b>Spain</b>	5G Private Trials & Pilots, 5GBarcelona, 5G Tonic, 5G test Corridors, 5G Infrastructure PPP, 5G-live cities	Barcelona, Bilbao, Cadis, Castelldefels, Ferrol, Gijon, Huelva, Jaén, La Coruña, Logrono, Lugo, Madrid, Málaga, Merida, Pamplona, Seville, Talavera de la Reina, San Sebastian, Santander, Segovia, Valencia, Vigo, Vitoria, Zaragoza ~25 commercial 5G cities
<b>Sweden</b>	5G Private Trials & Pilots, 5G test Corridors, 5G Infrastructure PPP, 5G-live cities	20 cities including Gothenburg, Kista/Stockholm, Malmö, Lund, Helsingborg, Uppsala, Vasteras, Arsta, Karlskrona

European Countries	5G Activities (5G Private Trials and Pilots, 5G National Programmes (incl. Platforms), 5G test Corridors, 5G Infrastructure PPP (Vertical Trials and Pilots)	Key Cities
<b>Switzerland</b>	5G Private Trials & Pilots, 5G-live cities	Burgdorf, Renens, Zurich. 50 cities covered by Swisscom (basic 5G with 90% geographical coverage)
<b>United Kingdom</b>	5G Private Trials & Pilots, UK5G, 5G Infrastructure PPP, 5G-live cities	Belfast, Birmingham, Bristol, Cardiff, Coventry, Edinburgh, Ipswich, Guildford/Surrey, Leeds, Liverpool, London, Manchester, Martlesham, Plymouth, Slough, Watford ~80 commercial 5G cities

Source: 5G-IA & IDATE DigiWorld

## 2.7. Spectrum assignment by public authorities (EU-27 plus the UK)

The 5G pioneer bands identified at EU level are the 700 MHz (694-790 MHz), the 3.6 GHz (3.4-3.8 GHz) and the 26 GHz (24.25-27.5 GHz) frequency bands. The technical conditions of the three 5G pioneer bands have been harmonised through Commission Implementing Decisions (EU) 2016(687) of 28 April 2016, 2019/235 of 24 January 2019 and 2019/784 of 14 May 2019 respectively. The last one, which concerns the 26 GHz band, has been lately amended by Commission Implementing Decision (EU) 2020/590 of 24 April 2020 to take due account of the developments at the last ITU World Radiocommunication Conference in 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 had 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 on-going. The review of progress towards making spectrum available to 5G shows various stages. Spectrum assignments by different EU MSs are detailed in the Annex section.

A number of auction processes scheduled for H1 2020 were postponed due to the covid-19 pandemic. Some were rescheduled and either have already taken place in the last months, or are expected by Q1 2021 or later.

### 2.7.1. Review of spectrum assignment progress

In 21 countries (EU-27 plus UK) at least one 5G pioneer band (total or partial) has been assigned. The latest spectrum auction ended on 17 December 2020 in Cyprus assigning both the 700 MHz and the 3.4-3.8 GHz bands. At the end of 2020, 48.2% (44.6% assigned and usable in 2020) of spectrum in the 700 MHz band, 51.7% (51.7%) in the 3.4-3.8 GHz band and 14.3% (10.7%) in the 26 GHz band have been assigned in the EU-27 plus the UK. However, not all assignments will be usable by end of 2020, which has been taken into account in the EU scoreboard, as marked in the values in parenthesis.

The 700 MHz band has been assigned in fourteen Member States: Austria (2020), Cyprus (2020), Czech Republic (2020), Germany (2015), Greece (2020), France (2015), Finland (November 2016), Hungary (March 2020), Italy (October 2018), Luxembourg (2020), Netherlands (2020), Slovakia (2020), Sweden (December 2018) and Denmark (March 2019). All in all, assignment of 700 MHz accelerated in 2020 with more than half of the global count to date.

In the mmWave bands, Italy, Finland and Greece have so far assigned spectrum in the 26 GHz band. Additional auctions in 26 GHz frequencies are expected. In the United Kingdom and Germany, local licences are available in the 26 GHz: *“local licences available on demand subject to co-ordination”*.

A number of auction procedures scheduled for 2019 were officially postponed to 2020 and sometimes further postponed due to the covid-19 epidemic; others were de facto postponed.

### **Spectrum auctions scheduled in 2021**

- Belgium, 700 MHz/3.6-3.8 GHz/1.5 GHz, 26 GHz in 2021
- Bulgaria: 3.6 GHz and 700 MHz bands first expected in Q2 2020 but likely in 2021
- Croatia, 700 MHz/3.6 GHz/26 GHz, first half 2021
- Denmark, 1500/2100 MHz, 3.5 GHz/26 GHz, and possibly the remaining part of the 2.3 GHz in March/April 2021
- Estonia, 700 MHz/3.6 GHz, likely in 2021
- Ireland, 700/2100/2300/2600 MHz, , expected in the first half 2021
- Lithuania, 700 MHz/3.4-3.8 GHz, likely in 2021
- Luxembourg, 26 GHz
- Malta, 700 MHz, June 2021 and 3.4-3.8/26 GHz likely in 2021
- Netherlands, 26 GHz, in 2021
- Poland, 3.4-3.8 GHz, expected in the first quarter 2021; 26 GHz expected before 2022 (subject to market demand)
- Portugal, 700/900/1800/2100/2600 MHz & 3.6 GHz, auction rescheduled from 2020 is still ongoing.
- Romania, 700 MHz/800 MHz/1500 MHz SDL/2600 MHz TDD/3.4-3.8 GHz, auction expected in the first half of 2021; 26 GHz possibly in 2021
- Slovenia, 700/1500/2100/2300/3400-3800 MHz (320 MHz) & 26 GHz, by Q1 2021
- Spain, 700 MHz, auction initially planned for Q1 2020, delayed until May 2020 and further delayed due to the pandemic, is now expected to be held by Q1 2021
- Sweden, 2.3, 3.5-3.7 GHz and 26 GHz initially scheduled for November 2020 postponed to 19 January 2021
- UK, 700 MHz (80 MHz) and 3.6-3.8 GHz (120 MHz) expected early 2021

### **Spectrum auctions scheduled/planned as from 2022**

- Belgium, 31.8-33.4 GHz and 40.5-43.5 GHz from 2022 to 2027
- Croatia, 3.4-3.6 GHz
- Latvia, 700 MHz, award expected in 2022

- Netherlands: 3.5 GHz, expected end of 2021/beginning of 2022

### **Spectrum auctions scheduled/planned after 2023**

- Netherlands, 3400-3450 MHz and 3750-3800 MHz for local use

#### **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 that allowed the use of spectrum for 5G in all pioneer bands, finishing out the spectrum awards in September 2018, followed by Finland which completed the 26 GHz band award process in June 2020. Greece ranked third in assigning 26 GHz spectrum in Europe.



## Usability of low-band (700 MHz) spectrum

700 MHz spectrum already assigned in fourteen EU-27 countries: Austria, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Luxembourg, Netherlands, Slovakia and Sweden.

**Table 6: Availability of 700 MHz spectrum in Eu-27 plus the UK (as of end December 2020)**

Member State	Frequencies	Tentative/Expected assignment date. Date of completion	Comments
Austria	703-733/758-788 MHz	August 2020	Licences include coverage conditions
Belgium	703-733/758-788 MHz	By year-end 2021	Domestic administrative issues at federal/regional level
Bulgaria	703-723/758-778 MHz	2021	2x20 MHz release for 5G
Croatia	703-733/758-788 MHz	First half 2021	EC issued a decision on 8 November 2018 to initiate proceedings against Croatia
Cyprus	703-733/758-788 MHz	December 2020	Started and ended on December 17, 2020
Czech Rep.	703-733/758-788 MHz	November 2020	Auction rescheduled in February 2020 and further rescheduled in May 2020 and further delayed to November 2020
Denmark	703-733/758-788 MHz	March 2019	
Estonia	703-733/758-788 MHz	Likely in 2021	
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	December 2020	Spectrum available in December 2020 Auction ended on December 16, 2020
Hungary	703-733/758-788 MHz	March 2020	
Ireland	703-733/758-788 MHz	First half 2021	
Italy	703-733/758-788 MHz	October 2018	5G services possible in 2022 due to TV use
Latvia	703-733/758-788 MHz	2022	Unresolved cross-border issues
Lithuania	703-733/758-788 MHz	First quarter 2021	
Luxembourg	703-733/758-788 MHz	July 2020	Public consultation in Q3 2018, Q3 2019, March 2020
Malta	703-733/758-788 MHz	June 2021	Availability date for 5G commercial use
Netherlands	703-733/758-788 MHz	July 2020	
Poland	703-733/758-788 MHz	First half 2021	Delay requested from 2020 to 2022 in December 2018. Applications due before 6 April 2020. Auction expected by 27 August 2021
Portugal	703-733/758-788 MHz	Early 2021	Auction was scheduled to begin in April 2020, rescheduled. Six lots of 2x5 MHz, 19.20 million per lot Rights of use: January/February 2021
Romania	703-733/758-788 MHz	Second quarter 2021	"National Strategy for the Implementation of 5G in Romania" between November 20th and December 21st, 2018.
Slovakia	703-733/758-788 MHz	November 2020	
Slovenia	703-733/758-788 MHz	2021	Public consultation issued in May 2019. Auction delayed to YE2020 in December 2019 and further delayed in 2020
Spain	703-733/758-788 MHz	First quarter 2021	Initially planned for Q1 2020, delayed until May 2020. Further delayed due to the outbreak of the novel coronavirus in the country.
Sweden	703-733/758-788 MHz	December 2018	40 MHz assigned, available as from Jan. 1 <sup>st</sup> , 2019 till Dec. 31 <sup>st</sup> , 2040
UK	703-733/758-788 MHz	Early 2021	80 MHz. Public consultation on auction design till December 9 <sup>th</sup> , 2019

Source: IDATE DigiWorld, based on NRA information

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

Spectrum within 3.4-3.8 GHz frequency band has already been assigned in accordance with 5G technical conditions<sup>7</sup> in 16 countries (EU-27 countries and the UK): Austria, Cyprus, Czech Republic, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Romania, Slovakia, Spain and United Kingdom.

3.4-3.8 GHz spectrum has been assigned<sup>8</sup> in 2016 and 2020 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 Slovakia, the 3.4-3.8 GHz (400 MHz) had been previously assigned for 4G usage and the conditions of the existing licences (valid until 2025) were modified into 5G-compatible ones. The auctions in Cyprus and Greece were completed in December 2020. Outside Europe, the USA is progressively catching up 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. In September 2020, the FCC announced winning bidders of 3.5 GHz (3550-3650 MHz) in auction 105. In December 2020, the 3.7-3.8 GHz started. After 55 rounds, it closed on 5 January 2020, having raised around 78.5 billion USD.

<sup>7</sup> 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

<sup>8</sup> Parts of this frequency band are used for 4G fixed wireless access

**Table 7: Availability of 3.4-3.8 GHz spectrum in EU-27 plus the UK (as of end December 2020)**

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	By year-end 2021	Administrative issues at federal/regional level
Bulgaria	3400-3800 MHz	2021	
Croatia	3400-3600 MHz	2022	
	3600-3800 MHz	First half 2021	
Cyprus	3400-3800 MHz	December 2020	Started and ended on December 17, 2020
Czech Rep.	3600-3800 MHz	2017	
	3400-3600 MHz	November 2020	Auction rescheduled in February 2020 and in November 2020
Denmark	3410-3800 MHz	March/April 2021	Delayed to 2021 on 8 December 2020 Licences expected to be valid from 1 June 2021 to 31 January 2042
Estonia	3400-3800 MHz	2021	Auction for 390 MHz of spectrum suspended in April 2019. New consultation held in October 2019
Finland	3400-3800 MHz	October 2018	
France	3400-3800 MHz	October 2020	Public consultation in October 2018. Auction ended in October 2020.
Germany	3400-3700 MHz	June 2019	Full availability in 2022, early stage in 2019
	3700-3800 MHz	December 2019	100 MHz dedicated to vertical sites, applications opened on November 21st, 2019
Greece	3400-3600 MHz	December 2020	Public consultation issued in Q1 2019 Another public consultation expected by YE2019 Ended on December 16, 2020
Hungary	3400-3800 MHz	March 2020	400 MHz assigned
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 quarter 2021	Public consultation in Q2 2018 including the 3800-4200 MHz band. New public consultation in Q3 2018. Another public consultation closed (04/2019) Temporary allocation to Telia
Luxembourg	3420-3750 MHz	July 2020	Public consultations in Q3 2018, May 2019, March 2020. 280 MHz + 50 MHz announced in December 2019 by the Prime Minister
Malta	n/a	2021	Public consultation in Q2 2018
Netherlands	3500-3700 MHz	End of 2021/beginning of 2022	Final recommendations disclosed. Spectrum available from September 2022
	3400-3450/3750-3800 MHz		Spectrum available from 2026
Poland	3400-3800 MHz	First quarter 2021	Public consultation in Q3 2018. Four blocks of 80 MHz
Portugal	3400-3800 MHz	Early 2021	Auction initially scheduled to begin in October 2020. Six lots of 10 MHz, 840 000 EUR per lot Rights of use valid as from January/February 2021
Romania	3400-3800 MHz	Second quarter 2021	110 MHz FDD and 145 TDD spectrum valid from 2020 to 2025. 400 MHz available from 2026
Slovakia	3400-3800 MHz	2021	Licenses valid until 2025.
Slovenia	3500-3800 MHz	2021	Public consultation issued in May 2019. Auction delayed to YE2020 in December 2019
Spain	3400-3600 MHz	2016	160 MHz assigned for 4G (and usable for 5G)
	3600-3800 MHz	July 2018	For 5G

Member State	Frequencies	Tentative/Expected assignment date Date of completion	Comments
Sweden	3400-3800 MHz	2Expected end of January 021	Initially scheduled for March 2020, rescheduled to November 2020. Expected to resume on 19 January 2021
UK	3400-3600 MHz 3680-3800 MHz	April 2018 Early 2021	150 MHz assigned in the 3.4-3.6 GHz band 120 MHz to be assigned. Public consultation on auction design till December 9 <sup>th</sup> , 2019

Source: IDATE DigiWorld, based on NRA information

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

26 GHz spectrum has been assigned in Italy, Finland and Greece, and available for local licences in Germany and the UK<sup>9</sup>

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 2400 MHz spectrum at 28 GHz in June 2018. The USA ranks third globally with 1550 MHz of such spectrum. Finland is the second country to have auctioned 26 GHz spectrum at European level and the fourth country at world level. Greece is the third European country to auction 26 GHz spectrum.

<sup>9</sup> In the United Kingdom, local licences are available in the 26 GHz: “local licences available on demand subject to co-ordination”.

**Table 8: Availability of 26 GHz spectrum in EU-27 plus the UK (as of end December 2020)**

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	First half 2021	
Cyprus	24.25-27.5 GHz	n/a	
Czech Rep.	24.25-27.5 GHz	n/a	Earmarked for 5G in 2019
Denmark	24.65-27.5 GHz	March/April 2021	Usage requirements
Estonia	24.25-27.5 GHz	2021	
Finland	25.1-27.5 GHz <sup>10</sup>	8 June 2020	Parts of the range are already available for shared use
France	26.5-27.5 GHz	n/a	Public consultation in Q2 2018
Germany	24.25 GHz to 27.5 GHz	2020	General authorisations in 2H 2020 Application procedure for local/regional use
Greece	24.25-27.5 GHz	December 2020	<b>Ended on December 16, 2020</b>
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. Study year-end 2020
Italy	26.5-27.5 GHz	October 2018	
Latvia	n/a	2021	
Lithuania	n/a	n/a	Depending on market demand
Luxembourg	24.5-27.5 GHz	2021	Consultation on use of 26 GHz spectrum ended on 8 December 2020
Malta	n/a	2021	
Netherlands	24.5-27.5 GHz	2021	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	After July 7, 2021	
Slovenia	26 GHz	January 2018	Two blocks (56 and 112 MHz) awarded, but not available for 5G
	26 GHz	2021	Public consultation issued in May 2019 for 5G
Spain	n/a	2021	1.4 GHz of spectrum could be assigned
Sweden	24.25-27.5 GHz	2021	Auction process considered and consultations launched Local licences in 2021
UK	24.25-26.5 GHz	2020	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. The [ITU Radio Regulations edition 2020 has been published](#).

<sup>10</sup> The lower range will be reserved for local/regional (vertical) players and research/development/educational usage.

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 Earth observation programme and those from the European Organisation for the Exploitation of Meteorological Satellites (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 1<sup>st</sup>, 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 (HABS). 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

### 2.8.1. Overview of the 5G baseband market as of end of December 2020

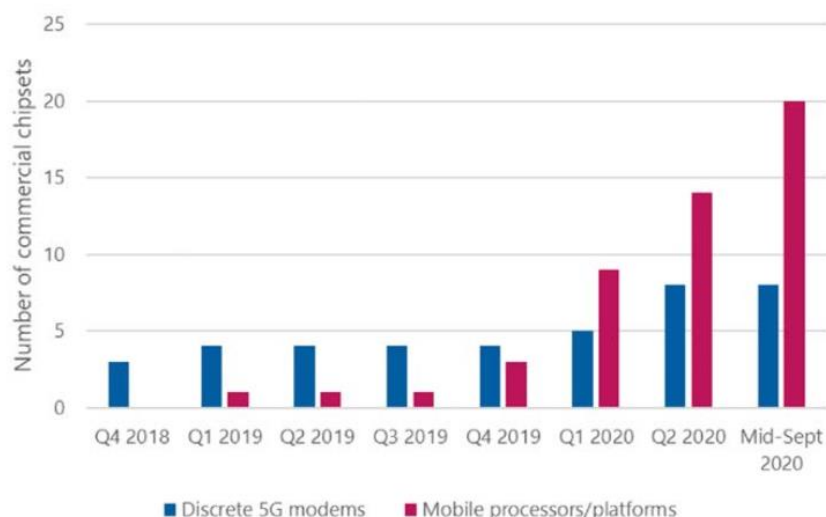
#### Now 3 generations of (high-end) 5G chipset and an expansion into lower tier

In 2019 and 2020, the 5G chipset market has seen several announcements that points to both an increased maturity and competition on the market. While Qualcomm has announced its third generation discrete 5G baseband aimed at the high-end portion of the market, in February 2020 and called the X60, it is only now that devices based on this generation are to be launched on the market.

In the meantime several mid-end 5G chipsets have been announced, not only by Qualcomm, but also its competitors and the end of the year has even seen the release of even lower end chipsets such as the Mediatek Dimensity 720 that is powering the cheapest 5G phone, the Oppo Realme v3, at 146 USD (in China) or the Snapdragon 480 (announced at the beginning of 2021).

While first integrated 5G SoC announced can be dated back to September 2019 with the Samsung Exynos 980, followed by Huawei/HiSilicon Kirin 990 5G, all targeting the high end market, the end of 2019 and the course of 2020 has seen several other 5G SoC announced and launched by Qualcomm (SD765/765G with its updated version the SD 768), Huawei (Kirin 820 and 985 5G), Samsung (Exynos 880) and Mediatek (Dimensity 1000L and 1000+ as well as the lower end Dimensity 820; 720, 700). This is not anecdotal as the gist of the new chipsets announcement are now System on Chips integrating one baseband with capabilities adapted to the price tear of the targeted device . This can be seen in the figure below that shows there are now more 5G SoC than discrete 5G baseband on the market and that this trend has only expanded since our last update in September 2020.

**Figure 10: Evolution in the number of commercial 5G chipset**



Source: gsacom

While those new lower tier chipset have initially had in common the fact that they only supported the sub-6 GHz frequency range, this has started to change with the introduction of Qualcomm Snapdragon 480 a further indication of the ever evolving market. Indeed, limiting 5G chipset to sub 6 GHz is a way to reduce the Bill of Material (BOM) and make it more adapted to both lower tier segments and

markets where mmWave is not yet available. However, as mmWave is slowly being introduced in more markets than just in the US (South Korea, Japan, Russia) limited support for mmWave in lower end 5G chipset now can be seen, the SD480 being the first to feature this capability. Announced on the 4<sup>th</sup> of January 2021, the SD480 support both sub 6 GHz frequency bands and mmWave, albeit with some limitations:

- Bandwidth limited to 200 MHz in the mmWave for 2.5 Gbps maximum 5G throughput
- No cross carrier aggregation between mmWave and Sub 6 GHz spectrum

As of the end of November 2020, around 40 5G chipsets had been in development or released but at the same time, only 29 chipsets could be considered as commercially available (7 from Qualcomm, 6 from Huawei, 5 from Samsung 9 from Mediatek and 2 from UniSoc). As of end of September 2019, we reported only 5 of them and only 8 at the end of December 2019.

It is to be noted here that in this count of 5G chipset. Discrete 5G modem that are not sold separately, such as the X52 or x51 Qualcomm modem are not included, even though, as such they could be considered as modems.

**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	X60 (basebands)	February 2020	Sampling in Q1 2020 for 1st commercial smartphone early 2021	Up to 7,5 Gbps in the DL, 3 Gbps in the UL	5nm baseband, support Sub6 GHz and mmWave, NSA and SA, 2CCA, mmWave + Sub6 CA, DSS, VoNR
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	Unclear if sold separately or only to be used in mid-range 5G SoC from Qualcomm
Qualcomm	Snapdragon 765 and 765G	December 2019	Q1 2020	up to 3.2 Gbps / 1.6 Gbps	based on Qualcomm x52 5G modem
Qualcomm	Snapdragon 768G	May 2020	NA	up to 3.7 / 1.6 Gbps	An updated version of the SD 765G to keep up with Mediatek competition
Qualcomm	X51			up to 2.5 / 1.2 Gbps (support for up to 100 MHz)	Does not support mmWave, will not be sold separately but integrated in future Qualcomm SoC
Qualcomm	Snapdragon 690	June 2020	H2 2020	up to 2.5 / 1.2 Gbps (support for up to 100 MHz)	Based on x51 5G modem, aimed at lower range 5G modem. It doesn't support mmWave, only sub 6 GHz
Qualcomm	RB5	June 2020	products based on RB5 expected by the end of 2020	Sub 6 and mmWave support	Qualcomm Robotic platform based on x55



Vendor	Product name	Announcement	Availability	Throughputs	Comments
Qualcomm	Snapdragon 750G	September 2020	available by the end of 2020	up to 3.2 Gbps / 1.6 Gbps	based on x52 modem, support sub 6 GHz and mmWave
Qualcomm	Snapdragon 888	December 2020		Up to 7,5 Gbps in the DL, 3 Gbps in the UL	integrate the x60 modem, support Sub6 GHz and mmWave, NSA and SA, 2CCA, mmWave + Sub6 CA, DSS, VoNR
Qualcomm	Snapdragon 480	January 2021	First devices to be launched "early 2021"	Up to 2.5 Gbps (5G)/660 Mbps (5G) vs 800/210 Mbps (4G)	Based on x51 5G modem, aimed at lower range 5G modem. Support for mmWave (up to 200MHz BW) and Sub-6 GHz (up to 100 MHz), SA and NSA modes, TDD, FDD, and Dual Spectrum Sharing (DDS)
Samsung	Exynos 5100	August 2018	End of 2018	Up to 2 Gbps in sub 6 GHz and 6 Gbps in mmWave	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
Samsung	Exynos 880	May 2020	May 2020 (already shipped in Vivo Y70S in China)	Up to 3,55/1,28 Gbps. 3,55 can be reached with dual LTE/5G connectivity	SoC with integrated 5G baseband for mid-range device. Only support sub 6 GHz
Samsung	Exynos 1080	November 2020	NA	up to 5.1 Gbps (sub 6) and 3.67 Gbps (mmWave)	"SoC only meant for Chines market at the beginning. A mid-range solution competing with the SD 765.
Samsung	Exynos 2100	To be announced on the 12th of January 2021	NA	NA	Will use snapdragon 888 licensing
Hi-Silicon	Balng 5G01	February 2018	End of 2018	Up to 2.3 Gbps	Only for Huawei products, designed for fixed 5G devices. 5G only
Hi-Silicon	Balng 5000	January 2019	NA	Up to 4,6 Gbps at sub 6GHz and 6,5 Gbps on mmWave	Dubbed as the first single chip multimode modem (2G/3G/4G/5G) and first to support 2CC of 100MHz
Hi-Silicon	Kirin 990 5G	43709	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
Hi-Silicon	Kirin 820 5G	March 2020	sampling in Q1 2020, available mid 2020 in devices	Up to 2,3 /1,5 Gbps	Sub 6 GHz only, based on Balng 5000 modem
Hi-Silicon	Kirin 985 5G	April 2020		Up to 1.277 Gbps / 173 Mbps	Sub 6 GHz only,
Hi-Silicon	Kirin 9000	October 2020	November 2020	Up to 6.5 Gbps	SoC integrating Balng 5000 modem, support sub 6 and mmWave

Vendor	Product name	Announcement	Availability	Throughputs	Comments
<b>Mediatek</b>	Helio M70 (MT6885)	June 2018	2019-2020	Up to 4,7 Gbps (DL) / 2,5 Gbps (UL)	Standalone modem. Devices powered by Helio M70 to be available in early 2020 while being sampled in Q3 2019. Partnership with China Mobile. It will use 7 nm EUV process from TSMC
<b>Mediatek</b>	Dimensity 1000L SoC / MT6885 based on Helio M70	May 2019	sampling in Q3 2019, available in devices in Q1 2020	Up to 4,6 Gbps (DL) / 2,5 Gbps (UL), support for 2x100 MHz CA	"5G SoC with an Helio M70 integrated. First commercial devices launched on 27th of December, 2019 with the Oppo Reno 3 in China. It is a lower performance version of the Dimensity 1000 to be released later
<b>Mediatek</b>	Dimensity 1000+ SoC	May 2020			5G SoC with higher performance than Dimensity 1000L but same connectivity
<b>Mediatek</b>	Dimensity 800 SoC	January 2020	First devices to be launched during H1 2020 but may slip in H2 with COVID-19	unannounced throughput	Multimode 5G SoC to power Premium mid-range devices. Support 2 carrier aggregation, NSA and standalone, only sub 6 GHz, DSS, VoNR
<b>Mediatek</b>	Dimensity 820 SoC	May 2020	1st devices in June 2020	2CC aggregation up to 100 MHz, sub 6GHz only, VoNR, up to 4.7 /2.5 Gbps	
<b>Mediatek</b>	Dimensity 800U			up to 2,3 Gbps	up to 100 MHz BW, 2 CC Aggregation, SA, NSA, Sub 6 only
<b>Mediatek</b>	Dimensity 720 SoC	July 2020		up to 2,77 Gbps in the DL	SA&NSA, 2 CC aggregation up to 120 MHz, Sub 6 GHz only
<b>Mediatek</b>	Dimensity 700 SoC			up to 2,77 Gbps in the DL	2CC 5G-CA, SA&NSA, DSS

Source: IDATE DigiWorld

### What differentiates those chipsets?

The number of feature sometimes makes it difficult to differentiate all those chipset and indeed a lot is shared on the paper. Below are the features where 5G chipset might differentiate:

- Support for Standalone mode (SA). While the 1st generation of 5G modem only supported the Non Standalone mode, all 5G chipset now support both NSA and Standalone mode, this way of deploying 5G that make it independent from 4G and where both the user plane and the control plane are handled by a native (and virtualized) 5G Core. The existing of NSA only device on the networks explain why SA won't simply replace NSA but will likely coexist for some years to come.
- Capability to aggregate up to 2 carriers of 100 MHz (FDD and TDD) in the sub 6 GHz frequency band: this enable increased performance in the sub 6 GHz, as early chipset were not capable of aggregating FDD and TDD spectrum, which is quite common to have for an operator. Lower end 5G chipsets have today limited carrier aggregation capabilities. While higher end chipset can aggregate up to 800 MHz in the mmWave bands, some are more limited (e.g. SD480 supports up to 200 MHz in the mmWave and 100 in the sub 6 GHz).
- Capability to aggregate sub 6 GHz and mmWave spectrum for increased maximum throughput up to 7.5 Gbps (Qualcomm x60). This is especially important for increased coverage and will ease the transition for operator from NSA to SA.
- Support for mmWave bands: Because the deployment in those frequency band has so far been limited outside Verizon, the absence of support for mmWave is not an issue and an opportunity to develop lower end / cheaper 5G chipset, while still providing an enhance user

experience over 4G. MmWave bands however has started to be deployed outside the US in the 2<sup>nd</sup> half of 2020 and should also be introduced in Europe in 2021.

- Support for DSS (Dynamic Spectrum Sharing) feature, which enable the dynamic deployment of 5G in 4G bands, as standardized within 3GPP (instead of dedicating fixed portion of spectrum to RAT as was usually done with refarming. While absent from early generations of 5G chipset, DSS is now commonly supported.

Those capabilities differentiate chipset between each other and often between the different generations of 5G chipsets.

### **State of the competition**

The 5G baseband market is quite different from the 4G and earlier generation baseband market. Actually, each new generation of cellular technologies has seen a player leaving the market and a new one emerge. As an example, TI left the baseband market with 3G and Infineon sold its cellular asset to Intel. In 4G, several players left the baseband market, such as Broadcom, despite several acquisition or Fujitsu. With 5G, Intel was the first to leave the (device) baseband market by selling its cellular assets to Apple. Due to the economic war between the US and China, the future of Huawei chipsets, with the inability to rely on TSMC foundry 5nm process starting on 15th of September 2020 is also uncertain.

In 5G Qualcomm is still considered the leader in market share but recently, the rise of Mediatek with its Dimensity range of 5G modem, now commercially available is somehow changing the competitive landscape and this is particularly true in China where tensions with the US put Huawei in a difficult situation regarding its chip design capabilities. While Counterpoint Research estimates Qualcomm market 5G smartphone market share to be around 39% of the sold in Q3 2020, Mediatek has been growing dynamically throughout 2020. In Q3 it even surpassed Qualcomm on the global smartphone chipsets market, benefiting from the growth in China and India.

While Samsung and Huawei, number one and two in the smartphone market have initially used their chipset internally, this situation has changed throughout the time, as both chipset manufacturers have been mentioned as selling their chipset to other device manufacturers, mostly Asian one. In a not so distant future, they will both be joined by Apple, after the Cupertino company acquired Intel cellular assets for mobile devices. For now, Qualcomm is still benefiting from this situation, since Apple is not currently capable of using its own silicon for 5G connectivity and has inked a licensing deal with Qualcomm to use their 5G products. The new iPhone 12, which is powered by Qualcomm x55 5G modem has positively impacted latest financial results from Qualcomm in the last quarter.

### **Mediatek is now the 5G challenger for Qualcomm**

After a slow 5G headstart, Mediatek has turned into a serious competitor in the recent months thanks to the growth in the very large Chinese market as well as thanks to the difficulties leading Huawei to partly rely on Mediatek 5G chipset in lieu of HiSilicon chipsets difficult to be produced in the context of US restriction on doing business with Huawei. In the recent months, Mediatek has been mainly competing on the mid-end and low end 5G chipset market, launching a host of different SoC. For various price range. The Dimensity 720 announced in July 2020 for instance power the cheapest 5G smartphone to date, the Oppo Realme v3 which can be found at around 120 EUR in China.

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. In February 2020, it announced its 2<sup>nd</sup> generation 5G chipset, the T7520 SoC, which Unisoc claims as “the all-around leader in power consumption for both light-load and heavy-load scenarios and delivers a power consumption reduction of up to 35% for some data business scenarios.”, a claim, which of course remains to be verified. Unisoc power smartphone commercially available from HiSense, CoolPad and AGM notably, smartphones that are targeting the Chinese market.

### **Apple to develop its own 5G modem for tighter control and integration**

After Intel quitted the smartphone chipset market in April 2019, Apple purchased most of Intel 5G business for 1 billion USD with the intent to develop its own 5G baseband. In the meantime, Apple is using Qualcomm 5G modem after it reached a 6 year license agreement as a settlement for the litigation between Apple and Qualcomm. The reason for Apple to develop its own modem is above all the capability to better integrate connectivity capabilities to Apple global ecosystem of devices, not only in iPhones and iPad, for which a homegrown ARM based processor has already been available for many years but also for the rest of its line of computers. In mid-June 2020, Apple indeed announced its choice to transition from Intel x86 architecture to the ARM architecture, something which resulted in the commercial launch of first ARM based Mac computers in November 2020. By mastering and fully controlling the processors of Mac computers, Apple will be able to develop and integrate new features, of which of course 5G connectivity.

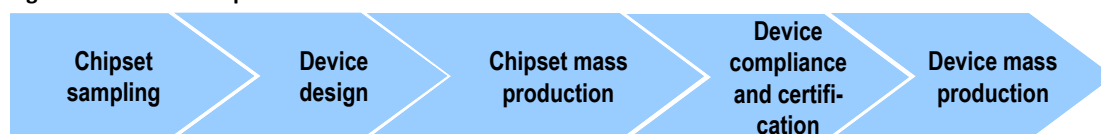
It is estimated that Apple own 5G modems could come to the market around 2023-2025. Such modems are very unlikely to be sold to other OEMs as they are meant to become a differentiating point for Apple. While designing a cellular modem is no easy task, Apple has proven in the past that it could acquire knowledge and competences in the design of new solutions, something that takes times to reach maturity but will in the end serve the interest of Apple.

In October 2020, Apple launched its line of 5G iPhones, using Qualcomm x55 modem.

### **2.8.2. 519 5G devices announced at the end of 2020**

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 11: 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. Since then, many other routers and CPEs have been released for various usage and with newer 5G chipsets and capabilities.

**Figure 12:** Example of routers based on Snapdragon 865 (based on 2<sup>nd</sup> gen x55 5G modem)



Source: Qualcomm

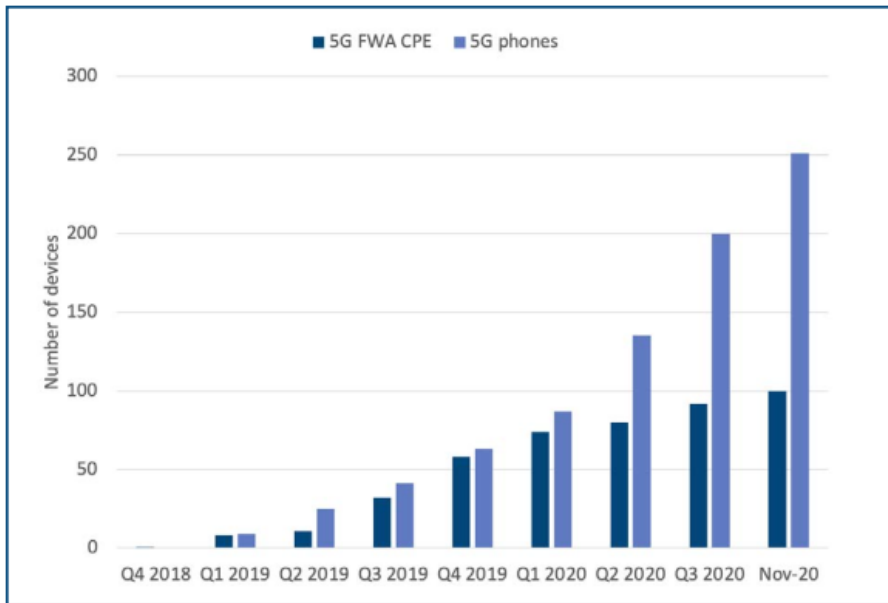
Since then however, the ecosystem has continued its expansion alongside that of the smartphone devices. An illustration of this is the announcement in October 2019 by Qualcomm that over 34 OEMs had planned to use its X55 5G modem alongside a specifically designed for FWA antenna solution.

**Figure 13:** OEMs planning to launch Qualcomm based x55 5G FWA CPEs



Source: Qualcomm

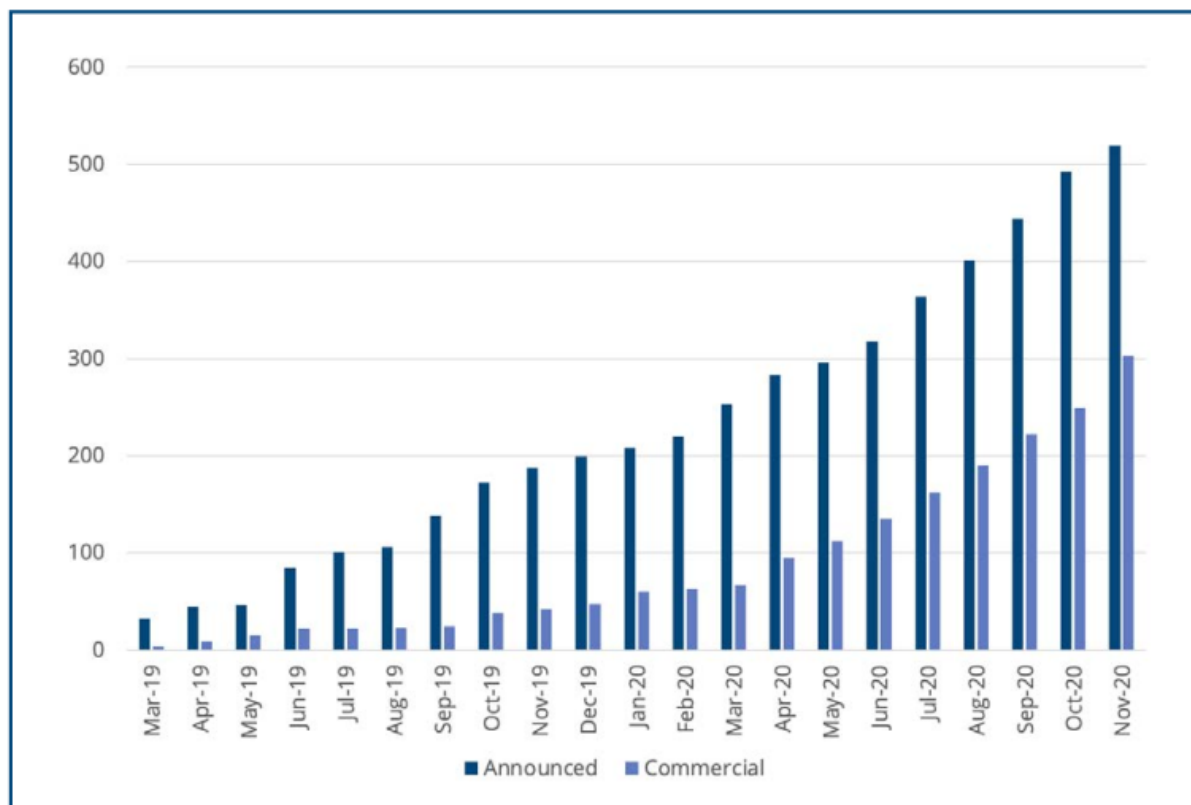
As an indication of the traction of 5G FWA CPE devices on the market, the evolution of the number of 5G FWA CPE devices is available below. Between Q3 2019 and Q4 2019, the number of such devices listed more than doubled and it took nearly one more year after that, between December 2019 and November 2020 for this number to double again. As of end of November 2020, 126 5G CPEs were listed. According to Gsacom, as of the end of September 2020, 37 operators had launched 5G FWA services in the world versus 33 in May 2020.

**Figure 14: Growth of the number of 5G FWA CPE devices announced (as compared to 5G phones)**

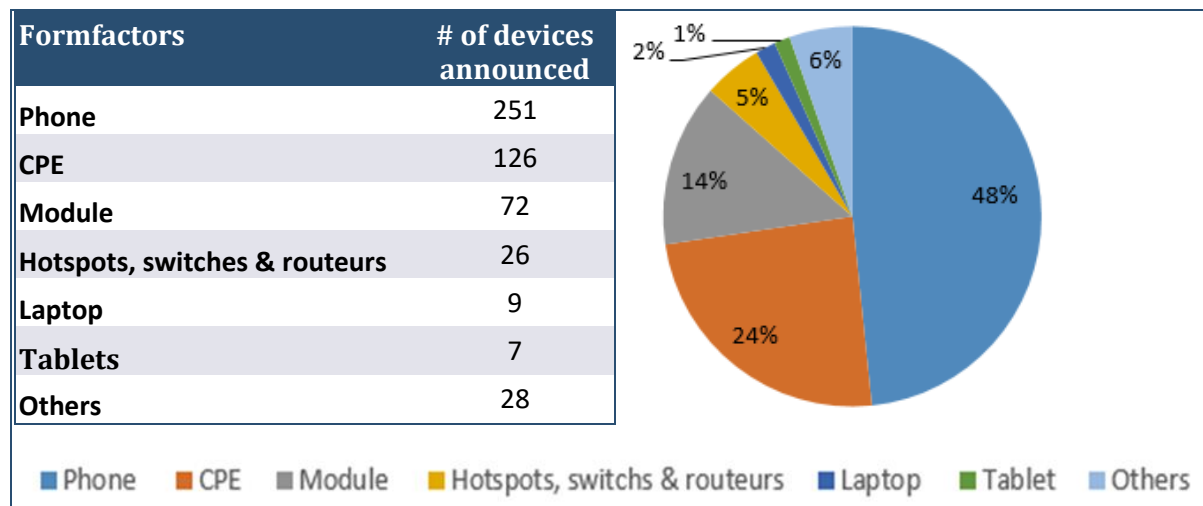
Source: Gsacom

### **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 end of November 2020, indeed, Gsacom reported 519 5G devices announced by 104 different vendors and 20 different categories of form factors, some of which are fairly similar. As a comparison, in December 2019, Gsacom reported around 15,000 different LTE devices. Of those 519 5G devices, at least, 303 are commercially available, which is a tripling as compared to May 2020 and a 36% increase as compared to September. It certainly indicates a momentum in the building of the ecosystem.

**Figure 15: Growth of announced 5G devices (not all commercially available) as of end of November 2020**

Source: Gsacom

**Table 10: Simplified distribution of the 5G device ecosystem as of end of November 2020**

Source: Gsacom, as of end of November 2020

The fact that smartphones are the 1<sup>st</sup> 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. Between December 2019 and the end of November the number of 5G smartphones has nearly quadrupled.

In detail most of the devices launched in 2020 have been based on second generation 5G baseband and it is only one year after its announcement that 3<sup>rd</sup> generation 5G modem will find its place in commercial devices.

While initial 5G devices often had either sub 6 GHz, either mmWave RF system, 2020 has seen first mmWave+sub6 GHz devices. The reason for not including support for both frequencies was 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. One important aspect though is that 5G devices that have been released in 2020 now support sub 6 GHz FDD and not just TDD. While TDD mode is important for mid and high frequency bands, FDD is key for lower frequency bands (those frequency bands used for 2G, 3G and 5G). While those band sport more limited throughput, they are key for 5G roaming, as operator will be vying for expanded coverage and SA deployments.

In 2020, as lower-tier 5G solutions have been released on the market thanks to a wider 5G baseband/SoC portfolio, the premium price for 5G device has continued to decrease. This decrease of price initially come principally from 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. Likewise, the newly released Snapdragon 480, while supporting both sub 6 GHz and mmWave only support bandwidth up to 200 MHz, in the end “only” providing up to 2.5 Gbps downlink throughput in 5G (vs 660 Mbps in LTE). 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 newly released iPhone 12, mini, 12 pro and 12 pro max is a good illustration of that. Indeed, in countries where 5G has not been launched, the same version of the device will be sold but with 5G deactivated.

### **The 3.5 GHz frequency band, not mmWave is the most popular frequency bands for 5G**

Despite much noise around mmWave bands 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. As of end of November 2020, 57% of



devices announced or in development supported this frequency band vs 30% for all mmWave bands. Given the wide availability of this frequency band worldwide, this is not a big surprise. While not providing as much bandwidth as mmWave bands (largest possible bandwidth configuration is 100 MHz) it is providing a much larger coverage. As compared to lower frequency bands, it still sports 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 (DSS), 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 MHz or 700 (APT) MHz) especially as operators in the US (AT&T and Verizon but also T-Mobile without DSS) have started to deploy in those low bands in 2020. During the last three quarters, the number of devices supporting those frequency bands has grown substantially indicating a clear interest from operators in those frequencies as they prepare to leverage their existing asset in complement to mid frequency band. In 2021, the support for sub 6 GHz carrier aggregation should further drive the support for those bands including in Europe

Not surprisingly again, much of the mmWave device ecosystem is driven by the need to support US 5G networks but this has started to change in 2020 as other mmWave deployments have taken place during the second half of this year in countries such as Korea and Japan. While no devices had been announced for n258 (26 GHz) band in December 2019, (the mmWave frequency of choice in Europe (and China) for latter deployments), this band has humbly jumped from 0 to 3 devices in March 2020 to 5 at the end of May 2020, and now 8 by the end of November which for now still remains anecdotal. In 2021, the ecosystem for mmWave devices should continue to build up as more countries, including in Europe will start to deploy some mmWave networks. In the last two months, the growth dynamic for mmWave devices has come from the n261 bands used by Verizon Wireless.

**Table 11: Distribution of announced 5G devices by range of frequency band\***

Frequency band range	Number of 5G devices announced (November 2020)	Average progress in the category Nov 20 / Sept 20
<b>39 GHz (mainly US)</b>	37	37,0%
<b>28 GHz (mainly US)</b>	119	153,5%
<i>n257 (JP, SK and US)</i>	20	33,3%
<i>n258 (Australia, China, Europe)</i>	8	60,0%
<i>n261 (Verizon)</i>	91	237,6%
<b>between 3.5 and 5 GHz (Global)</b>	724	32,2%
<b>between 1.8 and 2.6 GHz (Global)</b>	1 080	43,7%
<b>&lt; 1.8 GHz (Global)</b>	518	61,6%

Source: gsacom, halberdbastion and IDATE \* Note that one same device might be listed several times in different category when supporting several bands at the same time

### 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...

Industry efforts have now resulted in early (and accelerated) standardization of the technologies and as more than 120 operators have commercially (as of mid-November 2020) launched a 5G network throughout the world, most equipment vendors have completed their 5G portfolio to meet the various needs of the market. 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).

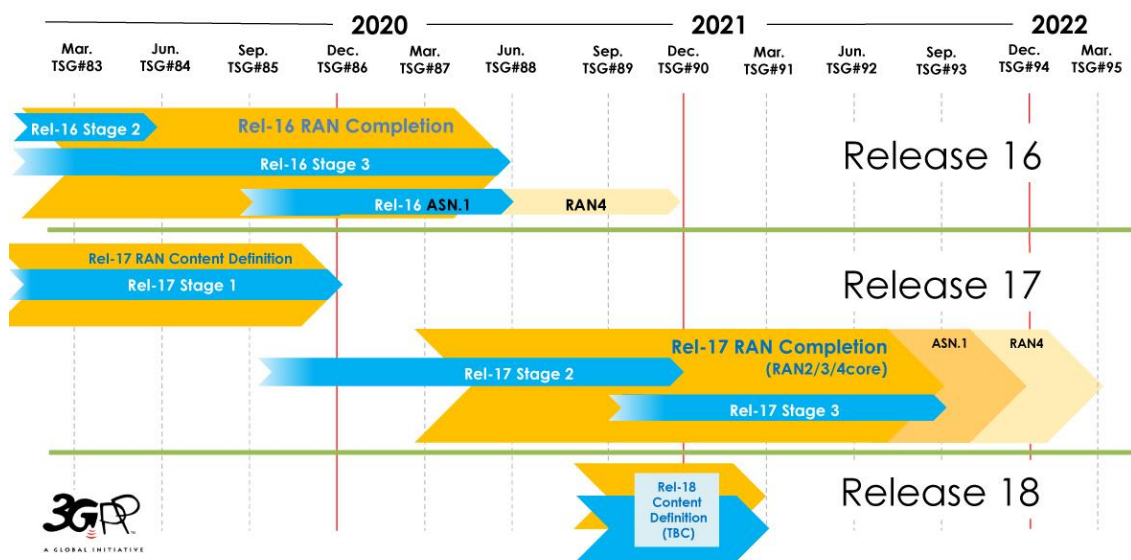
As Release 15 is now fully supported by equipment vendors and as first 5G Standalone Network with a native 5G core have been launched by the end of 2020, Release 16 is about to be finalized. Initially supposed to be frozen in March 2020, the next Release of 5G has seen its frozen date postponed to June 2020 due to COVID-19 epidemic. It should now be completely finalized by the end of this year and first compatible equipment should be launched shortly after.

Release 16 is considered as the phase 2 of 5G and is aimed at complementing the previous release after the initial calendar was quicken to enable early 5G deployments. Release 16 brings the following capabilities:

- NR-U: it will now be possible to deploy 5G NR in unlicensed spectrum, not only with an anchor in licensed spectrum but also as standalone. This is notably aimed at serving the development of 5G private networks. NR-U will also make it possible to have an anchor in unlicensed spectrum.
- URLLC: While Release 15 focused on eMBB use case, Release 16 will support ultra-reliable low latency communication for critical applications. It is notably aimed at serving the needs of the Industrial IoT.
- Improvement to CV2X communication with support of communication directly between the vehicles under and out of coverage thanks to PC5 interface.
- Integrated Access Backhaul: to support the densification of the network when fiber is not easily available, it will be possible to use a NR wireless link from central locations to distributed cell sites and between cell sites.
- Other enhancement to existing features: Massive MIMO, Dynamic Spectrum Sharing but importantly as well for devices energy saving features (Wake Up Signal, adaptive MIMO Layer reduction, low power carrier aggregation control ...)

The figure below present the update roadmap for 5G standard development:

Figure 16: 5G standard development roadmap



Source: 3GPP TSG SA#87e, 17-20 March 2020, e-meeting document SP-200222

© 3GPP 2020

Source: 3GPP

### Presentation of the 5G portfolio of the main equipment manufacturers

Below, we present the 5G portfolio of each equipment manufacturer. Their claim is mostly similar and as for device baseband, those claims can be seen through different angles. Table 12 below summarizes what stands out from each vendor solution:

Table 12: Infrastructure equipment 5G solutions from major vendors

Equipment vendor	Most notable for	Device manufacturer
Huawei	3 <sup>rd</sup> Gen Massive MIMO solution with support for up to 400 MHz bandwidth (for network sharing). Boast for having a unique lightweight integrated passive and active antenna system to facilitate deployment	Yes

Equipment vendor	Most notable for	Device manufacturer
<b>Ericsson</b>	With a complete portfolio, Ericsson advocate for a new way of building network with precision to deploy the appropriate capability at the right place. Recently, Ericsson has been very vocal about its Ericsson Spectrum Sharing (DSS) solution, a field where Ericsson is leading	No
<b>Nokia</b>	An Active Member of the ORAN Alliance, Nokia has been partnering with several new equipment vendors, as operators are pushing for a disaggregation of the RAN. After initial difficulties with its 1 <sup>st</sup> generation of homegrown baseband chipset, Nokia is developing its portfolio of Reefshark base station with multiple partnership with silicon vendors	No
<b>ZTE</b>	Claims to have the lightest Massive MIMO solution at 22 kg for easier site deployment and support for 400 MHz bandwidth to support network sharing. It uniquely provide solution to dynamically deploy 3 RAN technologies in the same band (vs 2 for its competitors)	Yes
<b>Samsung</b>	With a strong experience in TDD, Samsung Networks boast the Massive MIMO capabilities of its Radio solution both in C-band and mmWave	Yes
<b>NEC</b>	Veteran supplier of telecoms infrastructures in the optical and backhaul segments, it is now positioned in 5G wireless through the development of vRAN solutions for the domestic market initially. Recently it made the headline through its development of Open RAN 5G Radio Equipment for Rakuten fully virtualized 5G network	No

Source: IDATE DigiWorld

### Open RAN and the expected rise of new network vendors

As the native 5G core network will be fully virtualized, the virtualization of the Radio Access Network (RAN) and the development of new RAN architecture is paving the way for the implementation of open and interoperable solutions on the network.

Initially pushed by MNOs to end their dependency on one or two single equipment provider it has been seen as an opportunity for new players to enter the RAN market with software solution while traditional equipment vendors excepting Huawei have been forced to more or less timidly supporting the movement to continue working with some Tier 1 mobile operators.

**Figure 17: Mapping of new equipment vendor**



Source: IDATE DigiWorld

In support of the development of a standardized interface between the different equipment that make up the RAN, alliances have been formed such as the TIP (notably) or the ORAN Alliance. More recently and in a more political approach, the Open RAN Policy Coalition has been formed in the US. Indeed, in the country, with no more mobile infrastructure equipment vendor on the market, the move is seen as way to rebuild a presence for infrastructures also considered as strategic for the independence of the country.

While still relatively limited in its breadth this move should be seen as a solid trend for the years to come. While “legacy” equipment vendors have initially developed a virtualized RAN solution, those solutions remained proprietary and did not provide the openness that operators had been calling for.

Recently, certain move by both greenfield operators and legacy operators have shown that the ecosystem was moving in the right direction. If the launch of Rakuten fully virtualized 4G network in Japan is being observed carefully, massive testing by major telcos such as DoCoMo in Japan, Etisalat in UAE and Telefónica are also an indication that Open RAN is there to stay.

At this point of development, Open RAN solution still lack maturity as compared to more integrated and proprietary solution as it require new (IT) competencies that few operators have yet. One issue with Open RAN today lies in the fact that, as operators are deploying a new Radio Access Technology, they also need to have an end to end control of what is happening in the network (especially as network slicing is seen as a way for operators to transform their business model). The more vendors solutions are deployed in the network, the more difficult it is to identify where error come from when they arise.

In the years to come thus, new equipment vendors are going to continue to progress on the market but biggest “legacy” vendors are not yet threaten, even though they need to rethink their positioning.

**Table 13: Presentation of main new equipment vendors**

Equipment suppliers	Background	RAN products
<b>Accelleran (Belgium)</b>	Company created in 2012, having acquired several companies specialised in radio equipment (Phazr, Teko and CSS Antenna), particularly active in Italy and the private networks market.	Open RAN-compatible vRAN hardware and software solutions
<b>Airspan (USA)</b>	Founded in 2005 and specialised in software solutions for networks operators. Pioneer in virtualised solutions for network operators (IMS, EPC). Acquired Brocade's vEPC business in 2017. Selected by Telefónica and Vodafone from among other Open RAN suppliers.	All open standards DU, RRH and vRAN hardware and software solutions, for outdoor and indoor small cells
<b>AltioStar (USA)</b>	Company created in 2011. An Open RAN pioneer. Investors include: Telefónica, Rakuten, Qualcomm, Cisco, Tech Mahindra. Among the main Open RAN contributors and selected by Telefónica and Vodafone from among other Open RAN suppliers.	vRAN (virtualised distribution units and central offices) and MEC solutions
<b>JMA Wireless (USA)</b>	Company created in 2012, having acquired several companies specialised in radio equipment (Phazr, Teko and CSS Antenna), particularly active in Italy and the private networks market.	xRAN software solutions for mobile networks and CBRS
<b>Mavenir (USA)</b>	Founded in 2005 and specialised in software solutions for networks operators. Pioneer in virtualised solutions for network operators (IMS, EPC). Acquired Brocade's vEPC business in 2017. Selected by Telefónica and Vodafone from among other Open RAN suppliers.	End-to-end 5G network software solution (core and open vRAN)
<b>Parallel Wireless (USA)</b>	Company created in 2012, supplier of small cells positioned as the Open RAN leader; TIP member. Targets Tier 2 and 3 carriers in the US that are part of the Competitive Carriers Association (CCA) and employ virtualisation to reduce infrastructures costs. Also Tier 1 carriers in the US for Increasing network density in large cities. In Africa: supplying connectivity to unconnected regions.	End-to-end open vRAN solutions (unified 2G/3G/4G/5G mobile architecture)

Equipment suppliers	Background	RAN products
<b>Radisys (USA)</b>	Company created in 1987, taking over by Indian carrier, Reliance Jio in 2018. Supplier of innovative hardware and software building blocks, notably for virtualisation and edge computing Involved in open source projects such as TIP, M-CORD and xRAN (main contributor to O-RAN). Also positioned as an integrator.	C-RAN software solution
<b>Cisco (USA)</b>	World's leading supplier of core network equipment (routers and switches), the company has positioned itself in virtualisation solutions for operators, and now targeting RAN solutions as well Founding member of the Open vRAN initiative	Open vRAN solution: a multi-vendor, modular and open RAN architecture
<b>Commscope (USA)</b>	Network infrastructure supplier, notably optical fibre Diversification of its solutions via acquisitions, including Airvana (mobile access networks) in 2015 Active member of the Open RAN alliance Main clients: carriers' carrier for companies and public property	C-RAN solution for small cells designed for private network deployments

Source: IDATE DigiWorld

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

In 2020 and beyond, after early deployments, 5G has expanded its coverage thanks to lower frequency bands. This would not have been 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 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 is part of 3GPP Release 15 and while its support has been announced first by Qualcomm with its x55 5G chipset at MWC 2019, it is supported by all the 5G baseband players as well as most equipment vendors which have announced support for this feature. Ericsson is today considered as a leader but Samsung, Nokia, ZTE have all released their solution. Quite uniquely, ZTE supports the deployment of a third radio access technology such as 2G or 3G together with 4G and 5G.

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 quite limited and as such offer very limited performance.

It is to be noted that while the solution seem interesting on the paper, as every new technology, it also needs some maturation. Indeed, it has been reported that some DSS solution could incur a reduced spectrum efficiency on the 4G part of the spectrum. As a result from this initial situation, some operators could initially decide to allocate fixed portion of their spectrum to 4G and 5G instead of dynamically managing the allocation of resource depending on the network load.

Quite importantly as well, the support for low frequency bands in 5G will be critical for the launch of Standalone 5G, where the native 5G Core network will be able to handle the control and signaling plane, thus paving the way for more advanced/transformational 5G capabilities such as network slicing.



**Figure 18: Outlook for 5G features deployments worldwide**

Source: Qualcomm

### The increasing importance of semiconductor in building a differentiated portfolio

With the ever complexification of radio technologies, and in a very competitive environment, the chipset within the infrastructure is increasingly becoming a matter of differentiation. But as most of the main equipment manufacturers are today claiming to somehow design their own chipset, making bad choice can decisively impact competitiveness as recently experienced by Nokia.

Nokia indeed introduced its 1<sup>st</sup> generation of ReefShark chipset in January 2018 touting its capability to enable the reduction of massive MIMO antennas by a factor of two while reducing the power consumption of baseband unit by 64%, a key benefit as both size, weight and power consumption have a direct impact on operator OpEx. However, in order to achieve this prowess, Nokia made a chip design choice that put the Finnish vendor in a difficult position. Indeed, by making the decision to use FPGA, a programmable chipset, rather than a dedicated ASIC, Nokia actually quite negatively impacted its product margin. FPGAs indeed, provide flexibility by enabling to reconfigure the chip after it has been designed, something that Nokia believed to be an advantage. But that turned out to be a serious disadvantage as FPGAs are more expensive than ASICs and the time to market that this design choice was supposed to bring disappeared as one of its supplier experienced difficulties in the manufacturing of the chipset with its 10 nm foundry process. Nokia finally departed from this design choice by finally designing a more competitive SoC through partnership with silicon specialist such as Broadcom, Intel and Marvell for its range of product. This turn of event however quite negatively impacted Nokia's competitiveness. As of March 2020, Nokia indicated that 17% of its 5G products were powered by Reefshark with the objective of reaching 35% by the end of 2020, 70% by the end of 2021 and 100% by the end of 2022. At the end of Q3 2020, Nokia reported that 37% of its 5G shipments were powered by ReefShark

Because of the limited margin in the industry and the pressure on price that Chinese vendor Huawei has been able to impose, every point of margin is key, either to reinvest in Research and Development, either to more aggressively compete on prices.

Meanwhile, Huawei launched its 1<sup>st</sup> generation of own 5G base station processor called Tiangang in 2019, while Samsung launched its 2<sup>nd</sup> generation of base station chipset the same year. While other vendor Ericsson and ZTE are also said to design their own processors, they also ended up partnering with silicon specialist Broadcom and Intel.

### 5G infrastructure contracts announcements

In the race to 5G contracts for equipment manufacturers, it is sometimes difficult to say who is really winning so far because of not all the figures being released and made public, not at the same time and sometimes as well with no precision on the scale of the contracts. To make it worse, the situation seem to change quite rapidly as exemplified by Nokia figures. As of December 2020, Nokia had secured 187 5G commercial engagements, 138 commercial 5G deals and 44 live 5G networks contracts. Roughly one year ago, we stated that Nokia was considered to be trailing behind in terms of contracts, Nokia however stating that they were leading in terms of the comprehensiveness of the 5G solution sold to operators: “More than half of the deals that we have signed actually include more than just radio”. It is to be noted here that those deals likely include enterprise customers, 5G Private networks being known has having been a particular focus for Nokia.

As of end of December 2020, Ericsson states that it currently has 122 5G commercial agreements or contracts with unique operators out of which 71 have been publicly announced and out of which 77 are live 5G networks. As for Huawei, it claimed 91 5G contract globally but this was in February 2020. Huawei since then has given no update to those figures. In Europe, Huawei claims to have more than 46 commercial 5G contracts signed and to have shipped 120,000 5G base stations.

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. Looking at overall market share of telecom equipment revenues, it is still considered globally that Huawei is leading, with, according to Dell’Oro a 30% market share during the first 9 months of 2020, as compared to 15% for Nokia and 14% for Ericsson. Despite difficulties in Europe, the market dynamic in China is helping Huawei to strengthen its position. Together with ZTE, it is estimated that Chinese equipment manufacturers hold 41% of the market in revenues.

**Table 14: Network contracts announcement by infrastructure vendors – Based on figures known as of December 2020**

Vendor	5G contracts
<b>Ericsson</b>	<p>More than 122 5G contracts with mobile operators.</p> <p>In September 2020, Proximus (Belgium) selected Ericsson for its core network. At the end of October 2020, BT selected Ericsson 5G radio equipment for a selection of major UK cities. In November it confirmed a win Czech republic with CETIN and in January 2021, it announced a comprehensive 5G contract with Ooredoo across 10 markets</p> <p>Main customers in: USA (AT&amp;T, T-Mobile US, US Cellular, Verizon), Canada (Bell Canada, Telus, Rogers), Europe (Swisscom, TDC, Telenor, Vodafone UK, Wind, Deutsche Telekom, O2 UK, Orange France, Vodafone UK), Middle East (Etisalat, Optus, Ooredoo, STC), South Korea (KT, SK Telecom) China (China Mobile, China Unicom, China Telecom) and Australia (Telstra)</p>
<b>Huawei</b>	91 5G contracts with mobile operators. (February 2020)



Vendor	5G contracts
	China is the first market for Huawei. Huawei also provides 5G networks in South Korea, The Philippines, Thailand and other Southeast Asian countries, in Europe and Africa.
<b>Nokia</b>	<p>187 5G contracts with mobile operators</p> <p>In September 2020, Orange and Proximus in Belgium announced contracts with Nokia replacing Huawei. Nokia announced the same “swap” for BT in the UK. In December 2020, Nokia announced a win at Proximus Luxembourg in a replacement of Huawei equipments</p> <p>Main customers in: USA (AT&amp;T, T-Mobile US, US Cellular, Verizon), Canada (Bell Canada), Japan (SoftBank), Europe (Swisscom, TDC, Telenor, Vodafone UK, O2 Germany, O2 UK, Wind, Etisalat, Optus, Orange France, Telia Company, Vodafone Italy), Middle East (Ooredoo, STC), South Korea (KT, SK Telecom), Australia (Telus and Telstra).</p>
<b>Samsung</b>	<p>Contracts in the USA (AT&amp;T, U.S. Cellular, Verizon Wireless), Canada, Japan, and in South Korea (KT, SK Telecom and LG U+)</p> <p>In September 2020, Samsung signed a major network deal with Verizon, worth \$6.65 billion</p>
<b>ZTE</b>	55 5G commercial contracts around the world in September 2020. China is the first market for ZTE.

Source: IDATE DigiWorld

## 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 completed in August 2020
- 5G Strategy for Austria, April 2018.
- All MNOs launched 5G services.

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 28<sup>th</sup>, 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. In December 2019, the RTR published terms and conditions for the 2<sup>nd</sup> 5G spectrum auction scheduled for April 2020: it decided to lower the minimum bid by 55 million EUR to 239.3 million EUR, it also increased the duration of the licences from 20 to around 25 years. The auction was postponed due to Covid-19 in the second half of August 2020 instead of April 2020. The auction finally took place in August 2020. It raised 202 million EUR. T-Mobile paid 86.7 million EUR for 2x20 MHz of spectrum in 700 MHz frequencies, 20 MHz of spectrum in 1500 MHz frequencies and 2x15 MHz of spectrum in 2100 MHz frequencies. The incumbent A1 got 30 MHz of 1500 MHz spectrum and 2x25 MHz of 2100 MHz spectrum for 65.6 million EUR. Hutchison Drei won 2x10 MHz of 700 MHz spectrum, 30 MHz of 1500 MHz spectrum and 2x20 MHz of 2100 MHz spectrum at 49.6 million EUR. A1 did not win 700 MHz spectrum. Players benefitted from price reductions as they agreed to cover underserved areas.

In April 2020, the draft regulation on security measures for 5G networks was debated. The draft ordinance proposed in Austria establishes (a) a common set of rules applicable to all telecommunications networks; and (b) particular obligations for operators to protect the security of 5G networks (for networks with more than 100,000 users). The rules established for operators include:

- the obligation to notify a security incident that has a significant impact on the security of the communications network;
- the obligation to design and implement a security policy that ensures an adequate level of security in relation to existing risks;
- a set of obligations for 5G network operators with more than 100,000 users, such as:
  - to regularly submit an audit report;
  - to submit a declaration of conformity attesting to the observance of international standards such as 3GPP, expressly mentioned in the annex of this order;
  - to ensure the operation of the network operations center and the security operations center in the European Union;
  - to effectively monitor all critical components and sensitive parts of 5G networks through the network operations center and the security operations center;
  - to prevent unauthorized change of networks or components;
  - to ensure the physical protection of the critical and sensitive components of 5G networks;
  - restrict access to competent and qualified personnel, previously subject to security checks;

- use of appropriate tools to ensure software integrity when operating software updates;
- to establish a strategy to ensure the provision of infrastructure by several providers, including by taking into account technical constraints and interoperability requirements in different parts of other 5G networks.

In May 2020, Vienna announced it plans to increase 5G coverage by subsidizing new sites deployment locally between July 2020 and June 2022. The city expects to spend 20 MEUR.

### 3.1.2. Belgium

#### Main points

- Draft strategic plan 2020-2022 late in 2019 opened to public consultation including on information about the planned multi-band spectrum auction.
- BIPT granted temporary 5G 3.6-3.8 GHz licences to five players (Entropia Investments, Telenet, Proximus, Orange Belgium) in April 2020. Licences are valid until a traditional auction procedure takes place. Entropia Investments failed to pay for the permit and lost it in October 2020.
- Launch of 5G services by Proximus on April 1<sup>st</sup>, 2020
- 700 MHz and 3.5 GHz auction not expected before year-end 2021

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.

Due to the delay in assigning 5G spectrum, BIPT decided to award temporary licensees. In March 2020, Telenet, Orange and Proximus confirmed they applied before the 28 February 2020 deadline. In April

2020, the BIPT granted temporary 5G 3.6-3.8 GHz licences to Proximus, Cegeka, Entropia Investments, Telenet and Orange Belgium. Licensing was followed by the launch of 5G services by Proximus as from April 1<sup>st</sup>. Orange Belgium started testing 5G. Entropia Investments failed to pay for the permit and lost it. BIPT started to redistribute spectrum to other temporary licensees while Cegeka did not ask for additional spectrum. As a result, Orange Belgium, Telenet and Proximus which got 40 MHz each in April 2020, received 50 MHz while Cegeka will keep 40 MHz.

The auction is not expected before year-end 2021.

### 3.1.3. Bulgaria

#### Main points

- 5G border corridor Bulgaria, Greece, Serbia.
- 700 MHz and 3600 MHz 5G auction expected in 2021
- 5G launch by A1 on November 20, 2020

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.

In November 2019, CRC announced it planned to assign frequencies for 5G by mid-2020. The assignment was further delayed to 2021.

### 3.1.4. Croatia

#### Main points

- 700 MHz, 3.6 GHz and 26 GHz 5G auction planned for H1 2021
- 5G launch by Hrvatski Telekom on October 30, 2020 thanks to Dynamic Spectrum Sharing

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 ca. 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 call for spectrum allocation in 2.5-2.69 GHz for the period of May 2019 until October 2024. The frequencies could be used for 5G.

70 MHz of the 3400-3600 MHz band is not available in north Croatia, in two counties. After November 4, 2023 the entire 3400-3600 MHz band will be available countrywide. The entire 3600-3800 MHz band will be available countrywide after July 31, 2020 while one continuous block of 100 MHz of this band has already been available from September 1, 2019.

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

On October 18, 2019 HAKOM issued a public consultation on future assignment of 700 MHz, 1500 MHz, 3.6 GHz and 26 GHz bands. Public consultation was open until January 20, 2020 to enable all interested stakeholders to express their views and interests. As a result of the gathered information, HAKOM published a document stating the intention to conduct a public auction for the 700 MHz, 3.6 GHz and 26 GHz frequency bands. The auction was planned for H2 2020, but these plans are currently under revision due to COVID-19 epidemic.

700 MHz band in Croatia is still used for digital terrestrial television in DVB-T/MPEG-2 system. Termination of DVB-T broadcasting in this band to enable its use for wireless broadband was planned for mid-2020, together with transition to DVB-T2/HEVC system on frequencies below 694 MHz. In March 2020 HAKOM postponed transition to DVB-T2/HEVC system and releasing of the 700 MHz band for at least 6 months due to consequences of force majeure caused by COVID-19 pandemic and earthquake in densely populated area of capital Zagreb, on March 22, 2020. Release of the 700 MHz band is also largely conditioned by cross-border coordination (interference situation in 470-694 MHz) and demanding transition procedure as DTT is a dominant TV platform with 48% household's share.

In January 2020, the Government of the Republic of Croatia has adopted a resolution on Osijek as the Croatian 5G City and Slavonia as the first Croatian region to operate 5G networks commercially. Commercial work on 5G technology in Osijek is expected by the end of the 2020. 5G is a prerequisite for utilization the potential of digital transformation as a key factor for economic growth. For the successful introduction of technology it is necessary to encourage active co-operation between the relevant state bodies.

In June 2020, HAKOM postponed the multi-band auction (700 MHz, 3.6 GHz and 26 GHz) until the first half 2021 blaming the Covid-19 outbreak.

### 3.1.5. Cyprus

#### Main points

- Updated Cyprus Broadband Plan 2016-2020<sup>11</sup>
- 700/3600 MHz 5G spectrum auction completed on 17 December 2020. Four winners: Cyta, EPIC, Primetel and Cablenet Communications Systems

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 initially scheduled for November 2019 and rescheduled for March 2020. It is now expected by year-end 2020. Licensees will have to provide 40% 5G geographical coverage within 2 years and 85% within 5 years.

In the first months of 2020, concerns about potential adverse health effects of 5G were growing in the country and no licences had been assigned. As of end September 2020, no licences had been assigned.

#### 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). Six 2x5 MHz blocks of 700 MHz spectrum will be available. A spectrum cap has been set at 2x10 MHz. Licences will be offered with coverage obligations of 70% of the population and highways by year-end 2025. Data throughputs will have to be above 100 Mbps. The reservation price for each 2x5 MHz is set at 6 million EUR. Licences will be valid 20 years. The auction took place on 17 December 2020, after several postponements.

The winners are Cyprus Telecommunications Authority (Cyta), Primetel, Epic and Cablenet. The auction raised 41.6 million EUR for spectrum in the two bands (700 MHz and 3.5 GHz).

#### 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.

<sup>11</sup>

[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)

Eight 50 MHz blocks are available. A spectrum cap has been set at 100 MHz. Licences will be offered with coverage obligations of 70% of the population and highways by year-end 2025. Data throughputs will have to be above 100 Mbps. The reservation price for each 50 MHz block is set at 2.5 million EUR. Licences will be valid 20 years. The auction ended on 17 December 2020, after several postponements.

The winners are Cyprus Telecommunications Authority (Cyta), Primetel, Epic and Cablenet. The auction raised 41.6 million EUR for spectrum in the two bands (700 MHz and 3.5 GHz).

## 26 GHz

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

### 3.1.6. Czech Republic

#### Main points

- Implementation and Development of 5G Networks in the Czech Republic – Towards the Digital Economy” approved by the Czech government on January 13, 2020
- National Plan for the Development of Next Generation Networks 2016-2020.
- 3.7 GHz spectrum auctioned off.
- O2 Czech Republic launched 5G in July 2020
- Spectrum auctions in the 700 MHz and 3.5 GHz frequencies completed mid-November 2020 raising 5.6 billion CZK (212.9 million EUR)
- 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>).

## 700 MHz / 3.4-3.6 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 and was further postponed to year-end 2020 early 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.
- Consultation launched in March 2020 on a new framework for the 700 MHz and 3.4-3.6 GHz auction. The framework will include spectrum set aside for verticals and spectrum caps.
- In March 2020, the auction was delayed later in 2020 by CTU. The regulator modified rules for the 5G auction. The auction was further delayed due to complaints against the auction terms.
  - 700 MHz: two blocks of paired 10 MHz of spectrum and two blocks of paired 5 MHz spectrum are available of which 2x10 MHz are reserved for new players. The minimum prices for 700 MHz blocks are set at 700 million CZK (26.8 million EUR), 1.12 billion CZK (42.8 million EUR), and 1.4 billion CZK (53.5 million EUR).
  - In the 3.4-3.6 GHz, 10 blocks of 20 MHz of spectrum are available with spectrum caps for incumbents of 60 MHz and 100 MHz for new players. **It also decided to provide national roaming conditions to new** players in the 700 MHz and the 3.5GHz frequencies; In addition, 40 MHz of spectrum will be reserved for industry verticals (3400-3440 MHz).
  - New players can buy up to 100 MHz.
- The auction ended on November 13, 2020. In the 700 MHz band, O2 Czech Republic won the 2x10 MHz block with obligations to provide national roaming and PPDR services for public emergency and security bodies. The other 700 MHz 2x10 MHz blocks are acquired by T-Mobile Czech Republic and Vodafone Czech Republic. In the 3,400-3,600 MHz band, O2 Czech Republic and CentroNet gained blocks of 20 MHz connected with obligations to lease frequencies to support Industry 4.0. T-Mobile Czech Republic, Vodafone Czech Republic and Nordic Telecom 5G also won spectrum 20 MHz blocks.

All in all, the auction raised 5.6 billion CZK (211.9 million EUR). T-Mobile Czech Republic paid 1.89 billion CZK (71.8 million EUR), Vodafone Czech Republic 1.568 billion CZK (59.6 million EUR) and O2 Czech Republic 1.342 billion CZK (51 million EUR). CentroNet was charged 628 million CZK (23.9 million EUR), and Nordic Telecom 168 million CZK (6.4 million EUR). Poda and Sev.en Innovations participated but did not acquire any spectrum. The auction included conditions to encourage the entry of new players but none of the bidders acquired enough spectrum to be operational. **26 GHz**

In August 2020, CTU launched a public consultation on draft spectrum utilisation plan for the 26 GHz band.

### 3.1.7. Denmark

#### Main points

- 700/900 MHz auction held in March 2019
- 5G launch by TDC in September 2020, by Telenor mid-November 2020
- Multi-band auction (1500 MHz /2100 MHz/2300 MHz/3.5 GHz/26 GHz) expected in March/April 2021

The national 5G Action Plan for Denmark 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

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.

#### **Multi-band auction (1500 MHz/2100 MHz/2300 MHz/3.5 GHz/26 GHz)**

On 1 February 2019 and 25 March 2020, the Minister for Climate, Energy and Utilities decided that an auction should be held of the 1500 MHz, 2100 MHz, 2300 MHz, 3.5 GHz and 26 GHz frequency bands. The auction on the 1500 MHz, 2100 MHz, 2300 MHz, 3.5 GHz and 26 GHz bands is expected to commence in March 2021. The frequencies will be awarded nationwide on a service- and technology-neutral basis.

**In the 3.5 GHz frequencies**, licensees will be subject to coverage obligations, or leasing obligations in the first four years of the licence period for licences in 3740-3800 MHz spectrum or usage requirements. The licensee shall install antennas as well transmitting and receiving equipment capable of using the frequencies specified in the licence not later than 31 December 2023 at a minimum of 100 mast positions. The equipment at the relevant mast positions shall be connected to the necessary telecommunications infrastructure in such a way as to enable the licensee, via the relevant mast positions, to offer at least one electronic communications service (at the licensee's own discretion) to end-users by using the frequencies specified in the licence. The coverage obligation does not require a specific technology to be used. Licensees shall ensure:

- not later than 31 December 2023, a population coverage of 60% when using the 3.5 GHz frequency band, ensure
- not later than 31 December 2025, a population coverage of 75% when using the 3.5 GHz frequency band.

**Frequencies in the 26 GHz band** to be awarded in the auction comprises 2850 MHz unpaired frequencies (24.65 – 27.5 GHz). The licences are subject to usage requirements. The licensee shall install antennas as well transmitting and receiving equipment capable of using the frequencies specified in the licence not later than four years from the date of entry into force at a minimum of 100 mast positions. The equipment at the relevant mast positions shall be connected to the necessary telecommunications infrastructure in such a way as to enable the licensee, via the relevant mast positions, to offer at least one electronic communications service (at the licensee's own discretion) to end-users by using the frequencies specified in the licence.

### 3.1.8. Estonia

#### Main points

- 4 licences in 3.6 GHz frequencies postponed in 2021
- 700 MHz and 26 GHz tenders scheduled later in 2021

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 the first months 2020, the IT ministry decided to offer a 4<sup>th</sup> 5G licence. Applications are due by June 18<sup>th</sup>, 2020.

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 run until mid-December 2019.

In June 2020, a fourth licence was added in the forthcoming 5G auction.

### 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. All players launched 5G since then.
- Early award of trial licences to a large number of companies (October 2015-October 2017).
- Auction for the 26 GHz (25.1- 27.5 GHz) spectrum ended on June 8, 2020. The incumbent MNOs each got a 5G licence at 7 MEUR giving them the right to use 800 MHz of spectrum.

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.

In January 2020, Finland launched a consultation on the 26 GHz auction scheduled in the summer 2020. It will include spectrum from 25.1 to 27.5 GHz excluding the lowest 850 MHz part of the 26 GHz band that will be reserved for local and/or regional vertical players and research & development or educational usage. The auction took place on June 8<sup>th</sup>, 2020, and the current MNOs - Elisa, Telia and DNA - were each assigned 800 MHz of spectrum at the starting price of 7 million EUR. Licences are national for mainland Finland. Elisa won the 25.1-25.9 GHz frequencies, Telia the 25.9-26.7 GHz and DNA got the 26.7-27.5 GHz frequencies. The frequency band can be used for 5G networks as of 1 July 2020 and the licence is valid in mainland Finland until 31 December 2033. The lowest 850 MHz part of the pioneer band (24.25-25.1 GHz) will be reserved for local and/or regional vertical players and research & development or educational usage.

### 3.1.10. France

#### Main points

- 700 MHz frequencies assigned in December 2015.
- Consultation on 5G, 2016.
- Trial licences and trial cities, 2017-2020
- 5G pilot window, Jan. 2018.
- Provision of mid-band spectrum for trials in selected cities.
- 5G roadmap, July 2018.
- 3.5 GHz auction completed on October 1<sup>st</sup>, 2020. Results of the positioning auction published on October 20<sup>th</sup>, 2020.
- 5G launch by SFR in November 2020, by Bouygues Telecom and Orange France in December 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 in 3.5 and 26 GHz frequencies. 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-

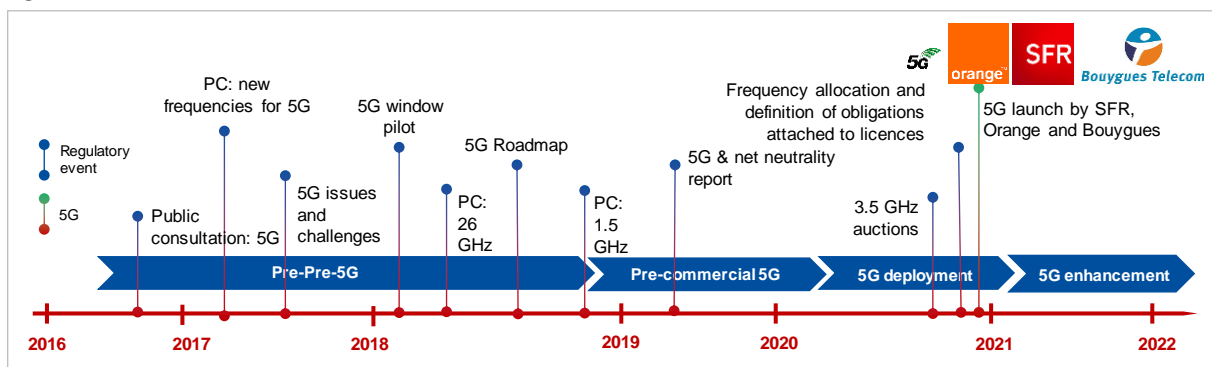
Monthléry (Bouygues Telecom, Orange), Bordeaux Mérignac (Bouygues Telecom ended, Bouygues Telecom), Nantes (SFR ended), Lyon (SFR ended, Bouygues Telecom), Pau (Orange ended), Toulouse (SFR-Airbus ended), Grenoble (CEA-Leti), Saint Denis (Orange), Cesson-Sévigné (b<>com ended), Lannion (b<>comn ended), Nozay (Nokia ended), Cesson-Sévigné, Saint Maurice de Rémens (Bouygues Telecom), Toulouse-Francal (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 3.4 GHz - 3.8 GHz band. The regulator is planning to release 31 TDD blocks (10MHz each) in the 3490 MHz – 3800 MHz 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 100 MHz. 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.
- The four bidders for 5G spectrum in mainland France have been revealed late in February 2020: Bouygues Telecom, Free Mobile, Orange and Altice requested the allocation of one of the four 50 MHz blocks awarded in exchange for optional commitments.
- In April 2020, the 3.5 GHz auction was postponed from April 2020 due to covid-19. In June 2020, Arcep announced the auction will take place at the end of September (Sept. 20 to 30). The auction for eleven 10 MHz blocks started on September 29, 2020. The first round (bidding) was completed on October 1<sup>st</sup>, 2020. The four MNOs paid a total of 2.786 billion EUR for 310 MHz of spectrum, in addition to the previous 50 MHz block awarded earlier in 2020 to each player at 350 million EUR

per block. Orange won 90 MHz of spectrum, SFR obtained 80 MHz and both Bouygues and Free got 70 MHz of spectrum. A spectrum cap had been set at 100 MHz of spectrum per MNO. The second round where players bid for “positioning” that spectrum in the band ended on October 20<sup>th</sup>, 2020. Allocations are as follows:

- SFR : 3490-3570 MHz
  - Bouygues Telecom : 3570-3640 MHz
  - Free Mobile : 3640-3710 MHz
  - Orange : 3710-3800 MHz
- In October 2020, Bouygues Telecom filed an appeal against French legislation forcing the MNO to remove non-compliant equipment.
  - In December 2020, Arcep issued a consultation (18 December 2020-26 February 2021) on draft procedures for 700 MHz and 3.4-3.8 GHz frequencies in La Reunion and in 700 and 900 MHz frequencies in Mayotte.

**Figure 19: 5G timeline in France**



Source: IDATE DigiWorld, as of December 2020

### 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 in 3.7-3.8 GHz spectrum. Applications opened on November 21<sup>st</sup>, 2019.
- 26 GHz spectrum expected to be potentially awarded upon application.
- Vodafone and Deutsche Telekom launched 5G in July 2019, Telefonica in October 2020. The new player 1&1 Drillisch has not launched 5G yet.

#### 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 20: 5G strategy in 5 steps**

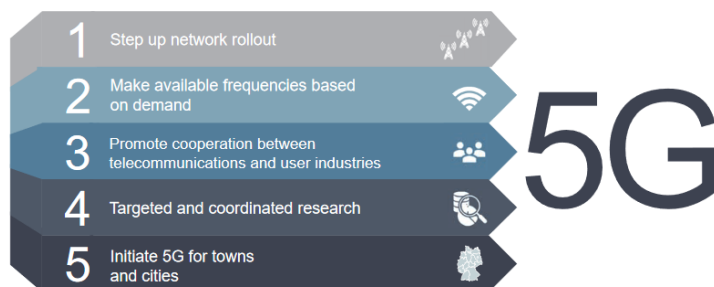


Figure 7 – Five fields of action to develop the 5G lead market in Germany  
Source: Federal Government

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

**Figure 21: Key milestones of 5G strategy for Germany**

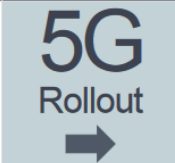

2016	2017	2018	2019	2020
<ul style="list-style-type: none"> <li>First test beds with 5G relevance</li> <li>Working group of the Federal Government and the federal states to implement the DigiNetzG</li> <li>Start of 5G Dialogue Forum</li> </ul>	<ul style="list-style-type: none"> <li>Start of consultations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

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 22: 5G research centers in Germany**

<b>Wolfsburg:</b> Volkswagen AG  <b>Bremen University</b>  <b>Paderborn University</b>  <b>Dortmund University of Technology</b>  <b>Duisburg-Essen University</b>  <b>Düsseldorf:</b> E.ON SE Vodafone GmbH  <b>Aachen:</b> Ericsson (Eurolabs) RWTH Aachen University  <b>Kaiserslautern:</b> German Research Centre for Artificial Intelligence (DFKI) Kaiserslautern University of Technology  <b>Stuttgart:</b> Daimler AG Nokia Bell Labs Robert Bosch GmbH TES Electronic Solutions GmbH		<b>Berlin:</b> 5G Berlin (Fraunhofer FOKUS & HHI) Adva Optical Networking Se BISDN GmbH Core Network Dynamics GmbH Deutsche Bahn Deutsche Telekom (5G-Haus) EICT GmbH Rohde & Schwarz SIT GmbH Berlin University of Technology  <b>Frankfurt (Oder):</b> Leibniz Institute of Innovations for High Performance Microelectronics  <b>Dresden:</b> 5G Lab Germany (TU Dresden and partners) Airrays GmbH  <b>München:</b> BMW DOCOMO Euro-Labs Huawei VIA Innogy Institut für Rundfunktechnik GmbH Intel Mobile Communications GmbH Nokia Nomor Research GmbH Siemens AG Munich University of Technology Telefónica
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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.

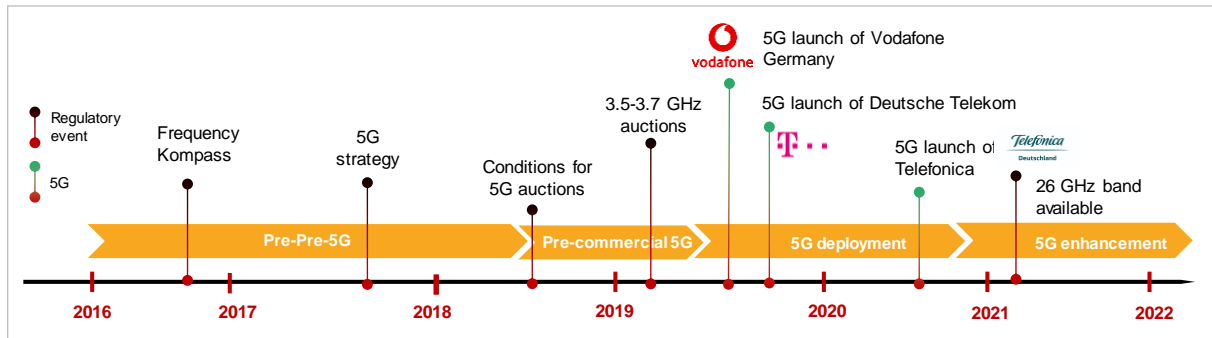
In January 2018, the German NRA released a [draft consultation](#) setting out that scarce spectrum in the 2 and 3.6 GHz bands would be auctioned. [Decisions I and II](#) were published in May 2018.

- In the 2 GHz band, 2x40 MHz will be made available as from 1<sup>st</sup>, January 2021. An additional 2x20 MHz will be available as from 1<sup>st</sup> 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 1<sup>st</sup> January 2022 (earlier stage as from 2019). Other public initiatives award conditions and auctions rules for 5G were released on November 26<sup>th</sup>, 2018.

The 5G spectrum auctions begun spring 2019. The qualification procedure was open from November 26<sup>th</sup>, 2018 until January 25<sup>th</sup>, 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 23: 5G timeline in Germany**

Source: IDATE DigiWorld, December 2020

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 and a 1.1 billion EUR plan to improve mobile coverage was agreed. 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. MNOs agreed to share 6,000 5G sites in rural areas and in transportation routes.

In the plan to counter the economic crisis caused by the covid-19, the German government decided to allocate 7 billion EUR to 5G.

### 3.1.12. Greece

#### Main points

- Trial licences in 3.4-3.8 GHz frequencies issued
- 5G cross-border corridor (Bulgaria, Greece, Serbia).
- Auction of 2×30 MHz in the 700 MHz band, 2×15 MHz in the 2100 MHz band (plus 2×45 MHz in the same band which is already allocated but licences expire in 2021), 280 MHz at 3.6 GHz, and up to 2,500 MHz in the 24 GHz – 28 GHz range completed on December 17, 2020.
- Vodafone expected to launch 5G in the first quarter 2021, following the spectrum auction

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.

#### Multi-band auction incl. 700 MHz, 3.4-3.8 GHz and 26 GHz spectrum

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

In October 2019, the auction for 3.5 GHz spectrum was postponed to the end of 2020. In January 2020, EETT issued another consultation on the multi-band spectrum auction (2x30 MHz in the 700 MHz band, 2x15 MHz in the 2.1 GHz band, 280 MHz at 3.7 GHz and up to 2500 MHz in 26 GHz spectrum depending

on spectrum demand). The consultation which closed on April 30, 2020 was about alternative ways of assigning the band. The government still expects to proceed with the multi-band auction by year-end 2020. Late in September 2020, EETT the Greek regulator kicked off the 5G auction process and invited applications for spectrum until 23 October 2020.

It published tender documents for all pioneer bands in September 2020. Licences in all pioneer bands will be valid for 15+5 years from December 20, 2020 till December 19, 2035 (except specific slots at 3.4-3.8 GHz which will be valid from May 1<sup>st</sup>, 2029). Licences in 700 MHz and 3.4-3.8 GHz include coverage obligations. The starting price for all the frequencies was 367.3 million EUR. The three MNOs submitted bids by the October 30, 2020 deadline. The auction raised 372.3 million EUR. Vodafone paid 130.1 million EUR in total: 37.5 million EUR for 14 blocks in 3400-3800 MHz frequencies, 51.1 million EUR for 2 blocks in 700 MHz frequencies, 6.5 million EUR for 2 blocks in 26 GHz spectrum and 35.1 million EUR for 4 blocks in 2 GHz band. Cosmote spent 123 million EUR: 15 blocks at 3.4GHz to 3.8GHz for 30.7 million EUR, 50.6 million EUR for 2 blocks at 700 MHz, 4 blocks at 2 GHz for 35.27 million EUR and 2 blocks in 26 GHz frequencies for 6.5 million EUR. The third player, Wind Hellas, committed 119 million EUR for 10 blocks at 3.4-3.8 GHz for 30.3 million EUR, 2 blocks in 700 MHz spectrum for 5.1 million EUR and 1 in 26 GHz band for 3.245 million EUR.

- The 3.4-3.8 GHz licence holder has to cover:
  - 20% of the population and deploy its network in at least two districts within 3 years,
  - Install at least 300 5G sites within 5 years
  - Provide at least 100 Mbps speeds with a maximum 10 ms latency
    - Within 3 years in most major continental motorways and on the major road north of Crete
    - Within 6 years in all Greek motorways
- Licensees at 700 MHz have to cover
  - Within 3 years: at least 99% of population at country level and 95% of population in each district, at least 95% of territory and maritime zones, 95% of motorways, 95% of railway networks (Athens-Patras and Athens-Thessaloniki (excluding tunnels)
  - At least provide 100 Mbps DL with a maximum latency of 10 ms and within 3 years to at least 60% of the population, 60% of motorways and rail networks (Athens-Patras and Athens-Thessaloniki (excluding tunnels) and 95% of major motorways (Athens-Thessaloniki-Evzoni, Peloponnese, Olympia-Odos, Ionian main road, Egnatia-Odos, Central Greece main road, Attiki-Odos, Northern Cretan main road
  - At least provide 100 Mbps DL with a maximum latency of 10 ms and within 6 years to at least 90% of the population, 90% of motorways and rail networks
  - At least provide 100 Mbps to 90% of the population living in underserved areas within 5 years

If the licensee is a new player, coverage obligations are less strict: it has to cover at least 80% of the population within 5 years.

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### 3.1.13. Hungary

#### Main points

- “Digital Success Programme 2.0”. Strategic study.
- European 5G hub for 5G.
- 700 MHz/2100 MHz/2600 MHz/3600 MHz auction ended end March 2020. 700 MHz spectrum not valid until 6 September 2020 5G launch by Vodafone in October 2019 with existing 3.5 GHz spectrum

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.

The multi-band auction was held at the end of March 2020 despite covid-19. 50 MHz was sold in the 700 MHz band (expected to be freed up on 6 September 2020), 30 MHz in the 2100 MHz band and 310 MHz in the 3600 MHz frequencies. No bids were submitted for the 2600 MHz spectrum. Magyar Telecom, Vodafone Hungary and Telenor Hungary won 15-year licences (until 2035, licences can be extended for 5 additional years once with the same pricing conditions) in the 700 MHz, 2100 MHz and 3600 MHz bands and acquired usage rights for 128.49 billion HUF (368 million EUR). DIGI did not take part in the auction. Its licence bidding application was rejected earlier in September 2019 by the Hungarian regulator NMHH. The player which protested against its exclusion lost legal action in November 2020.

## 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

### 3.1.14. Ireland

#### Main points

- National Roadmap on the use of 700 MHz frequencies published on March 2019, revised on May 2020
- 3.6 GHz licences auctioned by ComReg in May-June 2017
- On-going preparation of the multi-band auction for 700 MHz, 2100 MHz, 2300 MHz and 2600 MHz spectrum. Final decision expected in Q4 2020. Auction expected early 2021.
- Temporary licenses issued to players from 9 April to 8 July 2020 in 700 and 2100 MHz spectrum. Licences can be extended an additional three-month period.
- 5G launch by Vodafone in August 2019, by Eir in October 2019 and by Three Ireland late in September 2020

In May 2020, ComReg conducted tests at 20 5G antennas and concluded there were no health risks.

### **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.

Due to covid-19, ComReg issued on-demand temporary licenses to MNOs in April 2020. Meteor Mobile, Three Ireland and Vodafone Ireland received temporary licenses valid from April to July 2020 in 700 and 2100 MHz spectrum.

On 13 May 2020, ComReg published a Draft Information Memorandum and Draft Regulations on the multi-band auction. Comments due by 24 June 2020 will be published by the end of June 2020. Final decision is expected in Q4 2020.

The 700 MHz band should be auctioned early 2021.

### **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**

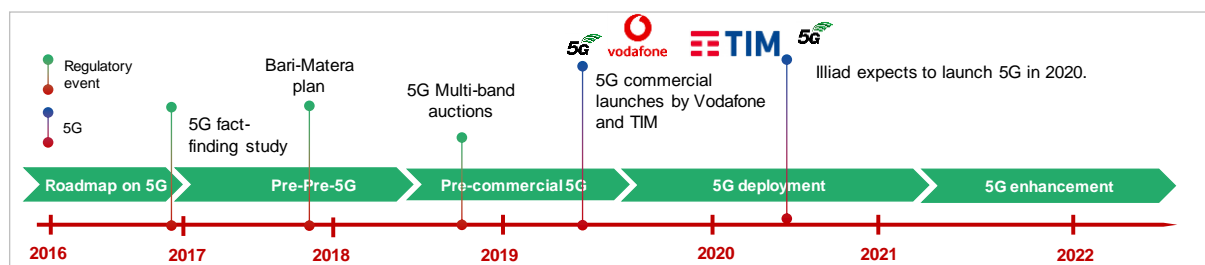
- 5G for Italy, 2016, 5G strategy, pushed by TIM, around identified cities and application areas.
- Trial licences and trial cities, mid-2017.
- 700 MHz/3.5 GHz auctions in October 2018, 26 GHz spectrum auctions, October 2018, first in Europe. Licences valid till year-end 2037.
- Launch of TIM 5G services in June 2019, Vodafone in August 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 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 24: 5G timeline in Italy**

Source: IDATE DigiWorld

### 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
<b>National population coverage</b>
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.
<b>National road and rail transport routes coverage</b>
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.
<b>Tourist locations coverage</b>
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 mid-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.
- TIM Italy and Vodafone have agreed on a passive network sharing deal for 5G including all 22,000 antenna sites controlled by the operators.
- In February 2020, Agcom opened a procedure to evaluate coverage obligations for the 5G network sharing venture involving Wind Tre and Fastweb in the 3.7 GHz concession. Wind Tre must offer coverage of at least 5% of the population of each Italian region within 48 months from the award of the license. The regulator wants to know whether these coverage obligations should be modified based on the infrastructure sharing deal signed by the two operators in June 2019.
- In August 2020, Agcom extended spectrum licences in the 900 and 1800 MHz bands, following a public consultation. The Iliad Italia's licence in the 900 MHz band is thus extended for 8 years from its current expiry date of end-2021, and TIM, Vodafone and Wind Tre's licences in the 2100 MHz frequency band are also extended until the end of 2029.



### 3.1.16. Latvia

#### Main points

- On-going preparation of 700 MHz spectrum assignment for 5G
- On-going preparation of 1500 MHz spectrum assignment for 5G
- 100 MHz of 3.5 GHz spectrum for 5G auctioned in November 2017. Remaining 50 MHz of 3.5 GHz spectrum for 5G auctioned in September 2018
- 5G launch by Tele2 in two sites in January 2020

#### 700 MHz

The Latvian regulator issued a consultation on 700 MHz spectrum assignment for 5G in March 2020. Three lots of 2x10 MHz +1x5 MHz of spectrum (703-713 MHz, 738-743 MHz and 758-768 MHz – 713-723 MHz, 743-748 MHz and 768-778 MHz – 723-733 MHz, 748-758 MHz and 778-788 MHz) are expected to be assigned. The reserve price is set at 1 MEUR for each lot. Licences would be valid for 20 years from the beginning of 2022. The consultation was opened till May 25, 2020.

#### 1500 MHz

At the beginning of 2019, SRPK cancelled Lattelecom'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, 2019. The auction is expected to take place early January 2021.

#### 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 (3400-3450 MHz and 3650-3700 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 1<sup>st</sup>, 2019.

### 3.1.17. Lithuania

#### Main points

- Draft plan for 5G approved in May 2020 including coverage obligations: at least one of the 5 largest cities covered by 2022, all 5 by 2023 and main routes by 2025
- 3.4-3.8 GHz frequencies assignment expected in the first quarter 2021 (temporary trials allowed in the band)
- 700 MHz frequencies assignment expected in 2021
- 26 GHz spectrum will be assigned when there will be enough demand

**700 MHz**

The regulator plans to assign one 2 x 10 MHz lot of FDD spectrum, two 2 x 5 MHz lots of FDD spectrum and three 5 MHz lots of spectrum for supplementary downlink (SDL). A SMRA (Simultaneous Multiple Round Auction) is to be organized, but the bidder will be allowed to bid only for one block of FDD spectrum and one block of SDL spectrum.

The auction is expected in the first quarter 2021.

**3.4-3.8 GHz / 3.8-4.2 GHz**

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 were expected to be awarded by year-end 2020 (depending on talks with Russia on interference issues in border areas). 100 MHz is put aside for PPDR services and communications. The auction is expected in the first quarter 2021. In the meantime, 3.5 GHz band spectrum has been allocated on a temporary and non-commercial basis to Telia Lietuva.

RRT in response to public reactions and the spread of disinformation on 5G, provided clarifications on the technology on its website.

At the end of May 2020, the government of Lithuania approved a draft plan for 5G. Drafted guidelines indicate that at least one 5G network should cover at least one of the national largest cities (Vilnius, Kaunas, Klaipeda, Siauliai or Panevezys) by 2022 and that at least one 5G network should be available in all 5 cities by 2023. Guidelines also introduced coverage obligations of all urban areas and main transport routes and hubs (motorways, rail routes, airports) by 2025.

**26 GHz**

The regulator waits for enough market demand before assigning spectrum.

**3.1.18. Luxembourg****Main points**

- 5G strategy in September 2018
- 700 MHz and 3.4-3.8 GHz auction completed in July 2020
- 26 GHz spectrum assignment postponed to 2021
- 5G launch by Post Luxembourg, Orange and Tango in October 2020

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

**700 MHz/3.4-3.8 GHz**

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 was expected by June 2020. In December 2019, the Prime Minister said that 50 MHz of spectrum will be added to the 280 MHz initially considered in the 3.5 GHz public consultation. ILR started to hold a consultation on the assignment procedure between 13 March and 10 April 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.

Assignment of the 700 MHz (703-733/758-788 MHz) and 3.4-3.7 GHz (3420-3750 MHz) bands is scheduled for 2020 in a SMRA Clock Hybrid single round sealed bid auction. Spectrum from 3.7-3.8 GHz will be considered separately. It is intended to be used by local applications.

Assignment rules were released in March 2020.

- In 700 MHz frequencies, players cannot get more than 2x10 MHz. In 3400-3800 MHz frequencies, players cannot bid for more than 130 MHz. Licences will be valid 15 +5 years.
- A reserve price has been set at 562 kEUR for 2x1 MHz in 700 MHz frequencies and at 30KEUR for 1 MHz of spectrum in 3400-3800 MHz frequencies.
- Licenses will include coverage obligations in both bands. In 700 MHz frequencies, players are expected to reach 50% geographical coverage by year-end 2022 and 90% geographical coverage by year-end 2024. They will have to light up 10 5G sites by year-end 2020, 20 5G sites by year-end 2021, 40 5G sites by year-end 2022 and 80 5G sites by year-end 2024 in 3400-3800 MHz frequencies.

<b>Category</b>	<b>Band</b>	<b>Lot Size</b>	<b># of lots</b>	<b>Lot rating</b>	<b>Reserve price</b>
A1	700 MHz (703-713 MHz paired with 758-768 MHz)	2x10 MHz	1	4	€ 5,626,000
A2	700 MHz (713-733 MHz paired with 768-788 MHz)	2x10 MHz	2	4	€ 5,626,000
B	3600 MHz	40 MHz	5	4	€ 1,200,000
C	3600 MHz	10 MHz	13	1	€ 300,000

The 700/3600 MHz auction was completed in July 2020. four out of the five bidders have acquired 5G frequencies in the 700 MHz FDD and 3600 MHz TDD spectrum auction, paying a total of 41.3 million EUR (Players' bids are not available). The 15+5 year-licenses include strict geographical coverage obligations for 700 MHz spectrum (50% geographical coverage by year-end 2022 and 90% by year-end 2024). In 3420-3750 MHz frequencies, players have to light up a minimum of 10 sites by ear-end 2020, 20 by year-end 2021, 40 by year-end 2022 and 80 by year-end 2024.

Orange, Post and Proximus were each awarded one of the three available lots of 2x10 MHz in the 700 MHz band.

In the 3600 MHz band, Orange and Post each acquired 110 MHz of frequencies, Proximus bought 100 MHz and Luxembourg Online 10 MHz. Eltrona participated in the auction but failed to secure spectrum rights.

## 26 GHz

The regulator ILR launched a consultation on the 26 GHz band late in October 2020. The consultation ended on December 8, 2020. The ILR considers alternative mechanisms to assign 26 GHz spectrum.

### 3.1.19. Malta

#### Main points

- **Strategy for 2018-2020 issued in November 2017**
- **Radio Spectrum Policy Programme 2019-2023 published in July 2019**

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 23<sup>rd</sup> and May 22<sup>nd</sup>, 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.

In September 2020, Melita was granted a trial 5G license. The trial started in September 2020 at the Melita Data Center and at locations in Sliema, Saint Julians and Valetta.

### 3.1.20. Netherlands

#### Main points

- 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”.
- Multi-band 700/1500/2100 MHz completed in July 2020 raised 1.23 billion EUR
- 3400-3450 and 3750-3800 MHz intended for local use scheduled respectively for 2022 and 2026
- 5G launch by VodafoneZiggo in April 2020, by T-Mobile and KPN in July 2020

In June 2019, the ACM released an updated spectrum plan for 5G. The telecom regulator intends to auction 700, 1500, 2100 and 3500 MHz. The 3500 MHz (3400-3450 MHz) is scheduled as from September 2022 and 3750-3800 MHz frequencies from 2026. 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.

#### 700/1500/2100 MHz

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. Licenses will include coverage obligations of 98% geographic coverage of all domestic municipalities. The auction itself is scheduled for June 2020. Applications are due before 6 April 2020.

The multi-band auction started on 29 June 2020. It raised 1.23 billion EUR. Each operator won 2×10 MHz in the 700 MHz band and 2×20 MHz in the 2100 MHz band. In the 1400 MHz band, KPN and VodafoneZiggo bought 1×15 MHz each and T-Mobile acquired 1×10 MHz. Spectrum in the 700 MHz and 1400 MHz will become available immediately, the 2100 MHz licences will be available from early 2021. Licences include coverage obligations of 98% geographic coverage of all domestic municipalities. Licenses which will be issued in summer 2020 will run until 2040. The auction was cleared by the Court of The Hague one day before the announcement by the regulator. A lawsuit had been launched by Stop5GNL to block 5G auctions and rollout blaming negative health effects.

#### 3.6 GHz

The 3.6 GHz 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.

#### 26 GHz

The use of the 26 GHz band is under consultation use of spectrum either for shared use or local authorizations from 2020. The consultation closed at the end of February 2020.

### 3.1.21. Poland

#### Main points

- 5G Strategy for Poland, January 2018.
- 5G spectrum consultation, July 2018.
- A few trials to date.
- 3.4-3.8 GHz auction stopped in March 2020 due to covid-19, expected likely in the first quarter 2021.
- 700 MHz auction expected by 27 August 2021
- 5G services launched by Polkomtel with 2.6 GHz spectrum in May 2020, by T-Mobile Poland early June 2020 in 2100 MHz spectrum, by Orange in July 2020 on 2100 MHz frequencies.

#### 700 MHz

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 November 2020, UKE announced the auction should be completed by 27 August 2020.

#### 3.6-3.8 GHz

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 3.4-3.8 GHz range via a competitive auction rather than a tender process.

In December 2019, UKE opened a consultation into its planned auction of four licenses in the 3.4-3.8 GHz band. The NRA indicated it wants to award the four licenses by mid-2020. The licenses will be valid until the end of June 2035. The proposed starting price for each block is PLN 450 million (103.4 million EUR). The process kicked off in March 2020. Four lots of 80 MHz will be auctioned: concessions A (3480-3560 MHz) and B (3560-3640 MHz) will offer full nationwide coverage, licenses C (3640-3720 MHz) and D (3720-3800 MHz) will have geographic restrictions:

- at least 10 base stations in the area of 1 voivodship city selected from the cities indicated within 4 months of receiving the licence;
- until 31 December 2023, at least 300 base stations throughout the country, including at least 10 base stations in the area of each of at least 20 municipalities selected from the indicated municipalities, with the proviso that at least 9 voivodship cities will be selected;
- until 31 December 2025, at least 700 base stations throughout the country, including at least 10 base stations in the area of each of at least 30 municipalities selected from the indicated municipalities, provided that at least 16 voivodship cities are selected.

The commitments were designed in a way to ensure network roll-out in the largest population centers, i.e. municipalities with more than 80,000 residents.

The auction was postponed from March to year-end 2020 due to covid-19. It is likely to take place in the first quarter 2021.

## 26 GHz

The auction is expected before 2022.

### 3.1.22. Portugal

#### Main points

- Multi-band auction (700/900/1800/2100/2600/3600 MHz) postponed in March 2020 due to covid and rescheduled for October 2020, and further rescheduled to early 2021
- 26 GHz auction expected in 2023

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 and 300 MHz of the 3.6 GHz band, between April and June 2020. Commercial usage is expected during 2020.

Early 2020, ANACOM launched a consultation on the upcoming multi-band auction including coverage and speed obligations of 100 Mbps for 85% of the population in 2023 and 95% in 2025. ANACOM also approved the draft rules for the auction with reserve prices as follows:

- 700 MHz; six lots of 2×5 MHz (19.20 million EUR per lot)
- 900 MHz; one lot of 2×5 MHz (30.00 million EUR per lot)

- 900 MHz; four lots of 2x1 MHz (6.00 million EUR per lot)
- 1800 MHz; three lots of 2x5 MHz (4.00 million EUR per lot)
- 2100 MHz; one lot of 2x5 MHz (2.00 million EUR per lot)
- 2600 MHz; two lots of 2x5 MHz (3.00 million EUR per lot)
- 2600 MHz; one lot of 25 MHz (3.00 million EUR per lot)
- 3.6 GHz (with restrictions until 2025); twenty lots of 20 MHz

The multi-band auction initially scheduled for sometime between April and June 2020 was postponed due to the Covid.. Auction rules were published in November 2020. New entrants are encouraged to participate: a bloc of 900/1800 MHz spectrum has been set aside for them. In addition, providing them nationwide roaming is mandatory. Nos, Vodafone, MEO, Novo (Grupo Masmovil) and DenseAir Portugal submitted applications before the 26 November 2020 deadline. The licences would be distributed early 2021.

Early 2020, Anacom modified spectrum held till August 2025 by DenseAir in the 3.4-3.8 GHz spectrum. The amount of spectrum held will be reduced from 168 MHz to 100 MHz and relocated in the lower part of the band.

### 3.1.23. Romania

#### Main points

- National Strategy for the Implementation of 5G in Romania
- Multi-band 5G auction rescheduled for the second quarter 2021

5G launch by RC&RDS and Vodafone in June 2019, by Orange in November 2019. 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 20<sup>th</sup> and December 21<sup>st</sup>, 2018.

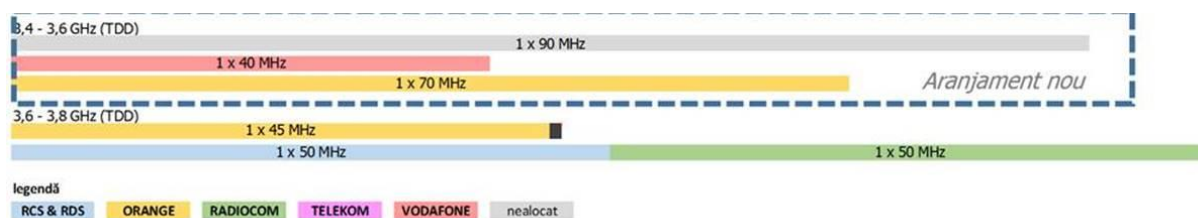
In December 2018, the Romanian regulator, ANCOM, has issued a consultation about its action plan for 2019. ANCOM’s President, Sorin Grindeanu, said in a press release that its main project will be the auction of the 700 MHz, 800 MHz, 1500 MHz, 2.6 GHz, and 3.4 – 3.6 GHz bands for 5G services.

In December 2020, ANCOM published its Action Plan for 2021 for comments before January 4, 2021. The Plan mentions the multi-band auction will be rescheduled for the second quarter 2021.

#### **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 20<sup>th</sup>, 2020.





Source: Ancom

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 to March 2020, the process was again postponed to Q4 2020 in March 2020. In September 2020, ANCOM's head told the auction could again be delayed from the initial target of December 2019 and be rescheduled for the second quarter 2021.

## 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 before 2022, subject to market demand.

### 3.1.24. Slovakia

#### Main points

- 700/900/1800 MHz auction initially scheduled for June 2020 ended in November 2020 raising a total of 100.2 million EUR.

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)/900 MHz/1800 MHz

A consultation on the planned award of the 700, 900 and 1800 MHz bands was issued in December 2019.

In April 2020, Regulacny Urad (RU) invited applications for the multi-band 700/900/1800 MHz auction. In the 700 MHz band, spectrum 2x30 MHz is available broken down into 15 2x5 MHz blocks at a reserve price of 16 MEUR each. RU set a spectrum cap of 2x15 MHz by player in 700 MHz frequencies. No

spectrum is finally not reserved for the fourth player in the market, SWAN Mobile. 700 MHz licenses will be valid for 20 years (till year-end 2040). 700 MHz licenses will be granted with coverage obligations of 95% of the population of every county town by year-end 2025 and 90% of the population outside county towns by 2027, with 70% of the country inhabitants covered by 5G by year-end 2027.

900 MHz spectrum will be sold with a reserve price of 840 kEUR for each 2x4.2 MHz block. Licenses will be valid six months after the auction till year-end 2025.

1800 MHz spectrum will be sold in three 3 MHz blocks to be used within a year after the auction. Licenses will be valid till year-end 2025.

In June 2020, the Slovakian telecoms regulator announced it postponed the multi-band 5G auction scheduled for June 2020 to a later unspecified date. Finally, the auction ended on November 24, 2020 raising a total of 100.229 million EUR. All the blocks were allocated. Orange paid 33.63 million EUR, O2 paid 33.39 million EUR and Slovak Telecom 32.66 million EUR.

- Orange, O2 and Slovak Telekom got a 2x10 MHz lot in 700 MHz frequencies (Orange: 723-733/778-798 MHz, 33.633 million EUR – O2: 703-713/758-768 MHz, 32 million EUR – Slovak Telekom: 713-723/768-778 MHz, 32.106 million EUR)
- At 900 MHz, O2 got 2x4.2 MHz spectrum for 840 KEUR
- O2, Slovak Telekom and 4ka (SWAN) obtained a 2x3 MHz lot of 1800 MHz each (O2: 1776.1-1779.1/1871-1874.1 MHz, 550 KEUR – Slovak Telekom: 1710-1710.1/1805-1805.1 MHz – 4ka: 1779.1-1782.1/1874.1-1877.1 MHz, 550 KEUR)

### 3.6 GHz band

(Source: [ec.europa.eu/newsroom/document.cfm?doc\\_id=44456](https://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.*

In early 2020, the conditions of the existing licences (valid until 2025) were modified into 5G-compatible ones.

### 3.1.25. Slovenia

#### Main points

- Consortium on 5G PPDR issues created in 2017
- Multi-band auction for 700/1500/2100/2300/3600 and 26 GHz spectrum to take place in 2021
- Temporary licenses till the auction
- 2.6 GHz 5G launch by Telekom Slovenije in July 2020

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:

- 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 an updated Radio Spectrum Management Strategy. The auction is scheduled for year-end 2020. In May 2020, AKOS begun preparations for the auction.

In December 2020, AKOS issued a consultation on its spectrum management strategy for 2021-2023. Due to the delay in publishing its management strategy, the multi-band auction is expected to be further delayed and take place in 2021.

#### Multi-band 700/1500/2100/2300/3600 and 26 GHz auction

The regulator plans to sell spectrum in all three 5G pioneer bands (700 MHz, 3.6 GHz and 26 GHz) at the same time by March 2021, alongside with 1500/2100/2300 MHz complementary spectrum.

Licence holders are expected to launch 5G in at least one city within one year after being awarded the licence and to use all frequencies within five years to cover all major cities. 700 MHz 5G service should also cover 99% of motorways and 60% of all train lines and main roads by December 2025.

AKOS introduced spectrum caps by frequency bands: 2x35 MHz in 700/800/900 MHz frequencies, 190 MHz in the 2.3/3.6 GHz spectrum, 800 MHz in the 26 GHz band and a global spectrum cap whatever the band: each bidder should not hold more than 425 MHz in 700/2100/2300/3600 MHz bands (including spectrum already owned in 800/900/1800/2600 MHz). AKOS also introduced special conditions for players holding less than 2x30 MHz in sub-1 GHz frequencies: they can provide speeds of at least 10 Mbps DL and 2 Mbps UL compared to at least 30 Mbps DL and 3 Mbps UL for players holding more than 2x30 MHz in sub-1 GHz frequencies.

### 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 (198.1 million EUR)
  - Orange has twelve 5 MHz blocks (132.1 million EUR)
  - Telefonica has ten 5 MHz blocks (107.4 million EUR)
- The 700 MHz auction initially scheduled for March and then for May 2020 postponed due to covid likely to the first quarter 2021
- 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, 2019, by Movistar, Masmovil (Yoigo) and Orange in September 2020

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).

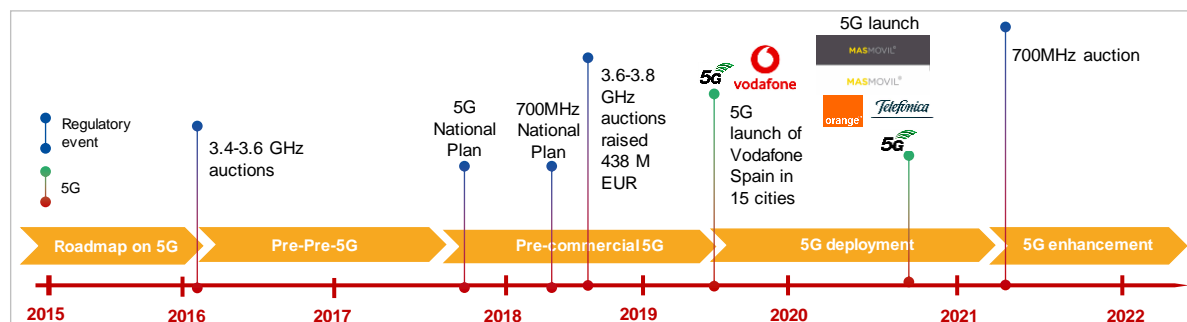
5GBarcelona will develop a European 5G digital hub based on an open experimental infrastructure in the metropolitan area for validating 5G technologies and services. It will be an open innovation environment based on the collaboration between public and private institutions that will harmonize the ecosystem 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 million EUR 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 and again postponed to the first quarter 2021 (700 MHz spectrum freed on 31 October 2020). 2x15 MHz spectrum caps were decided in July 2020.

**Figure 25: 5G timeline in Spain**



Source: IDATE DigiWorld

### 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.
- The 2.3 and 3.5 GHz auction initially scheduled for March 2020 was postponed to 10 November 2020, with applications invited until 30 June 2020, expected to resume on 19 January 2021
  - 320 MHz will be for sale in the 3.5 GHz band (3400-3720 MHz) in up to 15 licenses. One license will include 40 MHz of spectrum, the other 14 only 20 MHz. The reserve price is set at 100 MSEK (9.5 MEUR) per block. The 3720-3800 MHz portion will be made available on a local basis.
  - 80 MHz will be for sale in the 2300 MHz frequencies with 8 blocks of 10 MHz sold at a 20 MSEK (1.9 MEUR) reserve price.
- PTS has opened up additional trial licences for 5G in 3.6GHz-3.8GHz, 3.8GHz-4.2GHz, 40.5GHz-43.5GHz, 45.5GHz-47.0GHz, 47.2GHz-48.0GHz and 66GHz-71GHz. Testing is already being carried out using 3.4GHz-3.6GHz and 26.5GHz-27.5GHz spectrum.

- 5G launch by Tele2 and Telia in May 2020, by Tre in June 2020 and by Telenor in October 2020.

## 2.3 and 3.5 GHz

The auction was initially scheduled for the first quarter 2020. In November 2019, it was postponed to a later date in 2020 by PTS due to work being carried out to update the country's Electronic Communications Act to come into force in January 2020.

The regulator wants to offer up to 15 blocks of at least 20 MHz in the 3400MHz-3720MHz frequencies (a license will have 40 MHz), plus up to 8 nationwide 2.3 GHz licences, with at least 10MHz of spectrum each. Each bidder can get at least 80 MHz of spectrum in the 3.5GHz band. The minimum bid is set at 100 million SEK (9.7 million EUR) per 3.5 GHz lot (146 million EUR in total). The reserve price per 2.3 GHz licence is set at 20 million SEK (1.9 million EUR), for 160 million SEK (15.6 million EUR) in total.

In April 2020, PTS announced the auction will start on 10 November 2020 with applications to be submitted until 30 June. In November 2020, the auction was again postponed due to an appeal against the clause barring licensees to use Huawei equipment. Four companies (Telia, Net4Mobility, Tre and Teracom have been cleared to participate in the sale. At the end of December 2020, PTS announced the auction was expected to resume on 19 January 2021.

### 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. Updated in July 2019
- Statement on the review of spectrum used by fixed wireless services published in July 2018.
- Launch of 5G service by EE 5G on May 30, 2019, Vodafone on July 3, 2019, O2 in October 2019, Three on Feb. 14, 2020 (5G mobile) and August 19, 2019 (FWA).
- Plans to auction parts of 700 MHz and 3.6-3.8 GHz spectrum early 2021.
- Consultation on human exposure to ElectroMagnetic Field Emissions (EMF). Tests failed to find health risks.
- Consultation on 100-200 GHz frequencies
- Publication of the rules of the 700 MHz (80 MHz of spectrum) and 3.6-3.8 GHz (120 MHz) auction in March 2020: total spectrum cap set per operator of 416 MHz, no coverage obligations for the 700 MHz spectrum, two stages (bidding, and assignment to determine the specific frequencies needed by players and enabling them to get contiguous blocs).

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 February 2020, the DCMS announced the winners of 35 MGBP (42

MEUR) funding to further help 5G deployment. The government also launched a 30 MGBP (36 MEUR) 5G competition for the creative industries. 9 projects will receive 35 MGBP from the rural and industrial 5G competitions and additional 30 MGBP from an open competition dedicated to creative industries, including film, TV and video games, logistics and tourism.

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 57-666 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.

In February 2020, Ofcom launched a consultation on human exposure to EMF. It proposes to add specific licence conditions requiring adherence International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines on EMF. These rules would apply to spectrum licence holders for equipment that transmits at more than 10 Watts, and operators of licence-exempt equipment that can transmit at these powers. A first EMF emissions measurement campaign in 16 cities in 10 cities across the UK concluded emissions were a small fraction of ICNIRP levels. The study covered emissions close at 3.4 GHz and 60 GHz.

## 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.

In March 2020, OfCom published the rules of the 700 MHz auction. 80 MHz will be sold in six 2x5 MHz lots with a reserve price of 100 million GBP (110 million EUR) per lot and four 5 lots of 5 MHz SDL with a reserve price of 1 million GBP (1.10 million EUR) per lot. Licenses will not include coverage obligations.



The auction is expected early 2021. The regulations for the auction came into force on 18 November 2020.

### 3.4-3.8 GHz band

3400-3600 MHz spectrum was auctioned in April 2018.

### 3.6-3.8 GHz

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.

24 lots of 5 MHz of 3.6-3.8 GHz spectrum will be auctioned using a simultaneous multiple round ascending format. The reserve price is set at 20 million GBP (22 million EUR) per lot. This auction faces challenges from MNOs. O2 launched a legal claim against Ofcom for getting a larger chunk of spectrum. OfCom decided to delay the auction.

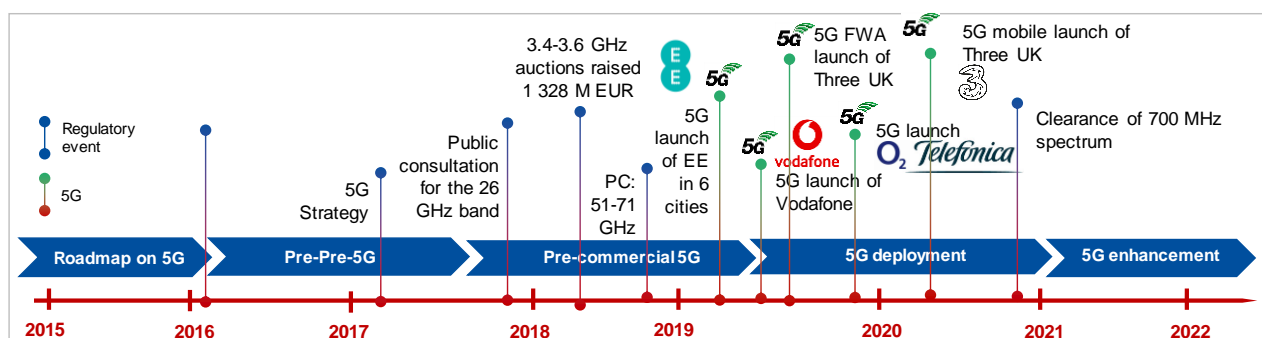
The regulations for the auction came into force on 18 November 2020.

The auction has been postponed to early 2021.

### 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”. 26 GHz frequencies are available on demand.

**Figure 26: 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-27 countries plus UK – End of December 2020

Country	Frequency band	5G strategy published	Spectrum assigned	Availability for 5G use	Channel width	Coverage obligations	Licence duration
Austria	700 MHz	✓	✓	✓	5 MHz	✓	20 years
	3.4-3.8 GHz	✓	✓	✓	5 MHz	✓	20 years
							31 December 2039
Belgium	26 GHz	✓	✗	✗	N/A	N/A	N/A
	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
Bulgaria	26 GHz	✓	✗	✗	200 MHz	N/A	N/A
	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
Croatia	26 GHz	✓	✗	✗	N/A	N/A	N/A
	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
Cyprus	26 GHz	✓	✗	✗	N/A	N/A	N/A
	700 MHz	✓	✓	✓ <sup>12</sup>	5 MHz	✓	20 years
	3.4-3.8 GHz	✓	✓	✓ <sup>13</sup>	50 MHz	✓	20 years
Czech Republic	26 GHz	✓	✗	✗	N/A	N/A	N/A
	700 MHz	✓	✓	✓	5 and 10 MHz	✓	15 years (2035)
	3.4-3.8 GHz	✓	✓	✓	20 MHz for 3.4 GHz 40 MHz for 3.7 GHz	✓	12 years for 3.4 GHz (2032) 15 years for 3.7 GHz
Denmark	26 GHz	✗	✗	✗	200 MHz	N/A	N/A
	700 MHz	✓	✓	✓ <sup>14</sup>	5 MHz	✓	20 years
	3.4-3.8 GHz	✓	✗	✗	N/A	✓ <sup>15</sup>	20 years
Estonia	26 GHz	✓	✗	✗	N/A	✗ <sup>16</sup>	20 years
	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	N/A	N/A
Finland	26 GHz	✓	✗	✗	N/A	N/A	N/A
	700 MHz	✓	✓	✓	60 MHz in 2x5 MHz+4x5 MHz SDL	✓	17 years
	3.4-3.8 GHz	✓	✓	January 2019	10 MHz?	✗	15 years
France	26 GHz	✓	✓	July 2020	N/A	N/A	31/12/2033
	700 MHz	✓	✓	✓	5 and 10 MHz duplex	✓	15 years
	3.4-3.8 GHz	✓	✓	✓	10 & 50 MHz	✓	15 years
Germany	26 GHz	✓	✗	✗	N/A	✗	15 years?
	700 MHz	✓	✓	✓	5 MHz	✓	15 years

<sup>12</sup> January 2021

<sup>13</sup> January 2021

<sup>14</sup> 700 MHz spectrum available in April 2020

<sup>15</sup> Coverage obligations for some licences. Licences no subject to coverage obligation or leasing obligation will be subject to usage requirements.

<sup>16</sup> Usage requirements

Country	Frequency band	5G strategy published	Spectrum assigned	Availability for 5G use	Channel width	Coverage obligations	Licence duration
Greece	3.4-3.7 GHz	✓	✓	✓	10 MHz	✓	31/12/2040
	26 GHz	✓	✗	?	N/A	N/A	N/A
	700 MHz	✓	✓	✓ Dec. 2020	10 MHz	✓	15+5 years (2035)
	3.4-3.8 GHz	✓	✓	✓ Dec. 2020	5 MHz	✓	15+5 years (2035)
Hungary	26 GHz	✓	✓	✓ Dec. 2020	200 MHz	✗	15+5 years (2035)
	700 MHz	✓	✓	✓ Sept. 2020	5 MHz	N/A	15+5 years (2035/2040)
	3.4-3.8 GHz	✓	✓	✓ Sept. 2020	5 MHz	N/A	15+5 years (2035/2040)
Ireland	26 GHz	✗	✗	✗	N/A	N/A	N/A
	700 MHz	✓	✗	✗	N/A	N/A	N/A
	3.4-3.8 GHz	✓	✓	✓	5 MHz	✗	15 years (July 2032)
Italy	26 GHz	✗	✗	✗	N/A	N/A	N/A
	700 MHz	✓	✓	✗ July 2022	5 MHz duplex	✓ FDD only	15.5 years (YE 2037)
	3.4-3.8 GHz	✓	✓ 200 MHz (3.6-3.8 GHz)	✓	20 MHz & 80 MHz	✓ 3.6-3.8 GHz <sup>17</sup>	18 years (YE 2037)
	26 GHz	✓	✓ 1 GHz (26.5-27.5 GHz)	✓	200 MHz	✗	18 years (YE 2037)
Latvia	700 MHz	✗	✗	✗	10 MHz/15 MHz	N/A	20 years (2042)
	3.4-3.8 GHz	✗	✓	✓	50 MHz	N/A	10 years (Dec. 2028)
	26 GHz	✗	✗	✗	N/A	N/A	N/A
Lithuania	700 MHz	✓	✗	✗	5 and 10 MHz	Likely	N/A
	3.4-3.8 GHz	✓	✗	✗	N/A	Likely	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Luxembourg	700 MHz	✓	✓	✓ <sup>18</sup>	10 MHz	✓	15 years
	3.4-3.8 GHz	✓	✓	✓ <sup>19</sup>	10 MHz	✓	15 years
	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	✓	20 years (2040)
	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	✓	June 30, 2035
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Portugal	700 MHz	✓	✗	✗	5 MHz	likely	20 years
	3.4-3.8 GHz	✓	✗	✗	20 MHz	likely	20 years
	26 GHz	✓	✗	✗	N/A	N/A	N/A

<sup>17</sup> Only for players holding at least 80 MHz in the 3.4-3.8 GHz frequencies

<sup>18</sup> When the licences will be awarded

<sup>19</sup> When the licences will be awarded

Country	Frequency band	5G strategy published	Spectrum assigned	Availability for 5G use	Channel width	Coverage obligations	Licence duration
Romania	700 MHz	✓	✗	✗	5 MHz	N/A	N/A
	3.4-3.8 GHz	✓	✓	✓	N/A	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Slovakia	700 MHz	✓	✓	✓	5 MHz	✓	20 years (2040)
	3.4-3.8 GHz	✓	✓	✓	10 & 20 MHz	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
Slovenia	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
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 & 40 MHz <sup>20</sup>	N/A	N/A
	26 GHz	✓	✗	✗	N/A	N/A	N/A
United Kingdom	700 MHz	✓	✗	✗	5 MHz	✗	Indefinite term
	3.4-3.6 GHz	✓	✓	✓	20, 40 and 50 MHz 5 MHz <sup>21</sup>	✗	Indefinite term
	26 GHz	✓	✓✗	✓✗	N/A	N/A	N/A

Legend: ✓: Yes ✗: No ✓✗: licences granted on an on-demand basis

Source: IDATE DigiWorld

<sup>20</sup> 40 MHz for only one license

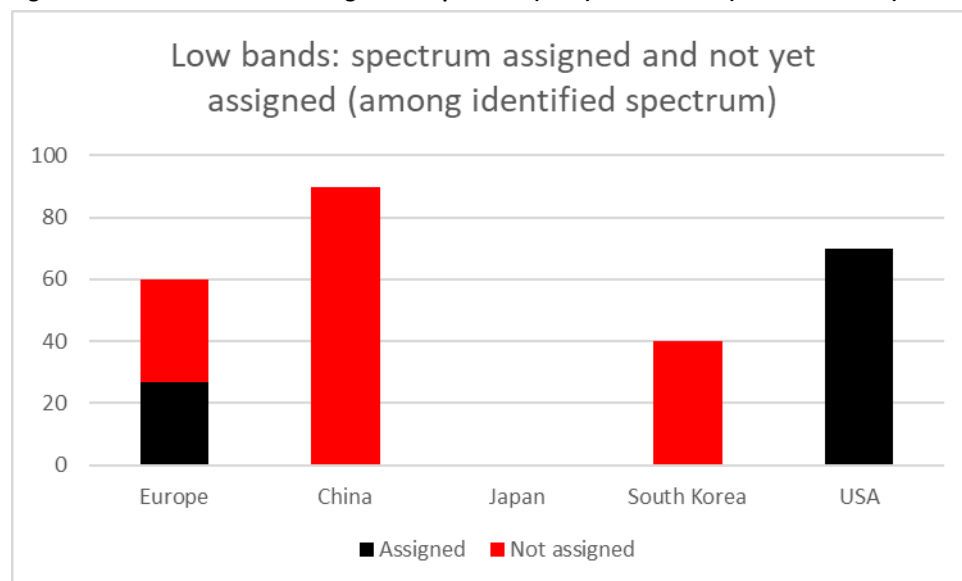
<sup>21</sup> 5 MHz for 3.6-3.8 GHz spectrum

### 3.3. 5G Spectrum comparison between EU and other leading countries

We compare spectrum in low, mid and high bands in the USA, China, Japan, South Korea with the EU-27 plus the United Kingdom. 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.

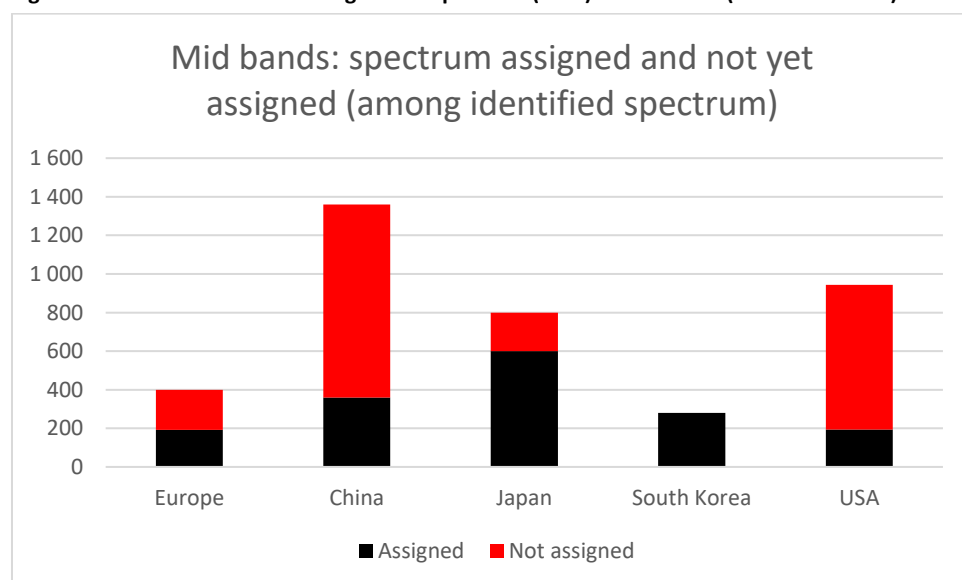
The graphs below show amounts of spectrum identified and assigned in low bands, mid-bands or high bands for each country or region.

**Figure 27: Identified and assigned 5G spectrum (MHz) – Low bands (December 2020)**

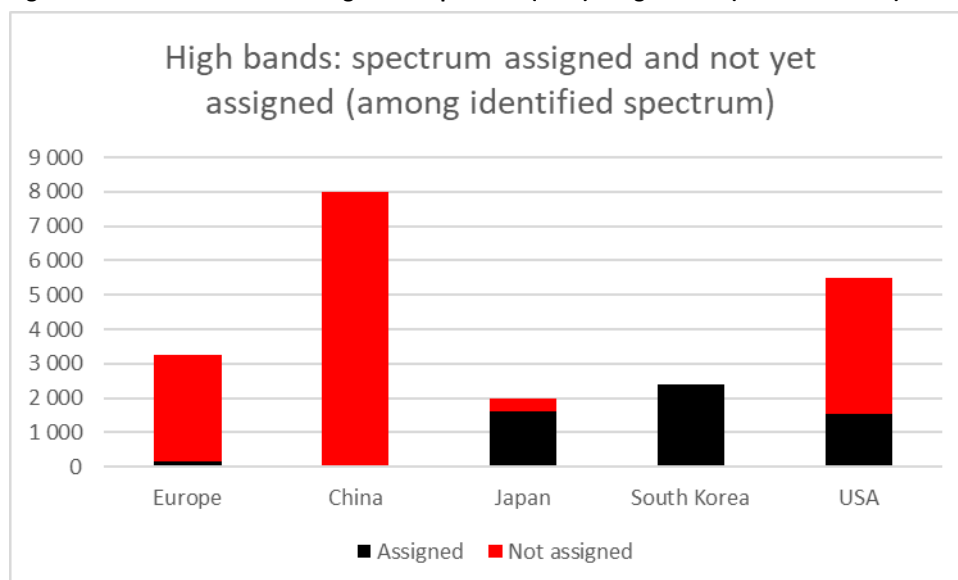


Source: IDATE DigiWorld

**Figure 28: Identified and assigned 5G spectrum (MHz) – Mid bands (December 2020)**



Source: IDATE DigiWorld

**Figure 29 : Identified and assigned 5G spectrum (MHz) – High bands (December 2020)**

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.

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. The bidding phase or clock phase ended on 5 March 2020 with gross bids totalling 7.6 billion USD. The following phase will see the winners trying to get specific frequencies.

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. Several Gulf countries claim to be the firsts to have launched 5G networks:

- **China:** Commercial launches for the three mobile players started in November 2019.
- **USA:** AT&T and Verizon launched mobile commercial services in early 2019. Sprint launched in May 2019 and T-Mobile USA in December 2019.
- **Japan:** KDDI, Softbank and NTT DoCoMo launched commercial 5G services in March 2020. Rakuten launched in September 2020.
- **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 claimed to be the world firsts 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 auctioned the upper bands in early 2020.

A specific fund for 5G was opened in 2016.

#### 5G spectrum

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 held 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 GHz<sup>22</sup> (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.
- The Federal Communications Commission announced the conclusion of Auction 103 in March 2020. This is its third auction of 5G suitable millimetre wave spectrum to date. The process started in December 2019 and involved frequencies in the upper 37GHz, 39GHz, and 47GHz bands, offering a total of 3,400 MHz of spectrum. The auction bid reached 7.6 billion USD (6.9 billion EUR). The price per MHz per capita for 10 years is 0.06 cEUR. The amount is much inferior to the price of past auctions in the 24 and 28 GHz bands.

Verizon spent 1.6 billion USD (1.45 billion EUR) on 4,490 licenses in 411 areas. AT&T dropped nearly 1.2 billion USD (1.09 billion EUR) on 3,267 licenses in 411 areas. T-Mobile spent a total of 873 million USD (793 million EUR) in the auction and won 2,384 spectrum licenses covering 399 areas. Sprint bid almost 114 million USD (103 million EUR) on 127 licenses in 38 areas.

- The Federal Communications Commission (FCC) awarded Priority Access Licenses in the 3550-3650 MHz band, also called CBRS (Citizens Broadband Radio Service) during the first mid-band auction in the USA. According to the FCC, this 70 megahertz of licensed spectrum will “further the deployment of 5G, the next generation of wireless connectivity, as well as the Internet of Things and other advanced spectrum-based services”. 20,625 of 22,631, or more than 91.1%, of available licenses were won during the auction process that reached a total of \$4,585,663,345.
- The FCC auction in the 3.7 GHz to 4.2 GHz band started on December 8, 2020. The FCC won't reveal the auction's winners for several days after the auction ends, which could be until February 2021.

## 5G trials

### *Verizon*

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.

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<sup>22</sup> The 28 GHz band had already been assigned. This auction assigned residual spectrum.



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.

#### *AT&T*

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*

The company started trials in 2017 in Atlanta, Chicago, Dallas, Houston, Los Angeles, and Washington DC. In June 2016, Sprint demonstrated a 5G trial using 73 GHz frequencies.

In May 2017 Sprint, SoftBank and vendor Qualcomm Technologies announced an agreement to collaborate on the development of the 3GPP 5G New Radio (NR) standard for 2.5GHz spectrum.

#### *T-Mobile*

The operator completed with Nokia in June 2018, 'the nation's first bi-directional over-the-air 5G data session on a 3GPP-compliant 5G New Radio system'. It conducted with a user equipment simulator and Nokia's 3GPP-compliant high-capacity 5G solution in the 28GHz frequency.

AT&T demonstrated with Nokia in November 2018, a 5G data transmission using its 600 MHz spectrum.

In January 2019, the company teamed up with Ericsson and Intel in Las Vegas to make a 5G data call and video call on a live 600MHz network. T-Mobile also accomplished a tri-band 5G video call with three users on different spectrum bands: 600MHz, 28GHz and 39GHz.

### **3.5.2. China**

5G deployment in China is strongly backed by the government. 5G ranks among the strategic priorities for the whole country (13<sup>th</sup> 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.

## 5G spectrum

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.

In February 2020, the MIIT asked China Telecom, China Unicom and China Broadcasting Network to share the 3.3-3.4 GHz band for indoor 5G use. Licensees will share 5G indoor access networks to further support quick 5G deployments. China Mobile is not allowed to use the 3.3-3.4 GHz spectrum in a move to increase competition.

### **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.

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 its 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 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](http://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 3<sup>rd</sup>, 2019.

### **5G spectrum**

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 initially planned in August 2020.

### **5G spectrum**

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 10 metres. At 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, the fourth mobile operator in Japan, plan to launch its 4G network April 2020. The operator announced a new 4G mobile carrier service plan will be available for 2,980 JPY (25 EUR) per month that will offer unlimited data within Rakuten network areas and 2 GB per month when subscribers ride on partner networks. The monthly price tag is roughly half the cost of service plans from competitors NTT Docomo, KDDI and Softbank. The company also announced a launch campaign offering 3 million subscribers the first full year of service free of monthly fees.

The operator launched a 4G fully virtualized cloud-native mobile network in April 2020. The architecture enables the operator to offer aggressive prices and lays the groundwork for the low cost and speedy implementation of 5G announced for the months to come.

### 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 network. The majority of mobile subscriptions are still 2G, and MNOs have already begun considering leapfrogging from 2G/3G directly to 5G.

A likely 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.

India's 5G auction, which was postponed in 2019 and was scheduled for April 2020, was again postponed by the authorities due to the operator's financial difficulties to pay licensing fees and other penalties.

### 3.6. 5G commercial launch dates

Table 16: 5G commercial launch dates in EU-27 plus the UK

Country	Operator	5G commercial launch	Expected 5G commercial launch
Austria	T-Mobile Austria	March 2019	
	A1 Telekom Austria	January 2020	
	Hutchison 3G Austria	September 2019	
Belgium	Proximus	April 2019	
	Orange Belgium		H1 2021
	Telenet Belgium		2021
Bulgaria	A1	November 2020	
	Telenor		H1 2021
	Vivacom	September 2020	
Croatia	A1 Croatia		H1 2021
	Hrvatski Telekom	October 2020	
	Tele2 Croatia		H1 2021
Cyprus	MTN		2021
	CYTA		2021
	PrimeTel		2021
Czech Republic	Telefonica	July 2020	
	T-Mobile	November 2020	
	Vodafone	October 2020	
Denmark	TDC	September 2020	
	Telenor Denmark	November 2020	
	Telia Denmark		H1 2021
Estonia	3 (Hi3G)	December 2020	
	Telia Estonia	November 2020	
	Tele2 Estonia		H1 2021
Finland	Elisa Estonia		H1 2021
	Elisa Finland	June 2019	
	DNA	December 2019	
France	Telia Finland	October 2019	
	Orange France	December 2020	
	SFR	November 2020	
Germany	Bouygues Telecom	December 2020	
	Free Mobile	December 2020	
	Deutsche Telekom	July 2019	
Greece	Telefonica Germany	October 2020	
	Vodafone Germany	July 2019	
	Vodafone Greece		Q1 2021
Hungary	Cosmote	December 2020	
	WIND Hellas	December 2020	
	Magyar (Deutsche Telekom)	April 2020	
Ireland	Telenor Hungary		2021
	Vodafone Hungary	October 2019	
	Vodafone Ireland	July 2019	
Italy	EIR Mobile	December 2019	
	Hutchison 3G Ireland	September 2020	
	TIM	June 2019	
	Wind Tre	October 2020	
	Vodafone Italy	June 2019	

Country	Operator	5G commercial launch	Expected 5G commercial launch
<b>Latvia</b>	Iliad	December 2020	
	Tele2 Latvia	January 2020	
	Bite Latvia		n/a
<b>Lithuania</b>	LMT	July 2019 (network only)	
	Bite Lithuania		2021
	Tele2 Lithuania		2021
<b>Luxembourg</b>	Telia Lithuania	H2 2019 (network only)	
	POST	October 2020	
	Tango	November 2020	
<b>Malta</b>	Orange	November 2020	
	Melita		n/a
	Vodafone Malta		n/a
<b>Netherlands</b>	GO		n/a
	T-Mobile	July 2020	
	VodafoneZiggo	April 2020	
<b>Poland</b>	KPN	July 2020	
	T-Mobile Polska	July 2020	
	Orange Poland	July 2020	
<b>Portugal</b>	Plus	May 2020	
	Play		n/a
	Altice (MEO) Portugal		H1 2021
<b>Romania</b>	NOS		H1 2021
	Vodafone Portugal		H1 2021
	Orange Romania	November 2019	
<b>Slovakia</b>	Telekom Romania		H1 2021
	Vodafone Romania	June 2019	
	RCS&RDS (DIGI)	June 2019	
<b>Slovenia</b>	Orange Slovakia		2021
	T-Mobile Slovakia	December 2020	
	O2 Slovakia		2021
<b>Spain</b>	Telekom Slovenije	July 2020	
	A1		2021
	Telemach		2021
<b>Sweden</b>	Orange Spain	September 2020	
	Telefonica (Movistar)	September 2020	
	Vodafone Spain	June 2019	
<b>Switzerland</b>	MasMovil (Yoigo)	September 2020	
	Telia	May 2020	
	Tele2	May 2020	
<b>United Kingdom</b>	Telenor	October 2020	
	Tre Sweden	June 2020	
	Sunrise	April 2019	
	Salt	Q3 2020	
	Swisscom	April 2019	
	EE	May 2019	
	Telefonica UK	October 2019	
	Vodafone UK	July 2019	
	Three UK	August 2019 (FWA)	

Source: IDATE DigiWorld – December 2020



### 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.

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

**Table 17: Number of cell sites/base stations for 5G trials and networks**

Country	Operator	Number of 5G cell sites	Announcement date
Austria	T-Mobile	600 locations across the country. 1,200 locations in all federal provinces by the end of the year	July 2020
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
Australia	Telstra	2,000 5G base station, availability in more than 60 cities and towns covering in excess of 41 per cent of the population	October 2020
China	China Mobile	300,000 base stations by the end of 2020.	July 2020
China	China Telecom	China Telecom announced plans to deploy 40,000 5G base stations by YE2019. <i>China Telecom has already deployed 40,000 5G base stations across China and co-shared another 20,000 with rival operator China Unicom in 2019, covering 50 cities under a network-sharing deal. Both carriers target having around 300,000 compatible base stations in use by end-2020.</i>	Early 2019 April 2020
China	China Unicom	China Unicom deployed a total of approximately 210,000 5G base stations. China Unicom, together with China Telecom, deployed approximately 150,000 5G base stations across China in S1 2020	August 2020
China	3 operators	Chinese operators built 257,000 new 5G base stations in the first half of 2020. 600,000 5G base stations by the end of the year	July 2020
China	3 operators	China's capital Beijing has deployed a total of 21,086 5G base stations	June 2020
Denmark	TDC	3800 cell sites upgraded for 5G	December 2020
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
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	12,000 5G antennas in operation. Plans 40,000 by the end of 2020	June 2020
Germany	Deutsche Telekom	15,000 new antennas on the 2.1 GHz band	July 2020
Germany	Vodafone	25 5G base stations in 20 cities	July 2019

Country	Operator	Number of 5G cell sites	Announcement date
		Already operates 60 5G sites and 140 antennas in 40 German cities. Will add 150 5G antennas before year end.	November 2019
<b>Italy</b>	Vodafone	The 5G network in Milan covers 80% of the city's population via 120 active sites	December 2018
<b>Kuwait</b>	Viva	Viva is rolling out a nationwide 5G network with over 1,000 5G NR-based radio sites in 2019	March 2019
<b>New Zealand</b>	Vodafone	Plans to have at least 100 5G cell sites by YE-2019. Tested 5 5G sites as from September 2019	August 2019
<b>Poland</b>	T-Mobile	1,600 base stations across the country	June 2020
<b>South Korea</b>	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
<b>South Korea</b>	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
<b>South Korea</b>	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
<b>South Korea</b>	3 operators	The three operators have already installed a total of 121,000 5G stations	July 2020
<b>UAE</b>	Du	Plans 700 5G base stations by year-end 2019	February 2019
<b>UK</b>	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
<b>UK</b>	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
<b>UK</b>	EE/BT	2,000 5G cell sites in May 2020	June 2020
<b>USA</b>	T-Mobile	Plans to deploy 2.5GHz spectrum on up to 30,000 macro sites over the next two years. Long term, plans to deploy 5G on 85,000 sites	June 2020

Source: IDATE DigiWorld – December 2020

### 3.8. 5G Private networks

In this section, we present a non-exhaustive list of 5G private networks in Europe.

**Table 18: Non-exhaustive list of 5G private networks**

Country	Company/Entity	Operator	Equipment Vendor	Comments
<b>Austria</b>	Magna Steyr	A1 Austria	Nokia	n/a
<b>Belgium</b>	Port of Zeebrugge		Nokia in collaboration with local service provider Citymesh	5G-ready private wireless connectivity. Connectivity to more than 100 endpoints across the entire port operations.
<b>Belgium</b>	Port of Antwerp	Proximus		Belgian full-service telecoms operator Proximus and the Port of Antwerp have signed a Memorandum of Understanding (MoU) to develop and test a private 5G network in order to evaluate potential industrial applications.
<b>Belgium</b>	Brussels Airport Company		Nokia and Citymesh	Brussels Airport Company is developing a private 5G-ready network in partnership with Nokia and Belgian operator Citymesh which it says will be operational in Brussels Airport by the end of March 2020.  IoT, automated vehicles, mobile safety systems and track & trace solutions. In a first phase, the 5G network will provide outdoor connectivity. A second phase will deliver 5G services indoors.
<b>China</b>	Bluetron	China Telecom	ZTE	The network is being used to test out a new machine vision application. This combines the 5G network, with its network slicing capabilities, and mobile edge computers to provide enhanced machine vision analytics. The 5G network enables fast backhaul of the video streams to the MEC facilities in network slices that guarantee the latency, jitter and packet loss parameters.
<b>China</b>	West China Second University Hospital in Sichuan Provinc	China Mobile	Huawei	The 5G network, augmented with mobile edge computing facilities has been used to showcase a variety of new applications including a hospital management system that incorporates data about patients, waiting times, asset location, and live video camera feeds to provide a visual smart hospital management system.  This will encompass a 5G and AR system enabling parents to see their prematurely born babies in intensive care, neonatal monitoring in ambulances in transit and 5G-enabled guidance robots for hospital visitors.
<b>Denmark</b>	Grundfos (pump manufacturer).	TDC NET	Ericsson	The project is a trial-run, with a view to a broader 5G-enabled Industry 4.0 deployment across its factories.

Country	Company/Entity	Operator	Equipment Vendor	Comments
<b>Finland</b>	Fortum Power and Heat (State owned energy company)			Traficom has granted the firm a 20 MHz chunk of local airwaves at 2300–2320 MHz at the site
<b>Finland</b>	Qualcomm, UROS	Elisa		<p>Finnish network operator Elisa has deployed a private 5G network for a new-generation IoT hub developed by UROS and Qualcomm set to open this year in Oulu, Finland.</p> <p>The Innovation Centre is the first facility in Finland to utilise private 5G networking in IoT product development and validation. The network itself is already up and running and will serve all IoT ecosystem partners at the hub facility.</p>
<b>France</b>	ADP Group and its subsidiary Hub One			Acquired a 10-year 4G and 5G license by ARCEP in February 2020 to be used in Paris' airports. Air France will also benefit from HubOne's 40 MHz.
<b>France</b>	EDF (French electricity company)			Acquired a 10-year license in the 2.6 GHz TDD band (20 MHz)
<b>France</b>	TansDev (mobility company)			Allowed to use the 2575-2595 MHz spectrum in Rouen, North West of France from 12 March 2020 to 11 March 2024
<b>France</b>	Lacroix	Orange	Ericsson	<p>French electronics manufacturer Lacroix Group has appointed Orange to deploy an indoor 5G network from Ericsson at a factory in France (Montrevault-sur-Evre) to run the rule over its value as a springboard for Industry 4.0, and as a foundation stone for its 'flagship' new 'factory-of-the-future'.</p> <p>Orange will manage a virtualized network core, distributed between the premises of Orange and the Lacroix plant. The spectrum band utilised for the new 5G network is unconfirmed.</p>
<b>Germany</b>	Mercedes-Benz, Sindelfingen plant	Telefonica	Ericsson	<p>Ericsson and Telefónica Germany built the network in the 220,000sq m complex and will hand over to Mercedes-Benz upon completion for operation. Initial applications will be factory automation and use to guide autonomous vehicles.</p> <p>The 730 million EUR Factory 56 facility is part of a €2.1 billion "future-oriented" car plant and the administrative area in Sindelfingen, in Germany.</p> <p>The company claimed that the factory will have zero-carbon production, and a 25 percent jump in efficiency compared with the old assembly line at the site.</p>

Country	Company/Entity	Operator	Equipment Vendor	Comments
Germany	Lufthansa, airline's aircraft hangar in Hamburg airport	Vodafone	Nokia	<p>The private network covers an area of 8,500 square metres. Lufthansa acquired a 3.7–3.8 GHz local licence.</p> <p>The idea is the new private 5G network, offering “industrial grade” reliability, alongside ring-fenced latency and bandwidth performance, precludes customers from physically attending inspections; instead they are able to provide live high-definition video feeds of their engine overhauls in their own facilities to the Lufthansa Technik team in Hamburg.</p>
Germany	Siemens		Qualcomm: 5G test network and 5G industrial test devices	<p>Late 2019: Proof-of-concept project at the Siemens Automotive Test Center in Nuremberg, Germany, demonstrating the first private 5G standalone (SA) network in a real industrial environment using the 3.7-3.8GHz band. The goal is to research the capabilities of 5G stand-alone networks for industrial applications.</p> <p>Siemens provided the industrial set-up (including the control systems and the IO devices) while Qualcomm provided the test network and equipment.</p> <p>Siemens has been reported in the press as having applied for local licences at six of its factory sites in Germany.</p>
Germany	BMW Group Leipzig plant.	T-Mobile	Ericsson	<p>The campus network at the BMW Group plant in Leipzig is initially based on the LTE standard.</p> <p>In addition to the private campus network, the public network will transmit the same signal strength. This ensures a perfect connection even for terminal devices that are not allowed to transmit in the private network.</p> <p>Ericsson and Telekom are currently working together to further develop the functionalities of campus solutions based on 5G standalone. The development includes a 5G dual-slice solution that can also integrate the industry spectrum.</p> <p>The company bought spectrum in the 3700-3800MHz band.</p>
Germany	Volkswagen			<p>Volkswagen will start construction of its own 5G mobile networks in 122 factories in Germany in 2020.</p> <p>The company bought spectrum in the 3700-3800MHz band.</p>

Country	Company/Entity	Operator	Equipment Vendor	Comments
Germany	Bosch		Ericsson	<p>Bosch acquired a 3.7–3.8 GHz local licence. The company is preparing to set up campus local area networks.</p> <p>Bosch started to build a private industrial 5G network at its semiconductor factory in Reutlingen, in Baden-Württemberg in Germany, to test for Industry 4.0 compatibility and network optimisation, along with industrial partners including ABB, Ericsson, Orange, and T-Systems.</p>
Germany	Center Connected Industry (CCI)	Deutsche Telekom	Ericsson	<p>Switched on a 5G standalone private network in April 2020, at the Center Connected Industry (CCI) at RWTH Aachen Campus.</p> <p>The end to end private network system is based on Ericsson's 5G standalone technology running in Deutsche Telekom's 5G spectrum. The network is currently built as an indoor solution integrated with an autonomous logistics device to demonstrate possible industry use cases.</p>
Germany	Port of Hamburg	Deutsche Telekom	Nokia	February 2018: Deutsche Telekom and Nokia partnered in 5G network slicing trials on private deployment on site at the port of Hamburg.
Germany	Rohde & Schwarz		Nokia	November 2020: The network is running in the 3.7-3.8 GHz band. Rohde & Schwarz has installed a private 5G network from Nokia at its plant in Teisnach, Germany. The network test company wants to run the rule over cellular-enabled Industry 4.0 applications in a dedicated 5G setup.
Japan	Fujitsu		Fujitsu Telecom Networks	<p>Japan's first commercial private 5G radio station license from the Kanto Bureau of Telecommunications.</p> <ul style="list-style-type: none"> <li>- Spectrum: 28.2 GHz to 28.3 GHz spectrum for 5G and 2.575 GHz to 2.595 GHz spectrum for LTE.</li> <li>- System configuration: 5G-NSA for data transmission, LTE for connection control between base stations and land mobile stations.</li> <li>- About 28,000 square meters on the grounds of Fujitsu Shin-Kawasaki Technology Square</li> </ul>
Japan	Toyota Production Engineering Corporation's manufacturing sites		<p>Nokia: connectivity piece—base stations, radios and core network equipment and Digital Automation Cloud for scalable operations and management.</p> <p>Japanese NS Solutions Corporation (ICT solution provider): wireless area design, license application support, system construction, and on-going maintenance and operation.</p>	5G ready private network to support IoT devices, equipment digitization and visualization.

Country	Company/Entity	Operator	Equipment Vendor	Comments
<b>Japan</b>	Mitsubishi Electric C.			<p>Allowed to test a local 5G system in a limited area using the 28.2-28.3 GHz spectrum band.</p> <p>Mitsubishi Electric said that it expects to launch demonstration tests at other business sites as well as establish new 5G infrastructure at its business sites and laboratories.</p>
<b>Poland</b>	PGE Systemy		Nokia	Nokia announced that Polish energy company PGE Systemy has chosen its 5G-ready, industrial-grade private wireless solution, following the successful trial of a 450MHz proof of concept (PoC) network in operation since April 2019.
<b>Spain</b>	FC Barcelona Stadium	Telefonica	Huawei	February 2019: Huawei collaborated with Telefónica to build standard dedicated 5G at the Nou Camp football stadium in Barcelona.
<b>Spain</b>	BASF	Masmovil	Cellnex, Nokia, Lenovo	November 2020: German chemicals company BASF and Spanish telecommunications infrastructure and services operator Cellnex Telecom signed an agreement to install what Cellnex said will be the first private network based on 5G technology in the Spanish chemical industry.
<b>Sweden</b>	Arlas Copco	Telenor	Ericsson, Fujitsu	October 2020: private 5G network in localised 3.7 GHz spectrum at Swedish tool manufacturer Arlas Copco's factory in Stockholm. The radio gear and core network are from fellow Swede Ericsson; Japan-based IT firm Fujitsu is also engaged.
<b>Sweden</b>	Saab		Nokia, Vinnergi	December 2020: Aerospace and defence company Saab has deployed a factory-wide private 5G network at a manufacturing plant in Sweden. The facility in Linköping, in the south of the country, produces 'aerostructures', notably for Airbus and Boeing. The project is starting with LTE in the upper part of the 1.8 GHz band, which works for indoor coverage; it will migrate to 5G in the second quarter of 2021
<b>Taiwan</b>	Inventec		Affirmed Networks (Microsoft), ASOCS	October 2020: Electronics manufacturer Inventec deployed a 5G standalone (5G SA) network at its plant in Taiwan, to bring automation and intelligence to its production line.

Country	Company/Entity	Operator	Equipment Vendor	Comments
<b>United Kingdom</b>	Ford, electric vehicle production site in Essex	Vodafone		<p>The project has received state funding as part of a GBP65 million (USD81 million) investment in 5G by the UK government. The facility is scheduled for completion in the autumn 2020.</p> <p>The aim is to reduce delays in manufacturing, increase bandwidth across the campus, improve security and reliability, and increase productivity.</p>
<b>United Kingdom</b>	Centrica Storage Limited, the gas storage and processing unit of UK gas and electricity supplier Centrica.	Vodafone	Ericsson	<p>The new private "5G ready" network, at Centrica's Easington facility in County Durham, will use Ericsson radio and core networking gear.</p> <p>Announced by Vodafone in August 2020, The setup will help CSL digitalise much of its critical maintenance and engineering operations</p>
<b>United States</b>	Phillips 66 (US oil company)	AT&T	Accenture	Industrial LTE and 5G setup for low-latency refinery automation and analytics.
<b>United States</b>	Whirlpool	AT&T	Seegrid	December 2019: Whirlpool is deploying a private 5G network in one its Ohio factories to solve a major problem: Driverless vehicles inside the plant rely on Wi-Fi to navigate.

Source: IDATE DigiWorld – December 2020

### 3.9. 5G network equipment –main manufacturers

#### 3.9.1. 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 with its Ericsson Spectrum Sharing solution (also known as DSS in 3GPP standard), a solution where Ericsson seem to lead. This capability enable spectrum sharing between 4G and 5G departing from the need for operator to dedicate a fixed portion of spectrum to each of its Radio Access Technology, as is usually the case with refarming.

While providing a wide range of deployment possibilities with equipment geared for all the situations (Macro, small cell, indoor...) Ericsson put the stress on the necessity to build the network with precision using the right equipment with the right capability at the right place, in order to maximize the required capability while enabling energy consumption saving. Thanks to Machine Learning, Ericsson is also providing a suite of software services aimed at managing performance and activating energy saving features when needed.



**Figure 30: Presentation of Ericsson 5G solution**

Source: Ericsson

### 3.9.2. Huawei

With more than 90 5G contract secured as of February 2020, Huawei claim the 5G leadership with an end to end solution from Core network to 5G RAN, by way of transport, backhauling and dedicated radio solutions to different situation of deployment. In its February 2020 product update announced in London, Huawei particularly put the stress on its third generation of Massive MIMO solution boasting the support for up to 400 MHz of bandwidth, notably geared for network sharing situation, integrated active and passive antenna solution for simplified deployment and a weight < to 25 kg for the 32T32R solution and < to 30 kg for its high-end 64T64R massive MIMO solution.

As densification of the network is key for operators, Huawei want to simplify as much as possible the deployment on-site and claims that its M-MIMO solution reduce on-site maintenance by 20% while also reducing the deployment time by 35% thanks to an integrated and simplified Active Antenna Unit. Also thanks to its complete outdoor simplified site solution, enabling to deploy Power, the blade RRU and blade AAU, the need for air conditioning is removed resulting in a 40% power saving claim.

Despite facing a ban on its products in the US and increasing pressure for US allies to implement a similar ban, Huawei is claiming the 1<sup>st</sup> position in terms of essential patent with 19% of the 5G essential patents.

Figure 31: Huawei 5G RAN portfolio

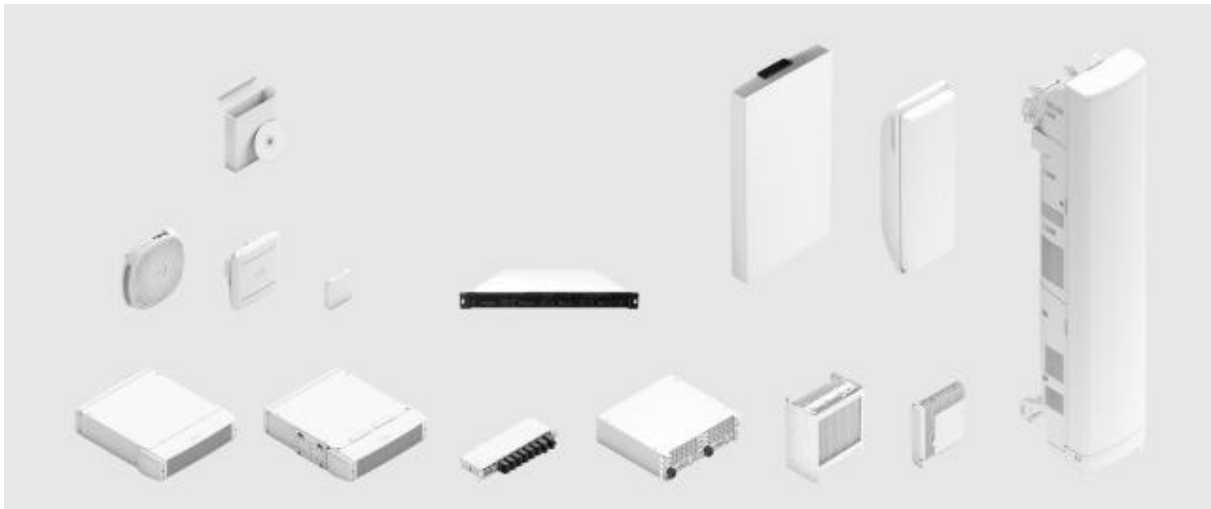


Source: Huawei

### 3.9.3. Nokia

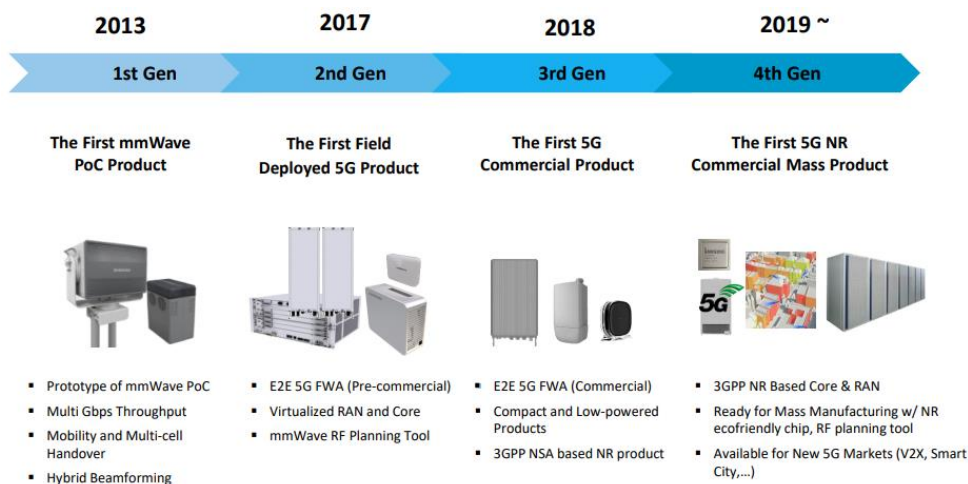
Nokia also proposes a complete 5G portfolio from core network to the RAN with its Airscale RAN solution. Having developed its own chipset solution called ReefShark, Nokia claimed the capability to decrease the size of massive MIMO antennas by 50%, and allow a 64% reduction in the power consumption of baseband units. After a first generation of chipset, Nokia has developed a lower cost chipset and inked partnership with Marvel, Intel and Broadcom to further develop its range of baseband chipset for its equipment

In April 2020, Nokia announced its next generation of 5G Airscale portfolio, putting the stress on its integrated antenna system supporting both passive and active antennas compact with dual and triple-band remote radio heads supporting cell site deployment requirements. While late in releasing its DSS solution, Nokia is also supporting the sharing of spectrum with 2G and 3G to facilitate user transition to the latest and most efficient radio technologies while maximizing spectrum usage.

**Figure 32: Nokia AirScale Radio Access for 5G**

Source: Nokia

### 3.9.4. Samsung

**Figure 33: 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. Not present in 3G it quietly developed its 4G portfolio and now 5G for which it heavily invested in mmWave. After its domestic market, where it is working with the 3 domestic operators it became a supplier of Jio network and it is now expanding in the US with 5G providing 5G equipment to Verizon and AT&T.

While appreciated for its solution in Europe, the lack of support is seen as a current obstacle to further deployment in the EU.

As other main equipment vendors, Samsung is designing its own base station chipset. In 2019 it launched its second generation chipset.

**Figure 34: Samsung 5G commercial products**

Source: Samsung

### 3.9.5. ZTE

While a smaller equipment vendor than the 4 main, ZTE has developed a complete 5G portfolio and benefited from the breadth of its domestic market. ZTE is notably known for its expertise in Massive MIMO, which it developed quite early for 4G commercial network and it has pursued the development of this solution for 5G network.

In March 2020, it launched its latest massive MIMO solution, claiming the lightest Active Antenna Unit solution available with less than 22 kg for the 32T32R configuration and support for 400 MHz bandwidth like Huawei.

Like most of the main equipment vendor is working on easing the integration and installation of 5G equipment by developing a range of radio unit adapted to different scenario, such as indoor coverage with QCell 5G solution but also with the Unisite+ solution that supports 7 different frequency bands in active, passive antenna system. This solution is aimed at replacing older equipment to provide increased capacity while enabling 30% power saving according to ZTE.

As part of the notable other solutions provided by ZTE, SuperDSS, a DSS solution supporting the deployment of 3 different RAT in the same spectrum (as opposed to two normally) or an integrated MEC solution ready for deployment.

Figure 35: ZTE Unisite+ solution



Source: ZTE

### 3.9.6. NEC

Veteran supplier of telecoms infrastructures in the optical and backhaul segments, it is now positioned in 5G wireless through the development of vRAN solutions for the domestic market initially. Recently it made the headline through its development of Open RAN 5G Radio Equipment for Rakuten fully virtualized 5G network in Japan, a radio unit that will also be provided to Docomo. This radio unit supports massive MIMO for 5G in the 3.7 GHz frequency band and complies with the open architecture standard. It is produced in NEC's Fukushima plant.

As part of its nascent 5G Radio portfolio, NEC has also developed mmWave Distributed Unit to support 5G indoor coverage. In addition to Rakuten Mobile, NEC is providing equipment for Docomo (3.7 GHz, 4.5 GHz and 28 GHz) as well as for Etisalat.

Through its sister company Netcracker, NEC also provides OSS/BSS solutions to operators.

**Figure 36: NEC network portfolio**



Converged Packet Optical  
Transport System



Fiber Optic Devices



IoT Platform Software  
"CONNEXIVE"



Mobile Backhaul "PASOLINK"



Optical Fiber Sensing



Submarine Systems



Traffic Management Solution



User Data Utilization Platform  
"NC7000-3A"

Source: NEC



### 3.10. Electromagnetic Fields (EMF) in the EU-27 Member States plus the UK

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-ionising<sup>23</sup> 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 Recommendation<sup>24</sup> 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-27 Member States plus the UK**

Countries	ICNIRP (Y/N)	Details on EMF
<b>Austria</b>	Yes	
<b>Belgium</b>	No	More restrictive than ICNIRP. Each region has its own limits. Current limits do not allow 5G deployment in the city of Brussels.
<b>Bulgaria</b>	No	Public exposure limit of 0.1 W/m <sup>2</sup> (300 MHz to 30 GHz)
<b>Croatia</b>	No	Exposure limits for power density are 16% of the ICNIRP guidelines
<b>Cyprus</b>	Yes	ICNIRP limits adopted in 2004
<b>Czech Republic</b>	Yes	ICNIRP limits adopted in 2000
<b>Denmark</b>	Yes	
<b>Estonia</b>	Yes	ICNIRP limits adopted in 2002. No permit for ERP power <100W
<b>Finland</b>	Yes	
<b>France</b>	Yes	ICNIRP limits adopted in 2002
<b>Germany</b>	Yes	
<b>Greece</b>	No	60% of ICNIRP guidelines for base stations located less than 300 m from schools, hospitals... 70% of ICNIRP guidelines in other areas
<b>Hungary</b>	Yes	ICNIRP limits adopted in 2004
<b>Italy</b>	No	20 V/m as a general limit in open areas. 6 V/m inside buildings used for more than four hours a day
<b>Ireland</b>	Yes	
<b>Latvia</b>	Yes	
<b>Lithuania</b>	No	Public limits for power density set at 10% of ICNIRP limits
<b>Luxembourg</b>	No	Limit at 3 V/m per operator and per antenna system. About 0.2% of ICNIRP limit above 2 GHz
<b>Malta</b>	Yes	
<b>Netherlands</b>	Yes	

<sup>23</sup> 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/](https://www.who.int/topics/radiation_non_ionizing/en/)).

<sup>24</sup> 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).

Countries	ICNIRP (Y/N)	Details on EMF
<b>Poland</b>	Yes	As of 1 January 2020, Poland applies the ICNIRP/EC Guidelines (Before 2020: 0.1 W/m <sup>2</sup> between 300 MHz and 3 GHz. 1% of ICNIRP limits above 2 GHz.)
<b>Portugal</b>	Yes	ICNIRP limits adopted in 2004
<b>Romania</b>	Yes	
<b>Slovakia</b>	Yes	ICNIRP limits adopted in 2007
<b>Slovenia</b>	Yes	
<b>Spain</b>	Yes	ICNIRP limits adopted in 2001
<b>Sweden</b>	Yes	
<b>UK</b>	Yes	ICNIRP limits adopted in 2000. EMF consultation in February 2020

Source: GSMA and IDATE DigiWorld



### 3.11. TDD synchronisation in the EU-27 Member States plus the UK

#### 3.11.1. Context

##### **TDD synchronisation status in the EU-27 plus UK**

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.

##### **Standardisation work on TDD synchronisation**

In the upcoming 3GPP Release 16 specifications, a new feature called Dynamic TDD may provide a possibility of unsynchronised TDD network arrangement in certain usage scenarios. This may allow unsynchronised TDD deployment in indoor environment or small cells deployment, while outdoor deployment may still require proper coordination between 5G operators operating in the same frequency band.

#### 3.11.2. 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.

### 3.11.3. France

On August 1<sup>st</sup>, 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 1<sup>st</sup> 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.

### 3.11.4. Germany

Decision of the President's Chamber of the Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen of 14 May 2018 on the order for and choice of proceedings for the award of spectrum in the 2 GHz and 3.6 GHz bands for mobile/fixed communications networks (MFCN); decision taken under sections 55(4), (5) and (10), section 61(1) and (2) and section 132(1) and (3) of the Telecommunications Act (TKG) – Reference: BK1-17/001 –<sup>25</sup>

“Moreover, the nationwide operation of TDD networks in Germany is new. In the case of unsynchronised operation, guard bands of 20 MHz will be needed between adjacent TDD usages by different network operators, or the networks will have to be synchronised. The 20 MHz guard bands required mean that the total spectrum of 300 MHz would lead to a net usable spectrum of only 240 MHz. However, channel bandwidths of 100 MHz are required to achieve full performance of 5G. The synchronisation is technically difficult and this issue is made even more difficult by the regional reservation.”

<sup>25</sup> Source:

[https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/FrequencyManagement/ElectronicCommunicationsServices/FrequencyAward2018/20180613\\_Decision\\_I\\_II.pdf?\\_\\_blob=publicationFile&v=2](https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/FrequencyManagement/ElectronicCommunicationsServices/FrequencyAward2018/20180613_Decision_I_II.pdf?__blob=publicationFile&v=2)

## Germany & Sweden<sup>26</sup>

An Agreement signed in September 2018 between the German Federal Network Agency and the Swedish Post and Telecom Authority concerning the use of the 3.6 GHz (3400-3800 MHz) frequency band states the following:

Use of frequencies without coordination by administrations:

- Germany may use the 3.6 GHz band without coordination with Sweden, if the predicted mean field strength produced by a base station does not exceed 32 dB(μV/m)/5 MHz, calculated for 10 % of the time, at a height of 3 m above the ground at the Swedish borderline or beyond.
- Sweden may use the 3.6 GHz band without coordination with Germany, if the predicted mean field strength produced by a base station does not exceed 32 dB(μV/m)/5 MHz, calculated for 10 % of the time, at a height of 3 m above the ground at the German borderline or beyond.
- For base stations that are synchronized<sup>1</sup> between Germany and Sweden or deployed as downlink only on both sides of the border, the following applies:
  - Germany may use the 3.6 GHz band without coordination with Sweden, if the predicted mean field strength produced by a base station does not exceed 67 dB(μV/m)/5 MHz at the Swedish borderline or beyond and 49 dB(μV/m)/5 MHz at a distance of 6 km from the Swedish borderline or beyond, calculated for 10 % of the time, at a height of 3 m above the ground.
  - Sweden may use the 3.6 GHz band without coordination with Germany, if the predicted mean field strength produced by a base station does not exceed 67 dB(μV/m)/5 MHz at the German borderline or beyond and 49 dB(μV/m)/5 MHz at a distance of 6 km from the German borderline or beyond, calculated for 10 % of the time, at a height of 3 m above the ground.

This Agreement entered into force from January 2019.

### 3.11.5. 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.

### 3.11.6. 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.

<sup>26</sup> Source: [https://www.pts.se/contentassets/1bb1d2473d724553a62c82007931e5e9/agreement\\_sweden\\_germany\\_3400-3800mhz\\_180827\\_final.pdf](https://www.pts.se/contentassets/1bb1d2473d724553a62c82007931e5e9/agreement_sweden_germany_3400-3800mhz_180827_final.pdf)

### 3.11.7. 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.

### 3.11.8. 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.

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