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5G Observatory Quarterly Report 3

Up to March 2019

European 5G Observatory

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1. Executive summary

This is the third quarterly report of the 5G Observatory for the first quarter of 2019.

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

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

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

European mobile operators have been working for two years with equipment manufacturers and vertical players on various trials in order to validate 5G's capabilities. At and-March 2019, it was clear that they are heavily involved in 5G testing with 147 trials reported at that time (up from 138 in Q4/2018) in EU-28 countries.

During the first quarter of 2019, many European mobile operators are preparing the deployment phase as the first 5G smartphones are expected to be available in the second quarter of 2019. In June 2018, Elisa already announced availability of a commercial 5G network in Tampere, Finland and Estonia's capital city of Tallinn. In late 2018, Orange started to announce detailed plans regarding 5G network deployment and commercial launch. In 2019, 5G deployments are expected with tens of base stations in many cities across Europe. Various operators (Vodafone, EE, Orange, DT…) have already announced deployments in many European cities. Contracts with network suppliers for 5G equipment should be signed in 2019 in order to allow full commercial service in 2020.

In Austria, T-Mobile announced commercial launch of 5G with friendly customers in rural areas in March 2019.

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	5G commercial launches (network only): Elisa (Finland and Estonia) in June 2018, Ooredoo (Qatar) in May 2018. T-Mobile Austria in March 2019 (friendly customers). 5G commercial launches (network and end user devices): Verizon (USA) in October 2018. Verizon will launch its mobile services called 5G Ultra Wideband Network in Chicago and Minneapolis on April 11, 2019. AT&T in December 2018 (end user devices available in Q1 2019). South Korean MNOs in December 2018 for enterprise customers and in April 2019 for residential customers. No clear indication of 5G investments by mobile operators. 5G planned launches: Japan in August 2020 (Pre-launches in 2019, notably for NTT DoCoMo autumn 2019).
Promote early deployment in major urban areas and along major transport paths	147 trials announced in EU-28. 33 trials in Russia, Turkey, San Marino, Switzerland and Norway. In 2017 and 2018, 10 digital cross-border corridors were announced and established for live tests of 5G in the EU. 3 large-scale projects have been selected on these corridors (5G-CARMEN, 5GCroCo, 5G-MOBIX).
Promote pan-European multi-stakeholder trials as catalysts to turn technological innovation into full business solutions	Large trials are part of H2020 Phase 3 projects. Three projects (5G EVE, 5G VINNI, 5GENESIS) started on 1 July 2018 and they will run for 3 years implementing and testing advanced 5G infrastructures in Europe (EUR 15 to 20 million investment).

Source: IDATE DigiWorld – April 2019

1.2. 5G deployment outside Europe

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

In the USA, Verizon launched its fixed wireless access service in October 2018 in four cities in the USA based on a proprietary standard. AT&T also announced the launch of a mobile 5G service based on the 3GPP standard in December 2019. The service was restricted to friendly[1] customers until the first quarter of 2019 and was extended to &&& additional cities during the first quarter of 2019. Verizon also launched a mobile service in Chicago and Minneapolis in April 2019.

After the announcement of limited commercial service targeting the enterprise market in early December 2018, the three South Korean operators launched 5G services on the same day in April 2019 . In South Korea, 5G deployment is massive as SKT has already deployed more than 30,000 5G base stations.

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

[1] Friendly customers are employees of the mobile operator or people using the service for no charge in exchange of reports on the service

China and Japan are already very active in the 5G field and operators will commercially launch 5G in 2019-2020.

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

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

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

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

At the end of March 2019, the most tested frequency band in Europe is by far the 3.6 GHz band (69% of the tests). The 26 GHz band is starting to gain traction.

Table 2: Assessment of 5G AP analysis criteria

5G AP analysis criteria	Assessment
Roadmaps and priorities for a coordinated 5G deployment	The European Commission published a guidance document for national 5G strategies and roadmaps. Ten MSs published specific national 5G roadmaps: Austria, Estonia, Finland, France, Germany, Luxembourg, Spain, Sweden, the Netherlands, and the UK. Fourteen EU MSs have published national 5G roadmaps or global strategy documents: Austria, Denmark, France, Germany, Greece, Italy, Luxembourg, Malta, Poland, Romania, Spain, Sweden, The Netherlands and the UK. Eighteen[2] EU MSs have launched public consultations on 5G spectrum/strategy.
Make pioneer spectrum bands available for 5G use ahead of WRC-19	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. • The 700 MHz band has been assigned in six MSs: Denmark, Germany, France, Finland, Italy and Sweden • The 3.4-3.8 GHz band has been assigned in accordance with 5G technical conditions[3] in 9 MSs: Austria, Czech Republic, Finland, Hungary, Ireland, Italy, Latvia, Spain and United Kingdom • The 26 GHz band has been assigned in Italy. In thirteen Member States at least one spectrum auction is complete (as at March, 2019). Three 5G spectrum auctions took place in Q1 2019: • Austria • Denmark • Germany (ongoing in April 2019) In fourteen MSs at least one spectrum auction is scheduled for 2019.
Spectrum: usage of 5G pioneer bands and/or of other bands identified by the RSPG	Usage: no commercial usage of 5G spectrum yet in EU-28 (Elisa launched its 5G network in Finland but services and devices were not available at the beginning of 2019)
Service verticals: feasibility of vertical use cases based on deals inked with key vertical players	Media & Entertainment: 32 trials Transport: 25 trials Automotive: 18 trials Other verticals: Industry 4.0, Agriculture, Smart cities, smart buildings, eHealth, Public Safety…
Top 10 European countries where trials are organised	Spain, France, Italy, Germany, UK, Finland, Netherlands, Estonia, Portugal, Romania
Technologies (Non-Stand Alone, Stand Alone…)	Non-Stand Alone 5G (3GPP Release 15) for all mobile operators except Verizon in the USA with a proprietary standard: Verizon 5G Technical Forum standard.
Functionalities tested: virtual networks/edge computing, broadcast/streaming, Heterogeneous Networks…	Mainly throughput and latency are tested in the first trials in Europe. The media and entertainment vertical is the most important one among the reported trials.

Source: IDATE DigiWorld – April 2019

[2] Consultations in 17 countries (Austria, Belgium, Bulgaria, Czech republic, Finland, France, Germany, Greece, Ireland, Italy, Lithuania, Poland, Portugal, Romania, Slovakia, Slovenia and the UK) are now closed (March 2019). A consultation is ongoing in Sweden.

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

2. Recent major developments

2.1. Latest developments at EU level

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

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

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

- enhancing the deployment of 5G networks by ensuring the availability of new necessary 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.

All Member States are required to adopt 5G roadmaps regarding the licensing of the 700 MHz band. Ten MSs have assigned or are about (before early April 2019) to assign 5G spectrum (mainly in the 700 MHz and 3.4-3.8 GHz bands).

2.2. Progress of national strategies and plans

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

In order to facilitate a consistent approach across Europe, the European Commission has published in November 2018 a Report[4] 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: 18 EU MSs have launched public consultations on 5G

By the end of March 2019, seventeen EU MSs had finalised public consultations on 5G spectrum/strategy: Austria (2017), Belgium (2018), Bulgaria (December 2018), Czech Republic (early 2019), Finland (2018), France (12/2017 and 10/2018), Germany (2018), Greece (2018), Ireland, Italy (2017), Lithuania (2018), Poland (2018), Portugal (2018), Romania (December 2018), Slovakia (2017), Slovenia (2017) and the UK. There was one public consultation ongoing during Q1 2019 on 5G spectrum in Sweden (February 2019) on upcoming award of the 2.3 and 3.5 GHz bands.

In other MSs the reflection has just started; Croatia did not publish a 5G roadmap / public consultation, but awarded trial licenses or organised round tables. The remaining MSs are still at the internal reflecting phase: Cyprus, Denmark, Estonia, Hungary, Latvia, Luxembourg, Malta, Netherlands and Spain.

5G strategies and plans by Member States are detailed in section 3.1 of the annex to this report.

2.2.2. National strategies

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

The review of progress made towards 5G market introduction shows various stages. Ten MSs published precise national 5G roadmaps (Austria, Estonia, Finland, France, Germany, Luxembourg, Spain, Sweden, The Netherlands, and the UK) whereas fourteen EU MSs have published national 5G roadmaps or global strategy documents (Austria, Denmark, France, Germany, Greece, Italy, Luxembourg, Malta, Poland, Romania, Spain, Sweden, The Netherlands and the UK).

As planned, Denmark published its 5G strategy in February 2019. In Estonia, 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 (January 2019). In January 2019, the Hellenic Telecommunications and Post Commission (EETT) in Greece 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

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

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.

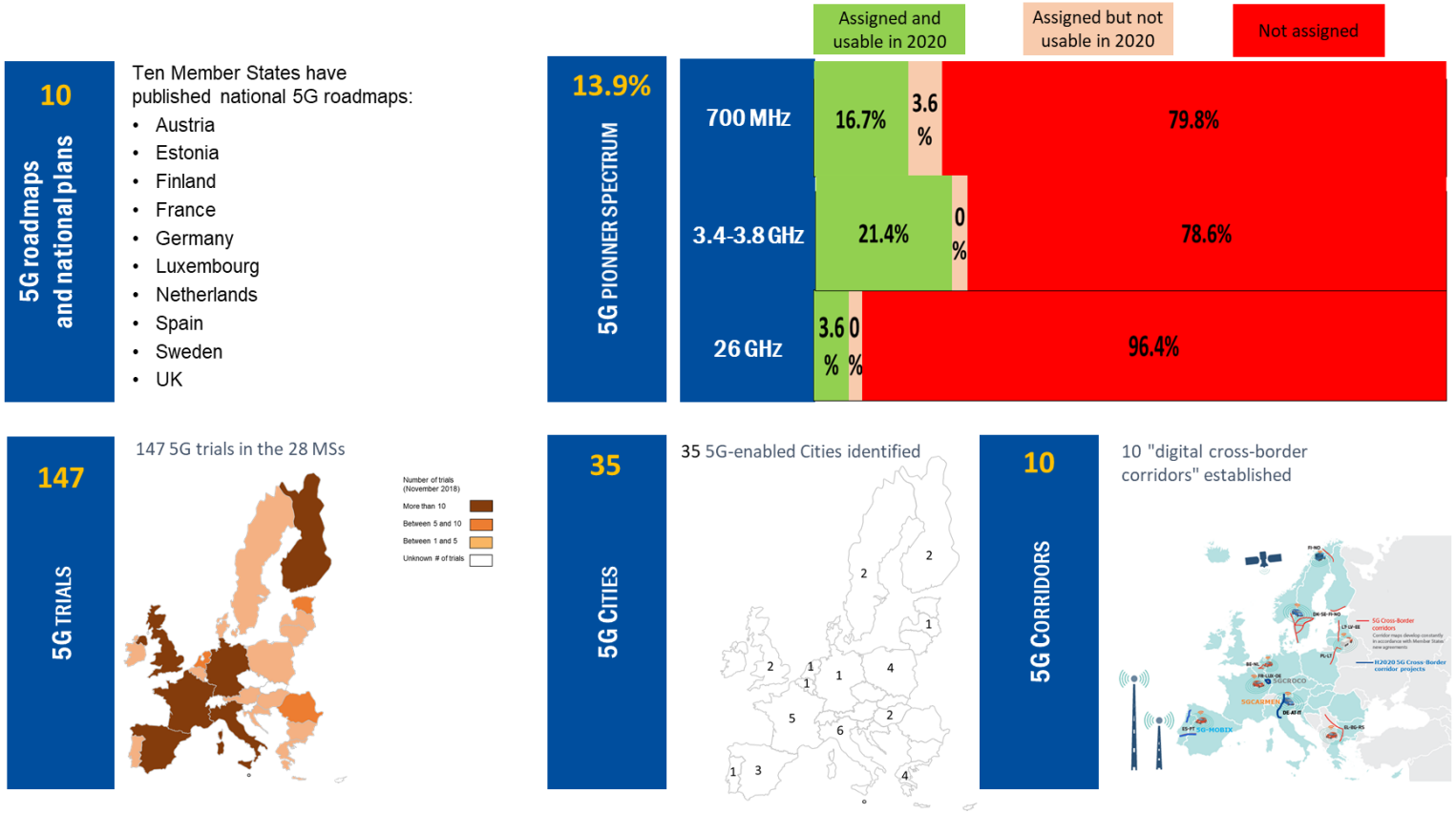
In 2019, six Member States plan to publish their 5G strategies: Cyprus, Malta (planned 3/19, not published yet), Hungary (4/19), Portugal (7/19), Croatia (Q4/19), and Lithuania (by end of 2019).

2.3. 5G scoreboard

2.3.1. 5G scoreboard – EU-28

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

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

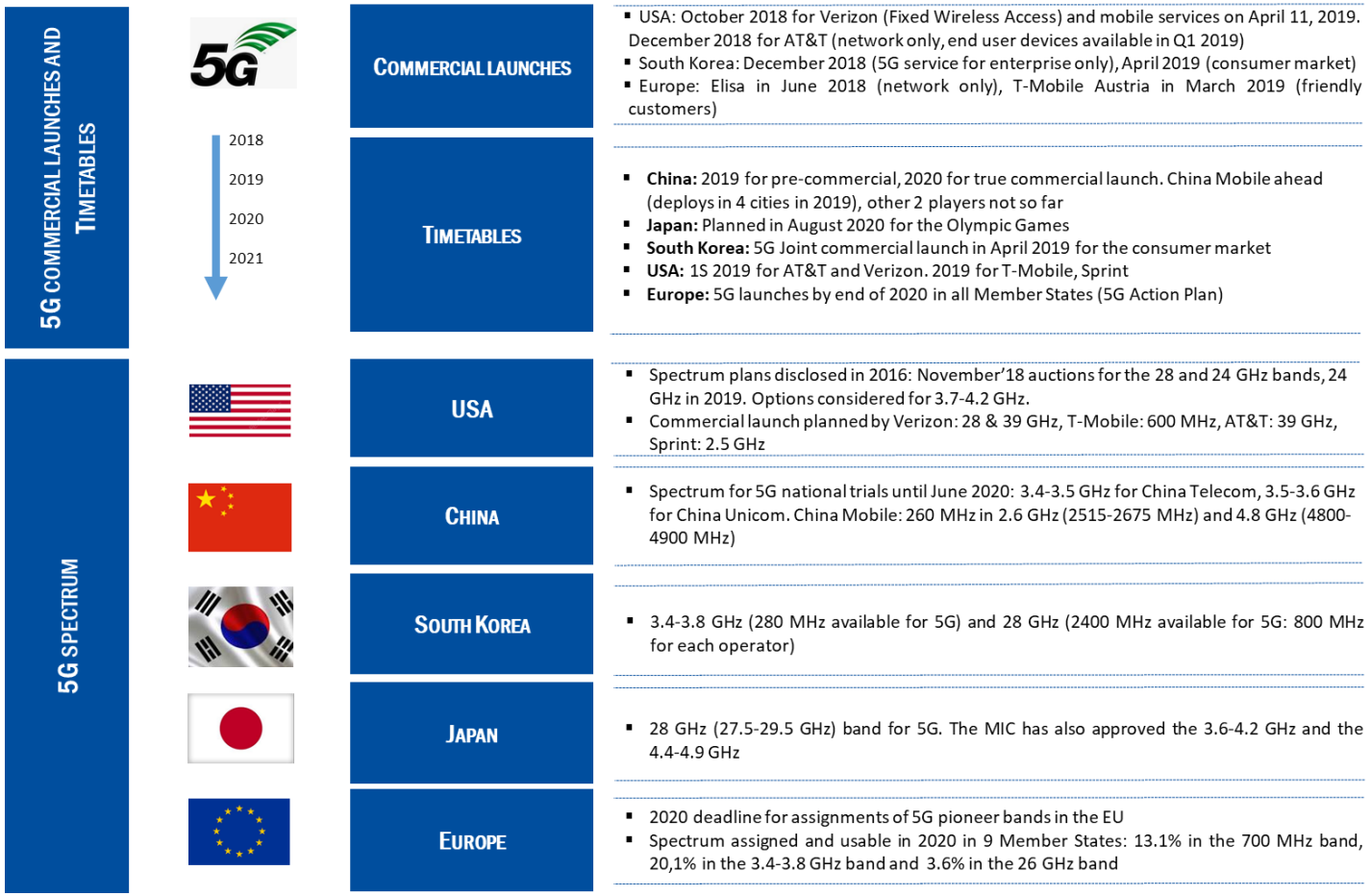


Source: IDATE DigiWorld

2.3.2. 5G scoreboard – International

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

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



Source: IDATE DigiWorld

2.4. Announcements of first commercial launches

5G is heating up in the world. Verizon launched a Fixed Wireless Access commercial service on October 1st, 2018. Some players have already announced their plans, whereas Elisa, T-Mobile Austria, Verizon, AT&T, the South Korean operators and Ooredoo claim they have commercially launched 5G.

2.4.1. Europe

Elisa (Finland and Estonia)

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.

T-Mobile (Austria)

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

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

Switzerland

In Switzerland, Sunrise announced 5G commercial launch in March 2019 and Swisscom in April 2019. At launch, Swisscom's network will encompass 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.

2.4.2. Ooredoo (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 (see here the 5G launch event). Ooredoo seems to be providing 5G wTTH (wireless To The Home) services on 3.5 GHz spectrum domestically with the very few compatible devices available (25 devices according to Gulf times). Ooredoo showcased its device. Considering 5G mobile devices are not ready yet, it states it is waiting for manufacturers to produce 5G capable devices (June 2019).

2.4.3. USA: Verizon 5G Home service launched in 2018, mobile services in April 2019

In the USA, Verizon 5G Home service was launched on October 1st, 2018, in limited areas of four US cities. The other mobile operators will launch their 5G services in the coming months.

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.

In August 2018, Verizon and Nokia have 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, has completed the transmission of a 5G mobile signal to a test van in Washington. The test was carried out with Verizon's mm-wave spectrum and 5G network core, along with Nokia's 5G radio equipment.

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

Verizon 5G 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 70 USD per month (50 USD/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 is offered for free (40 USD after the first three months). Speeds range from 300 Mbps to 1 Gbps, depending on location.

Launches in additional cities will follow.

Verizon uses CPE (Customer Premises Equipment) units and home routers from Samsung and is expected to use the Motorola Mod Z^3 for mobile 5G.

Verizon launched its 5G Ultra Wideband Network in Chicago and Minneapolis in April 2019. It provides download speeds that are significantly faster than 4G and carry a massive amount of data for a large number of simultaneous users. This launch coincides with the offering of the new 5G moto mod, which is exclusive to Verizon. Since March 14, customers anywhere in the U.S. could pre-order the 5G moto mod. When paired with the moto z3, the 5G moto mod creates the world's first 5G-enabled smartphone. Select areas of Chicago and Minneapolis are the first to experience Verizon's 5G Ultra Wideband mobile service use the NR standard developed by the 3GPP.Verizon announced that it intends to launch its 5G Ultra Wideband network in more than 30 U.S. cities in 2019. The company's 5G service plan comes with unlimited data, available for just 10 USD a month (with the first three months free) with any Verizon unlimited plan. Verizon will be the first U.S. wireless provider to offer Samsung's new 5G smartphone – the Galaxy S10 5G – in the first half of 2019.

AT&T

Since early 2017, AT&T has been performing fixed wireless & mobile 5G trials. The company works with partners such as Ericsson, Samsung, Nokia, and Intel. After Austin, TX, AT&T extended trials to Waco, TX, Kalamazoo, MI and South Bend, IN.

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 and AT&T's mm-wave 5G network for connectivity.

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.

AT&T was the first in the U.S. to announce the launch of a commercial standard-based mobile 5G network on 21 December 2018. 5G hotspots will be deployed in the dense urban areas of 12 cities: Atlanta, Charlotte, N.C., Dallas, Houston, Indianapolis, Jacksonville, Fla., Louisville, Ky., Oklahoma City, New Orleans, Raleigh, N.C., San Antonio and Waco, Texas. The service will extend in parts of 7 other cities in 2019: Las Vegas, Los Angeles, Nashville, Orlando, San Diego, San Francisco and San Jose, Calif.

The NETGEAR Nighthawk 5G Mobile Hotspot device runs on AT&T's 5G+ network over mm-wave spectrum. Customers outside of 5G+ network coverage will be able to use the device to access the best performing network in the country as well as AT&T's 5G Evolution networks (equipped with 256 QAM, 4×4 MIMO, and Multiple LTE Carrier Aggregation) available in 385 markets. The Nighthawk hotspot device will be available to customers for 499 USD upfront and a monthly 70 USD payment for 15 GB of data. This device requires an AT&T data plan compatible with 5G.

After launch of the AT&T 5G service in early 2019, the roll-out will be extended to 19 additional cities including Las Vegas, NV, Los Angeles, Nashville, TN, Orlando FL, San Diego, CA and San Jose, CA.

AT&T announced plans to grow its mobile 5G device lineup with a 5G smartphone from Samsung in the first half of 2019.

Sprint

Sprint, which could merge with T-Mobile US in 2019, disclosed a number of target markets ahead of its planned commercial launch in the first half of 2019. In February 2018, it named Atlanta, Chicago, Dallas, Houston, Los Angeles, and Washington DC as its initial wave of mm-wave 5G markets. Additional markets were revealed in May 2018, including New York City; Phoenix, AZ and Kansas City. Sprint will launch a first 5G LG smartphone in the USA by mid-year 2019.

While Sprint is still waiting the final approval for its merger with T-Mobile, it announced it will launch 5G commercial services in May 2019 in limited areas of four cities (Atlanta, Chicago, Dallas, Kansas City) to be extended to nine in 2019, including Washington DC and Los Angeles.

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 5G networks of AT&T and Verizon have been operating on millimetre wave spectrum since Q3 2018. The use of lower frequencies will allow Sprint to increase faster its coverage and at lower costs. At launch, the LG V50 ThinQ smartphone will be available. The operator also intends to offer the 5G-compatible Samsung Galaxy S10 later in summer 2019.

T-Mobile USA

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

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

T-Mobile announced to target mobile 5G launch by 2020 in Dallas, Las Vegas, Los Angeles, CA, New York City and in a number of other cities. It announced it will use its 600 MHz spectrum primarily and 28 and 39 GHz frequencies in the second stage. The idea behind is to be able to get high speeds with a broad coverage.

T-Mobile will launch 5G in the 600 MHz band in the second half of the year once compatible devices become available, and indicated it could deploy mm-wave 5G in urban centres as soon as the second quarter 2019.

2.4.4. South Korea

3.5 GHz and 28 GHz spectrum were auctioned off in South Korea in June 2018.

The February 2018 Winter Olympics in PyeongChang provided a stage for displaying 5G innovation. KT was very active. Samsung and KT provided a 4K streaming video service via a 5G network using 28 GHz spectrum. KT provided the 5G data network through a collaboration led by Intel with partners including Ericsson, Nokia and Alibaba, while Samsung unveiled its 5G mobile tablet device to deliver a 4K streaming video via Intel's base stations. KT demonstrated on its 5G network four types of data-heavy video streaming services: Sync view, Timeslice, 360 VR and Omnipoint view. KT also showed a 5G Connect Bus using 5G, capable of autonomous driving using Lidar sensors and the V2X technology. Hyundai demonstrated five Level4 autonomous cars on a 196 km trip to PyeongChang; the cars were connected to the KT 5G net for entertaining the passengers.

SK Telecom, LGU+ and KT launched their 5G service in a number of cities on 1 December 2018 for business customers. The launches came earlier than previously announced and thus expected. In fact, all MNOs announced in July 2018 their intention to jointly launch 5G in March 2019. This intention arrived one year after a first agreement signed in April 2018 on a shared 5G deployment and network. This first agreement's intention aimed at avoiding a very costly launch campaign when 4G came to reality back in 2011 and generating heavy cost savings of nearly 1 trillion KRW over the next ten years.

In early March 2019, the commercial launch was delayed following the rejection by the government of proposed 5G pricing plans submitted by operators.

SK Telecom indicated in March 2019 that the 5G rate plan is expected to cost KRW 55,000 (48 USD) per month for eight gigabytes (GB) of data.

It is expected that the deployment of nationwide 5G networks will be fully completed in 2022 or 2023.

Commercial launch of the 5G services by the three South Korean operators took place on April 5, 2019.

2.4.5. Japan

Historically, Japan has been at the forefront of mobile technology. Japan targets the Tokyo summer Olympic Games to launch 5G. However, NTT DoCoMo announced it could pre-launch 5G in September 2019 with plans to deploy commercial 5G services across Japan by mid-2020.

MIC is going to award in March 2019 six blocks of 100 MHz in the more desirable lower bands (3.7 GHz and 4.5 GHz), and four blocks of 400 MHz at 28 GHz.

NTT DoCoMo

A few months ago, NTT DoCoMo executives indicated that the Tokyo Summer Olympics were a target for 5G launch. This has been confirmed in June 2018 by Ms. Lan Chen, CEO of NTT DoCoMo Beijing Labs speaking at the MWC'18 in Shanghai. She announced a 5G "within 800 days", which should be in summer 2020. Assignment of 5G spectrum in Japan is expected by end of March 2019.

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

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

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

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

Softbank

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

KDDI

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

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

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

2.4.6. China

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

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

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

Time has accelerated significantly in 2018 and China Mobile brought forward its scheduled 5G launch by one year and finally plans to offer 5G services by year-end 2019 (pre-commercial launch in the course of 2019).

In December 2018, the Chinese government allocated spectrum for 5G national trials until June 2020 to players. 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.

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 Mobile

China Mobile started to conduct 5G trials during the second half of 2016. China Mobile plans to start offering 5G services in 2019, which is a year earlier than originally planned (2020). In 2018, China

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

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

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

China Unicom

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

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

China 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.

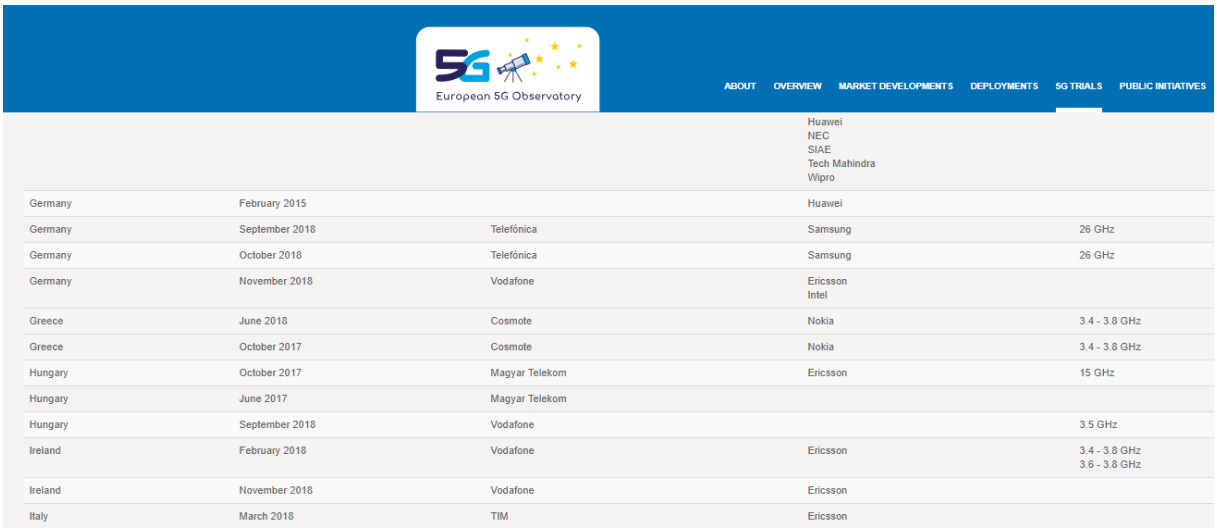
2.5. 5G pre-commercial trials

147 5G trials in the 28 MSs of the European Union, and 180 trials including Russia, San Marino, Norway, Turkey and Switzerland

2.5.1. Analysis of the 180 trials registered so far[5]

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



			Huawei NEC SIAE Tech Mahindra Wipro	
Germany	February 2015		Huawei	
Germany	September 2018	Telefónica	Samsung	26 GHz
Germany	October 2018	Telefónica	Samsung	26 GHz
Germany	November 2018	Vodafone	Ericsson Intel	
Greece	June 2018	Cosmote	Nokia	3.4 - 3.8 GHz
Greece	October 2017	Cosmote	Nokia	3.4 - 3.8 GHz
Hungary	October 2017	Magyar Telekom	Ericsson	15 GHz
Hungary	June 2017	Magyar Telekom		
Hungary	September 2018	Vodafone		3.5 GHz
Ireland	February 2018	Vodafone	Ericsson	3.4 - 3.8 GHz 3.6 - 3.8 GHz
Ireland	November 2018	Vodafone	Ericsson	
Italy	March 2018	TIM	Ericsson	

Source: IDATE DigiWorld, March 2019

As many as 180 trials have been listed so far throughout Europe. A little more than a third of the 180 trials are technical tests (58 trials). The share of technical tests dropped significantly in the past six months. The number of technical tests also decreased over the last quarter as mobile operators are now planning 5G network deployment.

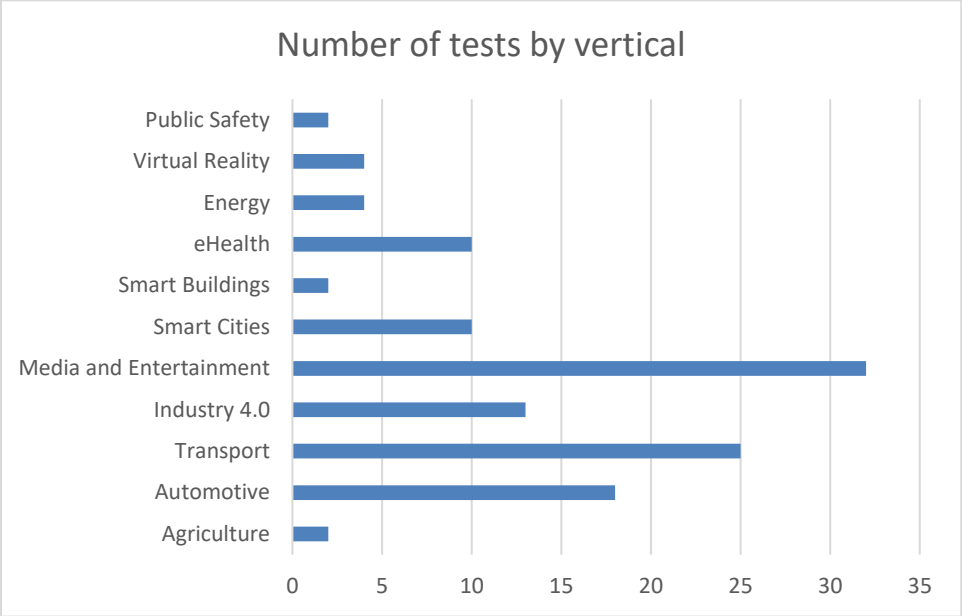
Media and automotive are the verticals majorly driving trials

The most trialled verticals are media and entertainment (32 trials) followed by transport (25 trials) and automotive (18 trials).

The 180 trials were organised in 28 countries (147 in 23 of the 28 EU MS and 33 in Russia, San Marino, Norway, Turkey and Switzerland). No trials have been reported so far in the following MSs: Czech Republic, Cyprus, Luxembourg, Malta, Slovakia and Slovenia.

[5] The analysis was made with the data available on the 5G Observatory on 1 April 2019

Figure 3: Verticals tested in 5G trials

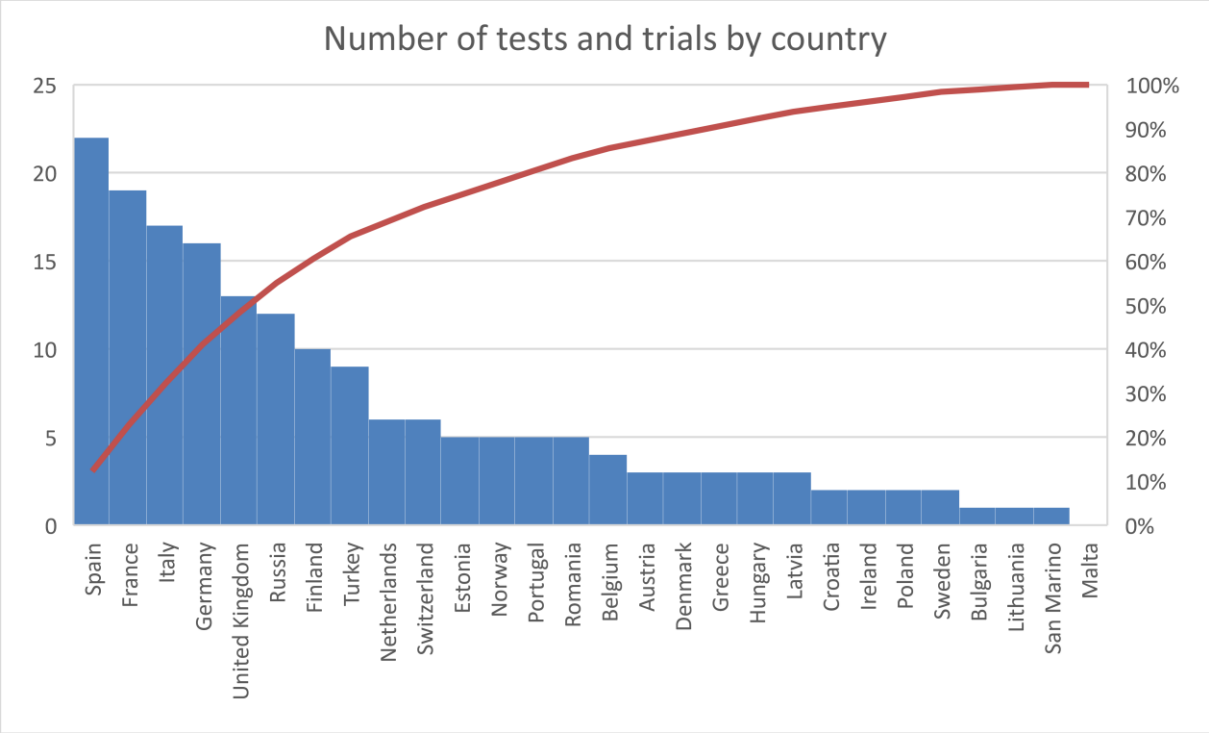


Source: IDATE DigiWorld, April 2019

The most numerous trials performed in Spain, France and Italy

The largest number of trials has been reported so far in Spain, France, Germany and Italy. These top four countries are totalling 40% of trials. Spain remains the first and France the second, however Italy has overpassed Germany in number of tests lately, pushing Germany to the 4th position.

Figure 4: 5G trials by country



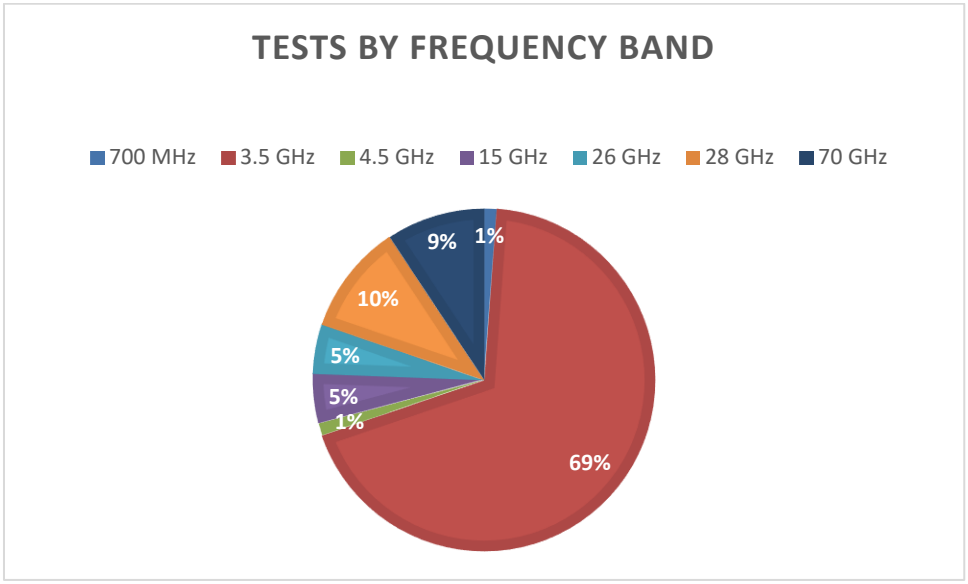
Source: IDATE DigiWorld, April 2019

On average, more than six trials by country have been listed so far.

The 3.4-3.8 GHz is again the most tested frequency band

When indicated (frequency bands tested are available only in selected trials, representing 47.7% of all trials listed), the most used frequency band for trials is by far the 3.6 GHz band (59 trials tested in the 3.4-3.8 GHz range out of 86 trials mentioning which band was considered). The 26 GHz band, which has been identified in four tests in Europe, is progressively gaining traction.

Figure 5: Frequency bands tested

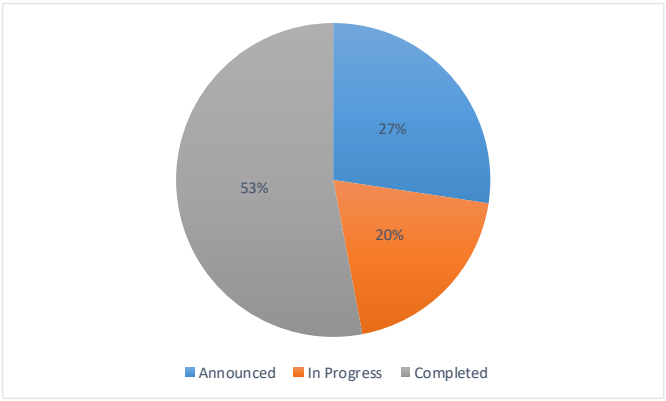


Source: IDATE DigiWorld, April 2019

More than half of the trials are completed

More than half of the trials are completed to date. Less than 1/3 (27%) of trials have been announced or planned. The rest are still in progress.

Figure 6: Status of 5G trials in Europe



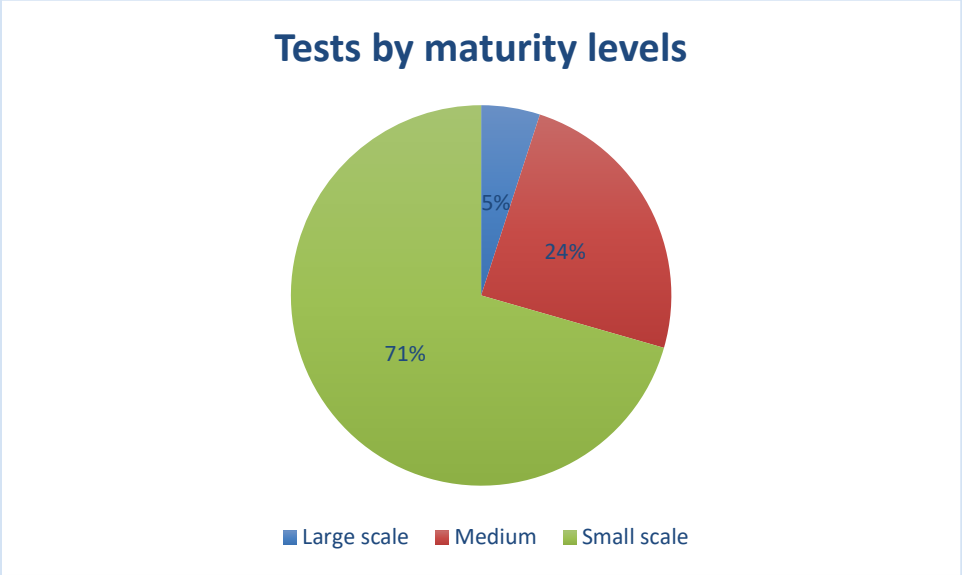
Source: IDATE DigiWorld, April 2019

Level of maturity of 5G trials

We evaluate the level of maturity according to three categories:

- 1: Most important 5G pilots: with at least two 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)

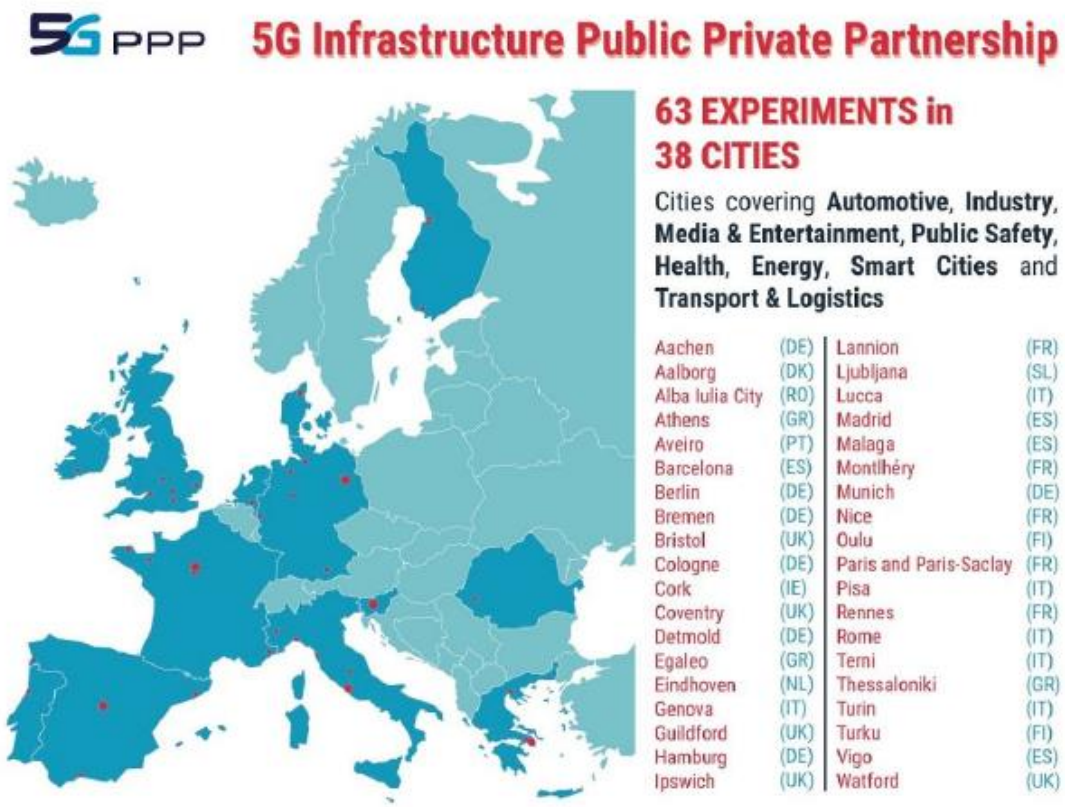
Figure 7: Level of maturity of trials



Source: IDATE DigiWorld, April 2019

The Elisa trial in Finland and the Austrian T-Mobile launch in March 2019, are the most important 5G pilots/deployments. Only 5% of the trials get a category 1. The vast majority of trials (71%) can be qualified as category 3 (small tests or demonstrators), and one fourth of them can be considered as intermediate (category 2).

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 with eleven cities in Paris's suburbs (including Paris, Châtillon, Linas-Monthléry and Saclay). Major trials take 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.

2.5.3. Digital cross-border corridors

Ten "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 Driving (CAD) is considered as a flagship use case for 5G deployment along European transport paths, in view of creating complete ecosystems around vehicles, beyond the safety services targeted by the Cooperative-Intelligent Transport System (CITS) roadmap of Europe.

This has led to a high-level agreement, in March 2017, between MSs at ministerial level, facilitated by the Commission, where MSs agree to intensify cooperation for the establishment of cross-border corridors for large-scale testing and early-deployment of 5G connectivity infrastructure for connected and automated vehicles.

In 2017, five digital cross-border corridors were announced and established live tests of 5G:

- Metz-Merzig-Luxembourg (France, Germany, Luxembourg)
- Rotterdam-Antwerp-Eindhoven (Netherlands, Belgium, Netherlands)
- Porto-Vigo and Merida-Evora (corridor Lisbon – Madrid),
- The E8 "Aurora Borealis" corridor between Tromsø (Norway) and Oulu (Finland) and
- The "Nordic Way" between Sweden, Finland and Norway

This list of corridors has been expanded during the EC Digital Day in April 2018 with announcements to work to develop corridors between:

- Spain and Portugal signed a Letter of Intent to have two joint corridors between Vigo and Porto and between Evora and Mérida.
- Greece, Bulgaria and Serbia to expand the corridor Thessaloniki-Sofia-Belgrade.
- On the Brenner pass motorway towards Italy (the Brenner motorway connects Innsbruck in Austria to Modena in northern Italy).
- Poland and Lithuania signed a letter of intent on 5/9/2018 to cooperate on technical, legal and policy of the cross-border CAD corridor 'via Baltica' (Warsaw, Kaunas, Vilnius) and Lithuania, Latvia and Estonia signed a memorandum of understanding for the 'Via Baltica - North'.

Table 4: 5G CAM cross-border corridors

Corridors	Political Commitment
Metz-Merzig-Luxembourg: FR-DE-LU	LoI between FR and DE in Sept. 2016. LU joined in Sept. 2017. Industry consultation in March 2018. Agreement for testbed signed.
Rotterdam-Antwerpen-Eindhoven: NL-BE	No LoI signed yet
Porto-Vigo, Evora-Merida: PT-ES	LoI signed on Digital Day 2018, 10 April 2018
E8 "Aurora Borealis": NO-FI	C-ITS-TEN-T legacy. First 10km Aurora open in FI for testing since Nov. 2017. LoI not yet signed
Nordic Way2: NO-SE-FI-DK	Follows-on Nordic Way 1, funded under C-ITS/CEF, which demonstrated that providing C-ITS services over cellular networks works.
Brenner Corridor: IT-AT-DE	Ahead of DD2, Italy and the three presidents of Euroregion 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.
Thessaloniki, Sofia-Belgrade: EL-BG-RS	Letter of Intent signed in June 2018 during Digital Assembly in Sofia.
EE-LV-LT Via Baltica (E67) Tallinn (EE) – Riga (LV) – Kaunas (LT) – Lithuanian/Polish border	MoU to be signed on 27-28 Sept. 2018 in Riga at the 5G Techritory event. Although focused on C-V2X, elements of the Riga-Tallinn segment are ITS (Smart E67 project).
LT-PL Via Baltica Kaunas-Warsaw	LoI Signed on 5 Sept. 2018. Goal is to cooperate in V2X, C-ITS, 4G LTE, LTE Advanced and 5G with the view to promote CAD.

Source: European Commission

2.6. 5G cities

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

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

These trial cities aim to provide support for 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 program 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, become a 5G smart city. 5GBarcelona will have 5 nodes, to which more will be added until reaching a deployment of 20% of the territory in 2020.
- The city of **Berlin** aims to stipulate research and development of 5G technologies, and one of the city's main strategic interest is to enable an innovation-stipulating environment and technology infrastructure, which can eventually provide the 5G experience to the public on the streets of Berlin.
- The City of **Oulu** is challenged to modernize the city governance and processes in the framework of constrained public expenditure and demand for deploying disruptive technologies enabling digitization, automation and robotisation in public service delivery. One of the main strategic priorities is to enhance innovation led economic growth and competitiveness of the local economy and companies to create employment outcomes for the people of Oulu, in order to ensure sustainable and healthy living environment. Arranging broadband connectivity (eMBB) and providing local free 5G network services network for mobile IoT based experiments is the first step to adopt the 5G technologies for citizens and city administration. City also targets people mobility related service trials and offers e.g. traffic-light data as open data for service development…
- Similarly, the City of **Patras** is aiming at organizing, transforming and finally extending its current digital infrastructure into an open platform that will interconnect 5G related technologies. This digital transformation is performed in order to address e-administration issues related to the City of Patras while enhancing the quality of life of its citizens.
- City of **Bristol** as one of the main UK 5G Hub sites, together with University of Bristol, aims especially to demonstrate the 5G technologies for public. The Bristol target has been mainly

to show the potential of 5G in shaping the future of social interaction, entertainment, urban planning and public safety. The similar events as "Layered Realities - Weekend", arranged in March 2018, are planned for near future. The promotional video from the event is also available. Bristol alongside with Bath will be the home of enhanced visual experiences for tourists using Augmented Reality and Virtual Reality in major local attractions as part of the 5G Smart Tourism project which was awarded GBP5 million in March 2018.

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

We estimate that there were 30 5G enabled cities at the end of March 2019: 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 Observatory:

- Belgium: Ghent
- Estonia: Tallinn
- Finland: Espoo, Oulu
- France: 5 cities in 2019
- Germany: Berlin
- Greece: Kalamata, Patras, Trikala (9/2019), Zografou (12/2018)
- Hungary: Budapest, Zalaegerszeg
- Italy: Bari, l'Aquila, Matera, Milan, Prato, Turin
- Netherlands: Amsterdam
- Poland: Gliwice, Łódź, Kraków, Warszawa
- Portugal: Aveiro
- Spain: Barcelona, Madrid, Malaga
- Sweden: Umea, Kista/Stockholm
- United Kingdom: Bristol, London

2.7. Spectrum assignment by public authorities

5G pioneer bands identified at EU level are the 700 MHz, the 3.6 GHz (3.4-3.8 GHz) and the 26 GHz (24.25-27.5 GHz) frequencies. Whereas the 700 MHz band has been harmonised through an EC Implementing Decision (EU) 2016(687) of 28 April 2016, a '5G-ready' amendment of the 3.6 GHz implementing decision has been adopted in January 2019[6]. The European Commission is about to adopt a harmonisation decision for the 26 GHz band in Q1 2019[7].

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

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

2.7.1. Review of spectrum assignment progress

At least one auction has been completed or is ongoing for one of the three pioneer bands as at March 2019.

In thirteen MSs at least one spectrum auction is complete or ongoing as at end March 2019. The Swedish auction for 700 MHz frequencies took place in December 2018.

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

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

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

In the mm-wave bands, only Italy has so far assigned spectrum in the 26 GHz band.

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

[7] ECC PT1 issued two CEPT reports (Report 67 on 3.6 GHz and Report 68 on 26 GHz) on '5G-ready' technical harmonisation measures in July 2018 in response to a Commission mandate of 2016. EC regulations will be based on these two reports.

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

The auction procedure in at least one spectrum band is scheduled for 2019 in fourteen MSs:

- Austria: 3.4-3.8 GHz,190 MHz in 3.4-3.6 GHz and 200 MHz in 3.6-3.8 GHz, March 2019
- Belgium, 700 MHz in Q3-Q4 2019, 3.6-3.8 GHz in Q3-Q4 2019, 400 MHz in 2019, 1.5 GHz in 2019
- Czech Rep., 700 MHz and 3.5 GHz in 2019
- Estonia, 3.6 GHz, Q2 2019
- France, 3.6-3.8 GHz, Q4 2019
- Germany, 2 GHz/3.4-3.8 GHz March/April 2019
- Greece, 3.4-3.8 GHz, Q4 2019. A public consultations on the 3.6 GHz band should take place in 2019 and 26 GHz in 2019/2020.
- Hungary, 700 MHz/3.5 GHz, Q3 2019
- Ireland, 700 MHz, 2019
- Luxembourg: 700 MHz and 3.6 GHz, 2019
- Netherlands, 700/1400/2100 MHz, late 2019. 700 MHz late-2019 or early-2020
- Lithuania, 3.-3.8 GHz, 2019
- Portugal, 700 MHz, Q4 2019
- Romania, 700 MHz and 3.6 GHz, 2019

Spectrum auctions scheduled as from 2020

- Denmark, 700 MHz, 2020 (2x30 MHz + 20 MHz in 700 MHz frequencies, 2x30 MHz in 800-900 MHz frequencies, 100 MHz in 2300-2400 MHz frequencies, initially scheduled in September 2018, postponed). The 3.5 GHz band will be auctioned from 2020, and later on the 26 GHz band.
- Finland, 26 GHz, spring 2020
- France, 26 GHz, 2020
- Lithuania, 700 MHz before 2022
- Malta, 700 MHz, mid-2021
- Poland, 700 MHz, 2020
- Slovakia, 26 GHz, after July 7, 2021
- Spain, 700 MHz, Q1 2020
- UK, 3.6-3.8 GHz, 2020

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 amount of spectrum potentially available for very high capacity, very high data rates but limited coverage, partially offset by massive MIMO. The 26 GHz band (24.25 – 27.5 GHz) is the pioneer high band for 5G in Europe.

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

Usability of low-band (700 MHz) spectrum

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

Germany was the first European country to assign 700 MHz spectrum in June 2015. To date, only five MSs have assigned 700 MHz spectrum: Germany, France, Finland, Italy and Sweden. The Swedish 700 MHz auction process took place in December 2018.

Table 5: Availability of 700 MHz spectrum in Member States (as of end March 2019)

Member State	Frequencies	Tentative/Expected assignment date Date of completion	Comments
Austria	703-733/758-788 MHz	Q2 2019 at the earliest	
Belgium	703-733/758-788 MHz	Q3-Q4 2019	
Bulgaria	703-723/758-778 MHz	Unknown	2x20 MHz release for 5G
Croatia		n/a	EC issued a decision on 8 November 2018 to initiate proceedings against Croatia
Cyprus		n/a	
Czech Rep.	703-733/758-788 MHz		The band will be released on 30 June 2020
Denmark	703-733/758-788 MHz	March 2019	Assigned in March 2019, with use expected from April 2020
Estonia	703-733/758-788 MHz	n/a	
Finland	703-733/758-788 MHz	November 2016	5G services in 2019
France	703-733/758-788 MHz	December 2015	5G services in 2019/2020
Germany	703-733/758-788 MHz	June 2015	5G services in 2019/2020
Greece	703-733/758-788 MHz	End 2020	
Hungary	703-733/758-788 MHz	Q3 2019	
Ireland	703-733/758-788 MHz	2019	
Italy	703-733/758-788 MHz	October 2018	5G services possible in 2022 due to TV use
Latvia	703-733/758-788 MHz	January 1, 2022	
Lithuania	703-733/758-788 MHz	Before 2022	
Luxembourg	703-733/758-788 MHz	H2 2019	
Malta	703-733/758-788 MHz	June 2021	Availability date for 5G commercial use
Netherlands	703-733/758-788 MHz	Late-2019 or early-2020	EC issued a decision on 8 November 2018 to initiate proceedings against the Netherlands
Poland	703-733/758-788 MHz	2020	
Portugal	703-733/758-788 MHz	Q4 2019	
Romania	703-733/758-788 MHz	Q3-Q4 2019	"National Strategy for the Implementation of 5G in Romania" between November 20th and December 21st, 2018
Slovakia	703-733/758-788 MHz	After 30 June 2020	The band will be released after 30 June 2020
Slovenia	703-733/758-788 MHz	n/a	
Spain	703-733/758-788 MHz	Q1 2020	
Sweden	703-733/758-788 MHz	December 2018	40 MHz assigned
UK	703-733/758-788 MHz	2020	

Source: IDATE DigiWorld, based on NRA information

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

3.4-3.8 GHz spectrum already assigned in 9 Member States: Austria, Czech Republic, Finland, Hungary, Ireland, Italy, Latvia, Spain and United Kingdom. Auctions are going on in Germany in early April 2019.

3.4-3.8 GHz spectrum has been assigned[8] in 2016 in Hungary, in May 2017 in Ireland, in Czech Republic in 2017, in April 2018 in the United Kingdom, in July 2018 in Spain and (the upper half of the band) in September 2018 in Italy. Parts of 3.4-3.8 GHz spectrum were awarded in Latvia in November 2017 and September 2018. Finland assigned the 3.6 GHz band in September 2018. In March 2019, Austria assigned 3.6 GHz spectrum. The 3.6 GHz auctions started in Germany in March 2019.

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

[8] Parts of this frequency band is used for 4G fixed wireless access

Table 6: Availability of 3.4-3.8 GHz spectrum in Member States (as of end March 2019)

Member State	Frequencies	Tentative/Expected assignment date Date of completion	Comments
Austria	3410-3800 MHz	March 2019	Four months after approval of the May 2018 tender document (period of approval not limited by law)
Belgium	3400-3800 MHz	Q3-Q4 2019	700, 1400, 3600 MHz spectrum concerned Renewal of existing licences to expire in March 2021 in 900, 1800 and 2600 MHz
Bulgaria	3400-3800 MHz	Initially planned in 2018	n/a
Croatia	n/a	n/a	n/a
Cyprus	n/a	n/a	n/a
Czech Rep.	3600-3800 MHz 3400-3600 MHz	July 2019 2017	
Denmark	n/a	2020	n/a
Estonia	3400-3800 MHz	n/a	Auction expected in Q2 2019 for 390 MHz of spectrum
Finland	3400-3800 MHz	Sept. 26, 2018	
France	3600-3800 MHz	Mid-2019	Public consultation in October 2018
Germany	3700-3800 GHz	March-April 2019	Full availability in 2022, early stage in 2019
Greece	3400-3800 MHz	Q4 2019	n/a
Hungary	3400-3600 MHz 3600-3800 MHz	June 2016 (90 MHz) Q3 2019	For 4G. New technical criteria to be elaborated for 5G
Ireland	3410-3435 MHz and 3475-3800 MHz	May 2017	Available from January 2019
Italy	3600-3800 MHz	September 2018	
Latvia	3400-3800 MHz	November 2017 October 2018	 Remaining 50 MHz
Lithuania	3400-3800 MHz	2019	Public consultation in Q2 2018 including the 3800-4200 MHz band. New public consultation in Q3 2018
Luxembourg	3600 MHz	H2 2019	Public consultation in Q3 2018
Malta	n/a	n/a	Public consultation in Q2 2018
Netherlands	3400-3800 MHz	n/a	n/a
Poland	3400-3600 MHz 3600-3800 MHz	n/a n/a	Public consultation in Q3 2018
Portugal	n/a	n/a	n/a
Romania	3400-3800 MHz	Q3-Q4 2019	n/a
Slovakia	3400-3600 MHz 3600-3800 MHz	July 2015 2017	Not for 5G. Licences until 2025.
Slovenia	n/a	n/a	n/a
Spain	3400-3600 MHz 3600-3800 MHz	2016 July 2018	160 MHz assigned for 4G (and usable for 5G) For 5G
Sweden	3400-3800 MHz	2019?	
UK	3400-3600 MHz 3600-3800 MHz	April 2018 2020	150 MHz assigned in the 3.4-3.6 GHz band

Source: IDATE DigiWorld, based on NRA information

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

26 GHz spectrum is assigned in Italy

Italy was the first Member State to auction 1 GHz of the 26 GHz band; at world level, it ranks second, after South Korea, which already awarded 2,400 MHz spectrum at 28 GHz in June 2018. The USA will likely rank third globally with 1550 MHz of such spectrum. The FCC started auctioning 28 GHz spectrum on November 14th, 2018, a few weeks later than Italy. The auction of 24 GHz frequencies will start just after closure of the 28 GHz auction.

Table 7: Availability of 26 GHz spectrum in Member States (as of end March 2019)

Member State	Frequencies	Tentative/Expected assignment date Date of completion	Comments
Austria	n/a	n/a	
Belgium	n/a	not before 2021	
Bulgaria	n/a	n/a	
Croatia	24.25-27.5 GHz	n/a	
Cyprus	n/a	n/a	
Czech Rep.	n/a	n/a	
Denmark	n/a	2020	
Estonia	n/a	n/a	
Finland	26.5-27.5 GHz	Spring 2020	Parts of the range are already available for shared use
France	26.5-27.5 GHz	2019	Public consultation in Q2 2018
Germany	26.5-27.5 GHz	2019	General authorisations
Greece	n/a	n/a	
Hungary	26.5-27.5 GHz	Q3 2019	
Ireland	n/a	n/a	Spectrum assigned in 2017 but restricted to point-to-point (P2P) links
Italy	26.5-27.5 GHz	September 2018	
Latvia	n/a	n/a	
Lithuania	n/a	n/a	
Luxembourg	n/a	H2 2020	
Malta	n/a	n/a	
Netherlands	n/a	n/a	
Poland	26.5-27.5 GHz	n/a	Band reorganisation envisioned
Portugal	n/a	n/a	
Romania	26.5-27.5 GHz	2020	
Slovakia	26.5-27.5 GHz	Will be assigned after July 7, 2021	
Slovenia	26 GHz	January 2018	Two blocks (56 and 112 MHz) awarded, but not available for 5G
Spain	n/a	2020	Potential rearrangement. 1.4 GHz of spectrum could be assigned
Sweden	26.5-27.5 GHz	2020	Auction process considered
UK	26.5-27.5 GHz	2020	Call for inputs in July 2017

Source: IDATE DigiWorld, based on NRA information

2.8. Product/market developments

2.8.1. Chipsets

As of end of March 2019, several 5G basebands have already been announced and should be integrated in products to be released as soon as in 2019 for the earliest device manufacturers.

Qualcomm, with its X50 modem was the first to announce its initiative, back in the end of 2016 and is today probably the most advanced player in terms of product availability, probably followed by Samsung, who announced its 5G baseband in August 2018 but with a much more integrated offering. As compared to Qualcomm, Samsung is indeed proposing, what it considers as the first integrated multimode 2G/3G/4G/5G baseband. The Qualcomm X50 module must be used together with a 2G/3G/4G baseband for Non-Standalone Operation.

In February 2019, Qualcomm unveiled the Snapdragon X55, its second-generation 5G modem, which supports all generations from 2G to 5G, all frequency bands from sub-1 GHz to mm-wave bands and both standalone (SA) and non-standalone (NSA) deployments.

As can be seen in Table 8 below, besides Qualcomm and Samsung, also Intel, Huawei, through HiSilicon, and Mediatek have also announced their 5G initiatives in terms of baseband. At the Mobile World Congress in February 2018, Huawei had announced, through its subsidiary Hi-Silicon, its own 5G baseband called Balong 5G01, a chipset that Huawei claimed to be the first 5G commercial chipset, a claim that is true if we consider it is effectively used in Huawei own 5G CPE but that doesn't reveal the level of maturity of the product. While both Qualcomm and Samsung chipsets support a throughput up to more than 5 Gbps in the mm-waves, Huawei Balong 5G01 currently supports a maximum throughput of 2.3 Gbps.
As for Intel and Mediatek, both players seem to lag behind in terms of product readiness. At MWC 2018, Intel was showcasing a solution still based on FPGAs, highlighting the integration steps still required for readily available and embeddable silicon. Mediatek seems to be in comparable situation, although much less is known about the development status of its Helio M70 5G baseband.

Table 8: Presentation of announced 5G chipsets

Vendor	Product name	Announcement	Availability	Bands	Throughputs
Qualcomm	X50 (baseband)	First announced in 2016	End of 2018	Sub 6 GHz and 28 GHz	Up to 5 Gbps
Qualcomm	X55 modem	February 2019	S1 2019	Sub 6 GHz and mm-waves	Up to 7 Gbps downlink and 3 Gbps uplink
Intel	XMM 8160	November 2018	2nd half of 2019	Sub 6 GHz and mm-waves	6 Gbps
Samsung	Exynos 5100	August 2018	End of 2018	Sub 6 GHz and mm-waves	Up to 2 Gbps in sub-6 GHz and 6 Gbps in mm-waves
Hi-Silicon/ Huawei	Balong 5G01	February 2018	End of 2018	Sub 6 GHz and mm-waves	Up to 2.3 Gbps

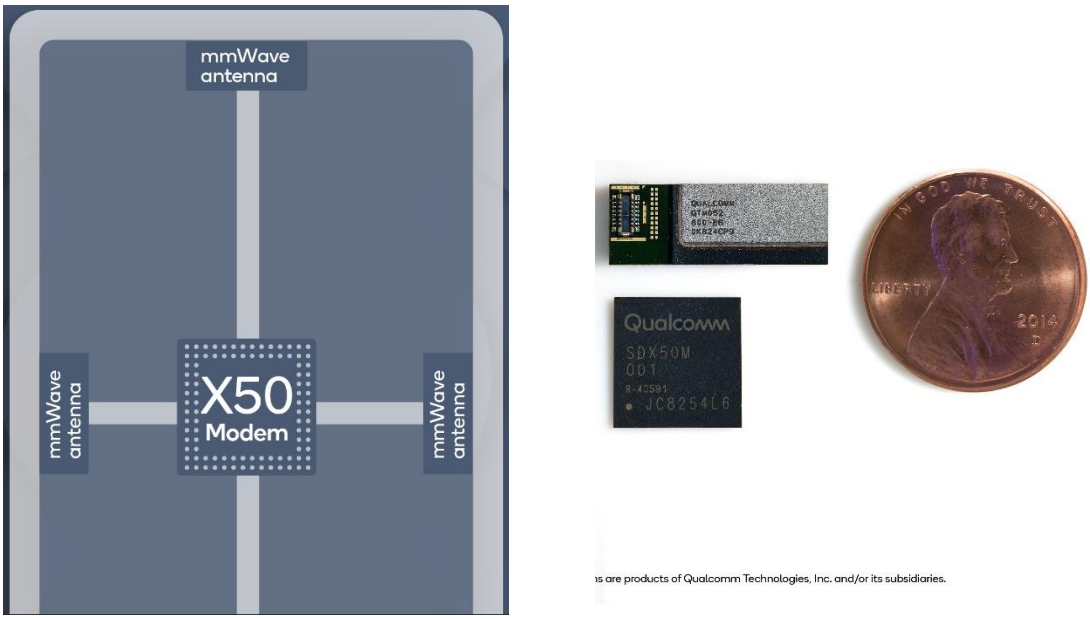
Vendor	Product name	Announcement	Availability	Bands	Throughputs
Hi-Silicon/ Huawei	Balong 5000	January 2019	2019	Sub 6 GHz and mm-waves	Up to 4.6 Gbps
Mediatek	Helio M70	June 2018	2019-2020	Sub 6 GHz and mm-waves	Up to 5 Gbps

Source: IDATE DigiWorld, March 2019

On paper, those chipset seem fairly similar, with support for 5G NR radio interface, both in Non Standalone (NSA) and Standalone, up to 8 channel aggregation, 256 QAM modulation in the downlink and support for both sub-6 GHz frequency bands and mm-waves. Because more bandwidth is available in the mm-waves than in the sub-6 GHz band, possible performance differs depending on the frequency band used. The announcement of Qualcomm, that 20 OEMs were working on implementing products based on the Snapdragon X50, highlights how Qualcomm seems to be ahead in the race to enabling 5G mobile devices.

A specific challenge with 5G for chipset manufacturers is the support of mm-waves because of the possibility for the hand, body, or any obstacle to easily block mm-wave signal. In order to circumvent this issue, Qualcomm has developed a new antenna module called QTM052 that brings support for mm-waves. In order to maintain connectivity, four of those modules are required in a device, so that whenever one antenna is blocked by something, another one can continue to receive a signal through a different path.

Figure 8: Layout of QTM052 mm-wave antenna module in a smartphone form factor



Source: Qualcomm

The first smartphone to integrate this complete solution from Qualcomm (5G baseband + mm-wave Radio Front-End) will be the Motorola Z3 announced in August 2018. 5G connectivity, however, will only be available as an additional “mod” to be purchased when available at the beginning of 2019. The

fact that a separate module is required shows that integration within mobile device is not yet over but still, that readiness of commercial 5G mobile devices will come closer than initially expected.

Noteworthy, the integrated strategy of players such as Samsung and Huawei, is to develop their modem (and other chipsets) internally. This strategy has started a few years ago and is now beginning to bear its fruits with, at least according to the promises, truly capable products. Essentially, this strategy enables a shorter Time-To-Market, but it is also aimed at reducing the dependence on players such as Qualcomm and eventually at tailoring better chipsets to the device manufacturing needs, and possibly providing more differentiation.

2.8.2. Devices

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 9: The steps a device takes to market

Source: IDATE DigiWorld, September 2018

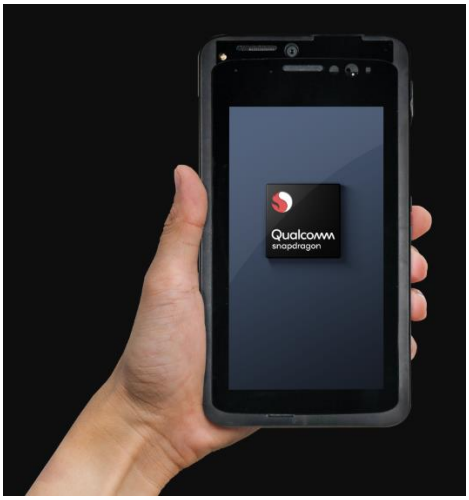
This time, with 5G, Fixed Wireless Access is one of the first use cases, rather than mobile usage and first commercial devices announced have been 5G home routers, such as the one announced by Huawei at MWC 2018 in Barcelona, or the one by Samsung more recently. Those early devices have been more specifically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

Figure 10: Huawei and Samsung 5G home routers for 5G Fixed Wireless Access

Source: Huawei and Samsung

Those first devices are available in indoor and outdoor versions. It is questionable whether they can be considered as true commercial devices because of not being openly available, and as the networks they have been designed for have not yet been launched. However, their development seems to be over, which is a good indication that the building of an end-to-end 5G device ecosystem is starting.

Figure 11: Qualcomm development platform used for demonstrating OTA call handover at 37 GHz



Source: Qualcomm

In terms of mobile device, one mobile hotspot from Huawei has been spotted at MWC 2018 but this may very well only be dummy device to illustrate future devices in preparation. The biggest challenge at this stage is to make the difference between prototypes and fully ready devices. As mentioned, earlier, Huawei and Samsung have been able to present devices earlier because of the shorter Time-To-Market than the development of their own 5G baseband has enabled.

Figure 12: Motorola Z3 functioning with a 5G mod

Source: Motorola

In August 2018, Motorola presented what they call a 5G upgradable device, the Motorola Z3. Like other Motorola devices, this smartphone supports add-ons developed by Motorola as an extension of the device. With the 5G mod, Motorola Z3 users will be able to support Verizon 5G mobile network that is to be launched in the beginning of 2019. While pictures have been provided to the press and devices displayed, no one has been able to test this “mod”.

It is thus clear that this announcement is more a marketing move from Motorola and Verizon than a real breakthrough. By the time this mod will be launched in early 2019, it is not impossible that other smartphones from other vendors with more integrated 5G connectivity will have been announced. LG notably has also announced that it would bring the first 5G smartphone in the US.

Figure 13: LG will work with sprint to launch its 1st 5G smartphone in the US

Source: Sprint

In the table below, we list the 5G devices that have been announced or presented so far. While it may seem limited at this stage, it should grow up rapidly, as commercial network are officially launched. Qualcomm has already announced that 30 OEMs so far were working on implementing Snapdragon X50 and X55 in their device. With 5G network official launch in South Korea in March/April 2019[9], smartphones from other vendors, notably Samsung and LG are likely to be announced.

Many announcement from device vendors were made during Mobile World Congress in February 2019 and are reported in Table 9 below.

Table 9: List of 5G devices announced or presented

Vendor	Product name	Baseband	Comment
HTC	HTC 5G Hub	Qualcomm	HTC announced a partnership with Sprint in November 2018 for the provision of a 5G mobile hot-spot, which it plans to launch in H1 2019
Huawei	Huawei 5G CPE Pro	Huawei	Announced in January 2019, the 5G CPE Pro supports both sub-6 GHz and mm-wave bands.
	Huawei Mate 30 series	Huawei	Should be available in the second half of 2019
	Huawei Mate X	Huawei	This foldable smartphone was announced during MWC'19
Intel	2-in-1 PC 5G prototype	Intel prototype	2 in 1 PC concept supporting the 28 GHz band
LG	LG V50 ThinQ smartphone		The LG V50 will be available in May 2019 for Sprint' subscribers in the USA.
Motorola	Z3	Qualcomm	Mid-tier smartphone with 5G connectivity available with an additional module to be purchased separately early 2019. Will be sold by Verizon
Netgear	Nighthawk 5G mobile hotspot	Qualcomm	Announced in October 2018. Will support mm-wave bands for AT&T

[9] The three Korean MNOs announced in December 2018 the launch of 5G services for enterprises

Vendor	Product name	Baseband	Comment
OnePlus	n/a	Qualcomm	Planning to launch a model with UK operator EE in H1 2019
OPPO	FindX 5G?	Qualcomm	Planned for H1 2019
Samsung	Samsung Outdoor CPE	Samsung	Indoor and outdoor Home router. 2x2 MIMO with each antenna having 32 antenna elements.
Samsung	Galaxy F Foldable	Samsung	This foldable smartphone was announced during MWC'19
Samsung	Galaxy S10 5G	Samsung	Planned for US operators AT&T and Verizon in 2019
Sony	Xperia X23?		
TCL	TCL Alcatel 7	Qualcomm	Planned for H1 2019
VIVO	Vivo Nex	Qualcomm	Planned for H1 2019
Xiaomi	Mi Mix 3 5G	Qualcomm	Planned for H1 2019
ZTE	Axon 10 Pro 5G	Qualcomm	5G "smart terminals" to be launched end of 2018 / early 2019

Source: IDATE based on announcements (April 2019)

Other OEMs such as Asus, HMD, inseego, Netcomm Wireless, Sierra Wireless, Telit, WingTec and WNC have signed an agreement with Qualcomm to use the manufacturer's chipset. Sharp, Fujitsu and Sony are currently working for the Japanese market. Apple is expected to wait until 2020 before launching a 5G iPhone.

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 are often focused on pieces of technologies or concepts, such as Massive MIMO, the use of mm-wave in different mobility scenarios…

As industry efforts have now resulted in early (and accelerated) standardization of the technologies and as first operators are now preparing for network launch by the end of the year 2018 or early 2019, most equipment vendors have built and presented a 5G solution so that first networks can start to be deployed, even though commercial devices are not there yet.

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 not finalized version of the standard, or as is the case of

network operator having built a pre-standard (such as Verizon with the 5GTF). As 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, beamforming 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, early deployments are likely to be in this band rather in the 26 GHz band, because of its better coverage capabilities and the feeling of operators that they are not yet running out of capacity (as compared to the U.S. for instance)

Below, we present the 5G portfolio of each equipment manufacturer. Their claim is often similar and as for device baseband, those claims can be seen through different angles. Table 10 below summarises what stands out from each vendor solution:

Table 10: Infrastructure equipment 5G solutions from major vendors

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

Source: IDATE DigiWorld, March 2019

5G infrastructure contracts announcements

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

Table 11 : 5G infrastructure contracts

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

Source: IDATE DigiWorld, March 2019

3. Annexes

3.1. National strategies and plans by MS

3.1.1. Austria

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, Q2 2019 at the earliest.

5G Strategy for Austria, April 2018.

All MNOs started 5G trials.

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

The Austrian Government set up a steering group for 5G in February 2017. The "5G strategy for Austria" document was approved in April 2018.

The document defines three phases:

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

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

3.1.2. Belgium

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.

3.1.3. Bulgaria

5G border corridor Bulgaria, Greece, Serbia.

The Communications Regulation Commission (CRC) of Bulgaria closed a public consultation on frequency allocations in October 2017. It proposed to sell eight blocks of 5 MHz in the 1.5 GHz band (1452-1492 MHz), three paired blocks of 5 MHz in the 2 GHz band (1920-1935 MHz/2110-2125 MHz), 14 paired 5 MHz blocks of frequency division duplex (FDD) spectrum in the 2.6 GHz band (2500-2570 MHz/2620-2690 MHz), ten blocks of 5 MHz TDD spectrum in the 2.6 GHz band (2570-2620 MHz), 34 blocks of 5 MHz in the 3.6 GHz band (3430-3600 MHz) and further 22 blocks of 5 MHz TDD in the 3.6 GHz band (3645-3700 MHz and 3745-3800 MHz).

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.

3.1.4. Croatia

Strategy for Broadband Development in Croatia 2016-2020.

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

A round table on "introduction of the 5G network in Croatia" was held in May 2018.

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

3.1.5. Cyprus

Cyprus Broadband Plan 2016-2020.

Consultation in September 2015 for 800 MHz, 2600 MHz and 3600 MHz spectrum.

In 2016, the Cyprus Broadband Plan 2016-2020 was published; it covers broadband action plans and strategic objectives for 2016-2020.

3.1.6. Czech Republic

National Plan for the Development of Next Generation Networks 2016-2020.

3.7 GHz spectrum auctioned off. Spectrum auctions in the 700 MHz and 3.5 GHz frequencies scheduled for 2019.

The Government of the Czech Republic adopted the National Plan for the Development of Next Generation Networks in October 2016.

The Czech Telecommunication Office (CTU) auctioned off 3.7 GHz spectrum in 2017 to four bidders, including two new players:

- Telecom 5G: two 40 MHz blocks 3720-3760 MHz and 3760-3800 MHz
- O2 Czech Republic: one block 3680-3720 MHz
- PODA: 3640-3680 MHz
- Vodafone Czech Republic: one block 3600-3640 MHz

Each 40 MHz block was sold for CZK 203 million (9.2 million USD), for a total of CZK 1.015 billion.

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

Consultation for the 3.4-3.6 GHz band took place from June 2018 until January 2019.

At the beginning of 2019, CTU gave more details on the 5G auction that includes the 700 MHz and the 3.4-3.6 GHz bands for consultation until 25 January 2019. CTU indicates the auction would take place in the second half of 2019 and be completed at the beginning of 2020 at the latest.

3.1.7. Denmark

A public consultation for the Danish award of spectrum in the 700 MHz, 900 MHz and 2300 MHz bands took place in March 2018. An action plan has been defined early in 2018. It has to be approved by the Minister before year-end 2018.

In March 2018, the Danish Energy Agency launched a consultation (including a draft Information Memorandum) for the auction of spectrum licences in the 700 MHz, 800-900 MHz and 2300-2400 MHz bands. As a result of the consultation, the process was scheduled for 25 September 2018 and postponed until further notice at the beginning of September 2018.

The national 5G plan was published in February 2019.

The plan says 5G is expected to be introduced on the 3.5 GHz band from 2020, and later on the 26 GHz band.

In March 2019, Denmark has completed its auction of the 700, 900 and 2,300 MHz bands, raising total proceeds of DKK 2.21 billion (EUR 296 million). Use of the 700 MHz band is expected from April 2020.

3.1.8. Estonia

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

In January 2019, the Minister of Enterpreneurship 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. The auction for 390 MHz of spectrum in the 3.6 GHz band should take place in Q2 2019.

3.1.9. Finland

Early award of trial licences to a large number of companies (October 2015-October 2017).

The 700 MHz band frequencies 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 scheduled took place in September 2018.

Elisa, first 5G network in Europe launched in June 2018.

Early award of trial licences to a large number of companies (October 2015-October 2017).

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

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

3.1.10. France

700 MHz frequencies assigned in December 2015.

Consultation on 5G, 2016.

Trials licences and trial cities, 2017.

5G pilot window, Jan. 2018.

Provision of mid-band spectrum for trials in selected cities.

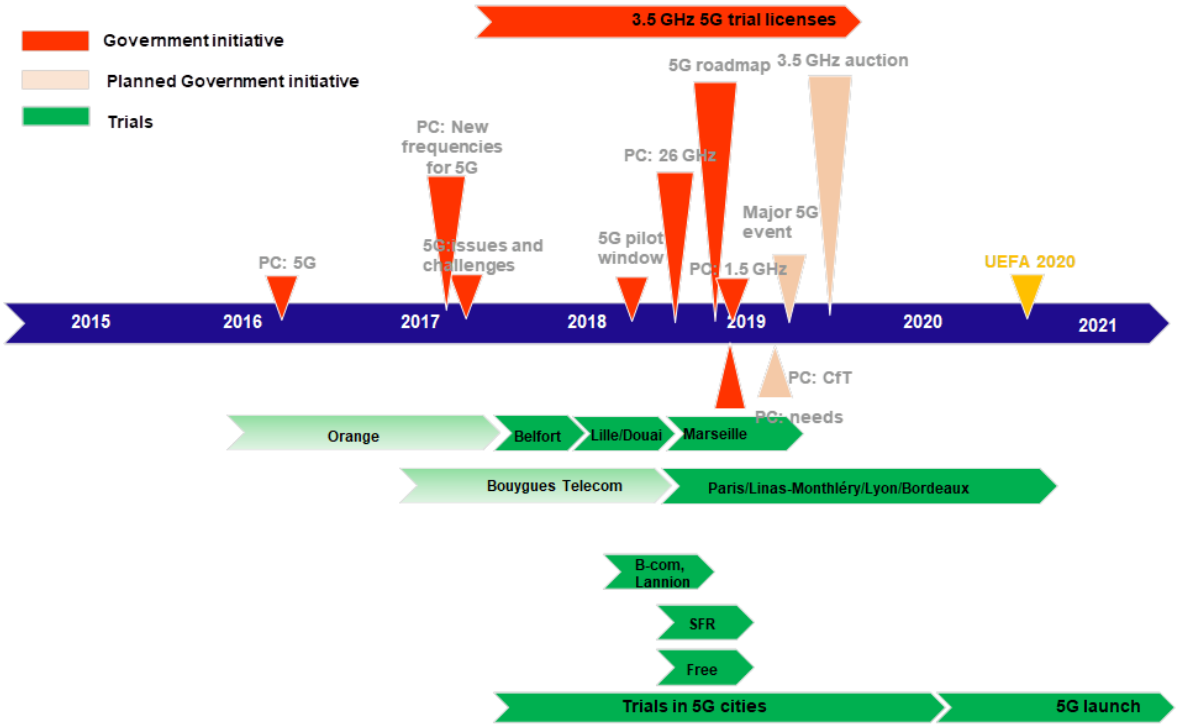
Ongoing discussions and study to open up 3.4-3.8 GHz and 26 GHz spectrum to 5G. 3.4-3.8 GHz auction a priori scheduled for mid-2019.

5G roadmap, July 2018.

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".
- 5G trial authorisation in Lille, Douai, Bordeaux and Lyon in February 2018
- 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 authorisation in Marseille, Belfort, Lille/Douai, Sophia-Antipolis, Chatillon, Linas, Pau, Paris (Orange), Bordeaux, Paris, Vélizy, Linas-Monthléry, Lyon, Bordeaux (Bouygues Telecom), Nantes, Lyon, Vélizy, Paris, Toulouse (SFR), Grenoble (CEA-Leti), Cesson-Sévigné, Lannion (b<>com), Nozay (Nokia),
- 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 could be issued in mid-2019.
- In H2 2018, discussions are organised on verticals (connected vehicle, industry 4.0).
- Live scale tests are awaited for early 2019.
- In the first half 2019, the Government expects to organise a major event on 5G.
- The call for applications is scheduled for the second half of 2019.

Figure 14: 5G timeline in France



Source: IDATE DigiWorld, as of December 2018

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.

3.1.11. Germany

The 700 MHz frequencies assigned in June 2015.

“5G for Germany”, autumn 2016.

5G spectrum roadmap, 2018.

Final conditions for 5G Auction, November 2018.

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 15: 5G strategy in 5 steps

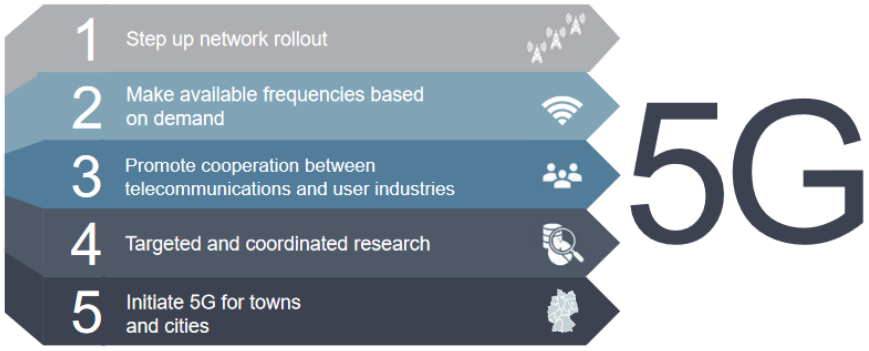


Figure 7 – Five fields of action to develop the 5G lead market in Germany
Source: Federal Government

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

Figure 16: Key milestones of 5G strategy for Germany

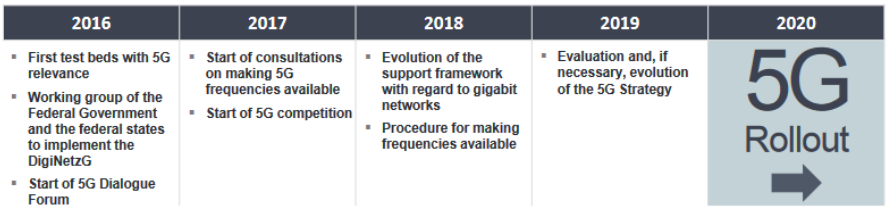
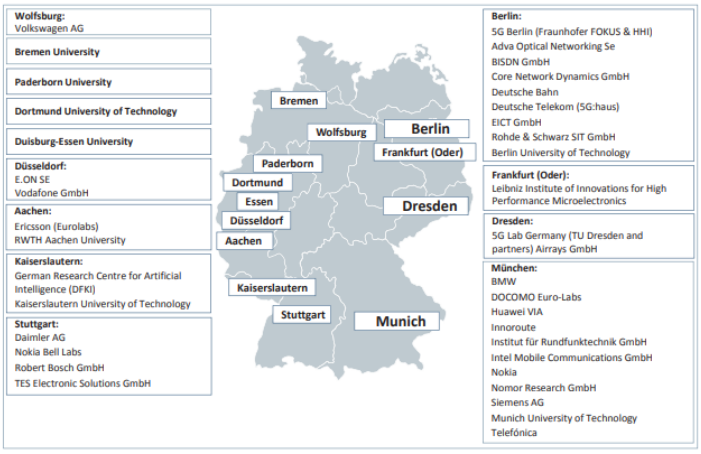


Figure 11 – Milestones of the 5G Strategy for Germany (as at June 2017)
Source: Federal Government

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

Figure 17: 5G research centers in Germany



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

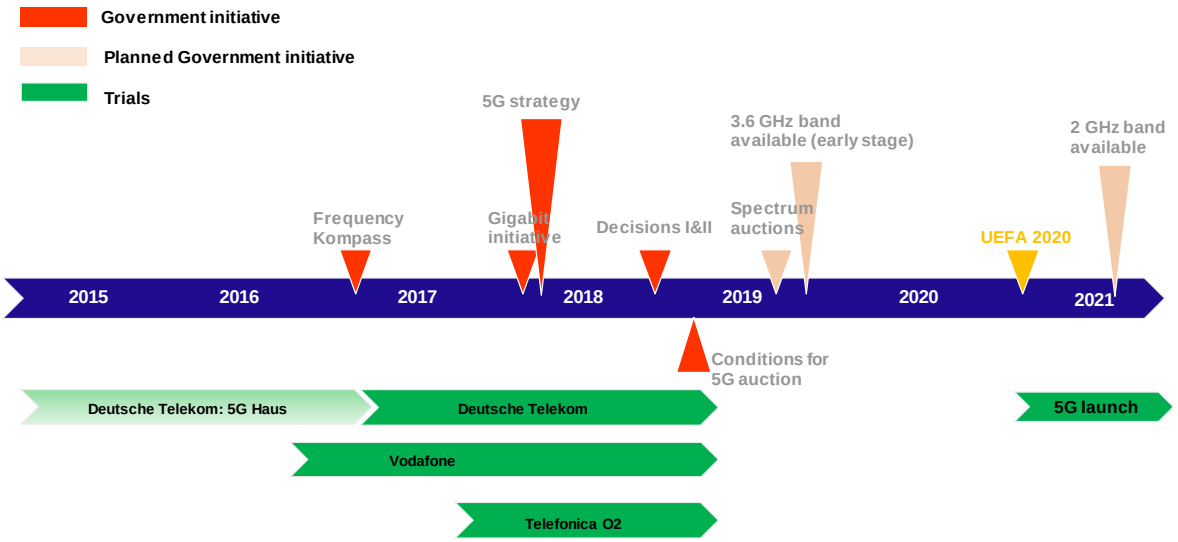
Based on the submitted views, the German NRA released key elements and launched a formal demand for nationwide assignments in the 2 GHz and 3.6 GHz bands in June 2017.

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

- In the 2 GHz band, 2x40 MHz will be made available as from 1st, January 2021. An additional 2x20 MHz will be available as from 1st January 2026.
- In the 3.6 GHz band (3.4-3.7 GHz), some of the spectrum is assigned de facto on a nationwide basis (until 2021/2022) will be available as from 1st January 2022 (earlier stage as from 2019). Other public initiatives award conditions and auctions rules for 5G were released on November 26th, 2018.

The 5G spectrum auctions are scheduled for spring 2019. The qualification procedure is open from November 26th, 2018 until January 25th, 2019. Coverage conditions have been strengthened while the 5G timetable seems to have been softened. Conditions are set in two stages (2022 and 2024).

Figure 18: 5G timeline in Germany



Source: IDATE DigiWorld, as of December 2018

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, 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.

3.1.12. Greece

Upcoming trial licences in 3.4-3.8 GHz frequencies with award of licences in Q4 2019.

5G cross-border corridor (Bulgaria, Greece, Serbia).

EETT expects to see 5G trials using upcoming trial licences.

EETT expects to award 3.4-3.8 GHz spectrum in Q4 2019.

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

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

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

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

3.1.13. Hungary

"Digital Success Programme 2.0". Strategic study.

European 5G hub for 5G.

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.

3.4-3.8 GHz

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

26 GHz band

- Intensive fixed service use currently in 24.5-26.5 GHz sub-band.
- Expiry date of most of the licenses 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.

3.1.14. Ireland

3.4-3.8 GHz band

360 MHz of TDD spectrum has already been auctioned in 2017. Licenses for 5G services will start 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 licensed 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.

3.1.15. Italy

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 November 2018, 26 GHz spectrum auctions, October 2018, first in Europe.

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.

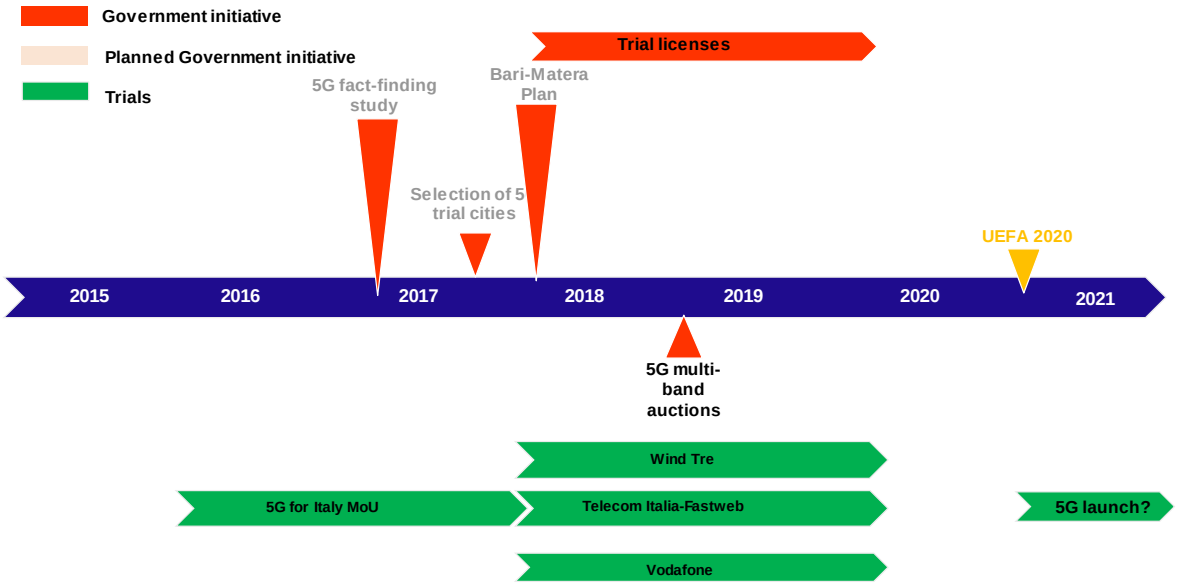
In March 2017, the Government selected five 5G trial cities, including Milan (Vodafone), Prato (Wind Tre-Open Fiber), L'Aquila (Wind Tre-Open Fiber), Bari and Matera (Telecom Italia-Fastweb-Huawei

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 19: 5G timeline in Italy



Source: IDATE DigiWorld, as of December 2018

Coverage obligations

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

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

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

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

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

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

- Globally 1,275 MHz are offered for sale broken down into 700 MHz frequencies (75 MHz), all the upper part of the 3.4-3.8 GHz frequencies (200 MHz divided in two blocks of 80 MHz and two blocks of 20 MHz in 3.6-3.8 GHz) and all the upper part of 26 GHz frequencies (1 GHz divided in five 200 MHz blocks in 26.5-27.5 GHz).
- Telecom Italia, Wind, Tre, Vodafone, Illiad 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, Illiad 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. 700 MHz frequencies raised globally 2.04 billion EUR. Telecom Italia announced it had paid 680.2 million EUR for 2x10 MHz. Illiad paid 676.5 million EUR for 2x10 MHz. Vodafone spent 683.2 million EUR for 2x10 MHz. Licenses are valid 15 years, starting in 2022.
- The mi-band auction ended on October 2nd, 2018, 14 days after start and 171 rounds. Telecom Italia and Vodafone won the largest blocks of spectrum (80 MHz each) for approx.1.7 billion EUR each. Respectively they paid 1.694 billion EUR and 1.685 billion EUR. Wind and Iliad paid 483.9 million EUR each for 20 MHz of spectrum each (483.92 million EUR for Wind and 483.9 million EUR for Illiad). 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, Illiad received another lot for a little less at 32.9 million EUR, while Fastweb, Wind and Vodafone paid 32.6 million EUR each.
- > On 21 February, TIM Italy and Vodafone have agreed on a passive network sharing deal for 5G including all 22,000 antenna sites controlled by the operators.

3.1.16. Latvia

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

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

3.1.17. Lithuania

RRT opened a public consultation on the use of 3.4-3.8 GHz and 3.8-4.2 GHz frequencies from April to May 2018. A second public consultation on the use of 3.4-3.8 GHz frequencies was issued between October and November 2018.

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

3.1.18. Luxembourg

5G Strategy, September 2018.

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

Assignment of the 700 MHz and 3.6 GHz bands is scheduled for the second half of 2019. The 26 GHz frequencies are expected to become available in the second half of 2020.

3.1.19. Malta

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

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

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

In December 2018, the MCA published a draft amending decision on "the assignment process for the 1.5 GHz band for terrestrial systems capable of providing electronic communications services in Malta" (MCA_D_17_2868).

3.1.20. Netherlands

Connectivity Action Plan, July 2018.

A multi-band spectrum (700/1400/2100 MHz) auction is scheduled for 2019/2020.

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

The spectrum in the 700 MHz band will be auctioned at the next mobile spectrum auction, which is expected to be held in late-2019 or early-2020.

ACM is reviewing the possible use of 3500 MHz spectrum for mobile services.

3.1.21. Poland

5G Strategy for Poland, January 2018.

5G spectrum consultation, July 2018.

A few trials to date.

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.

3.1.22. Portugal

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

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

At the end of 2018, Portugal indicated that it was establishing a working group to work on the development of the Portuguese national 5G action plan.

3.1.23. Romania

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

ANCOM launched a public consultation on the "National Strategy for the Implementation of 5G in Romania" between November 20th and December 21st, 2018.

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

3.1.24. Slovakia

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

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

3.6 GHz band

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

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

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

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

3.1.25. Slovenia

In January 2017, the Slovenian Government and AKOS called for project applications for testing 5G. In the call, trial licenses 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.

3.1.26. Spain

Early spectrum assignment process in the 3.4-3.6 GHz range took place in 2016. It is likely to be used for 4G.

The 3.6-3.8 GHz auction ended in July 2018 and will be used by 5G networks:

- Vodafone has eighteen 5 MHz blocks (€198.1m)
- Orange has twelve 5 MHz blocks (€132.1m)
- Telefonica has ten 5 MHz blocks (€107.4m)

The 700 MHz auction will be held in the first months of 2020.

5G National Plan 2018-2020 – 5G Observatory in Barcelona, July 2017 consultation, release in 2018

The 5G process in Spain started in July 2017 when the Government opened a public consultation about the 5G National Plan consisting of 25 questions.

The 5G National plan 2018-2020 aims at "promoting the development and deployment of 5G technology" via the auction of spectrum in the 1.5 GHz and the 3.6 GHz bands in early 2018, and at "developing their infrastructures and telecommunications networks with a 5G platform".

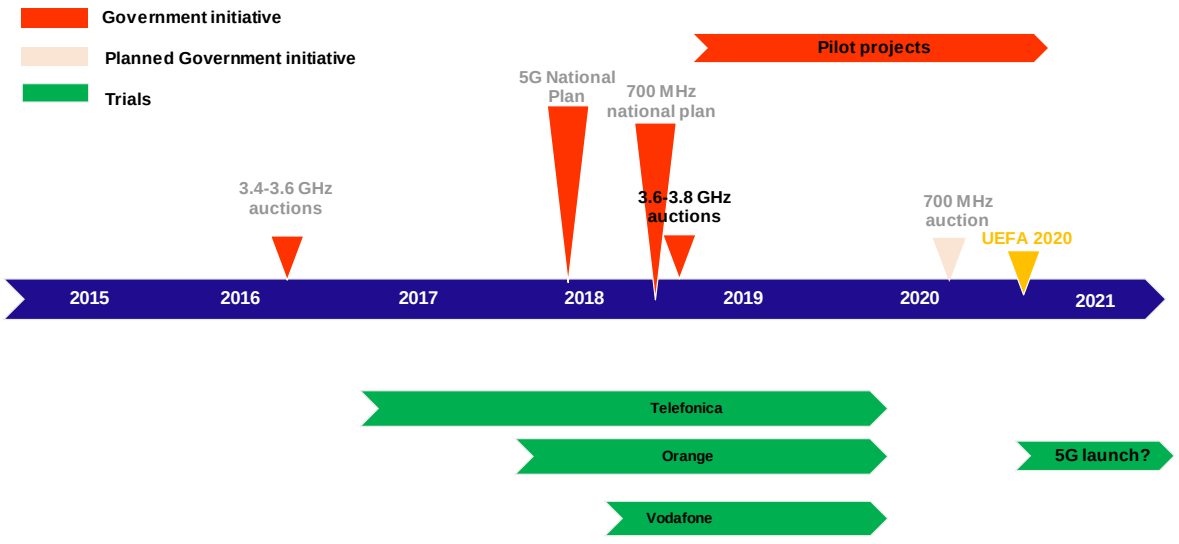
The Spanish government has allocated 1 MEUR to create a national 5G observatory in Barcelona, part of a project designed to boost the candidature of Barcelona as the European capital of 5G technological innovation. The observatory is part of the "5GBarcelona" joint initiative of the regional government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

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

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

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

Figure 20: 5G timeline in Spain



Source: IDATE DigiWorld, as of 27 July 2018

3.1.27. Sweden

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 licenses 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 Hz in the 24.5-275 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.

In February 2019, a public consultation on upcoming award of the 2.3 and 3.5 GHz bands in Sweden was published. It is important for enabling 5G (documentation in Swedish only).

3.1.28. UK

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.

"5G Testbeds and Trials", April 2018-March 2019.

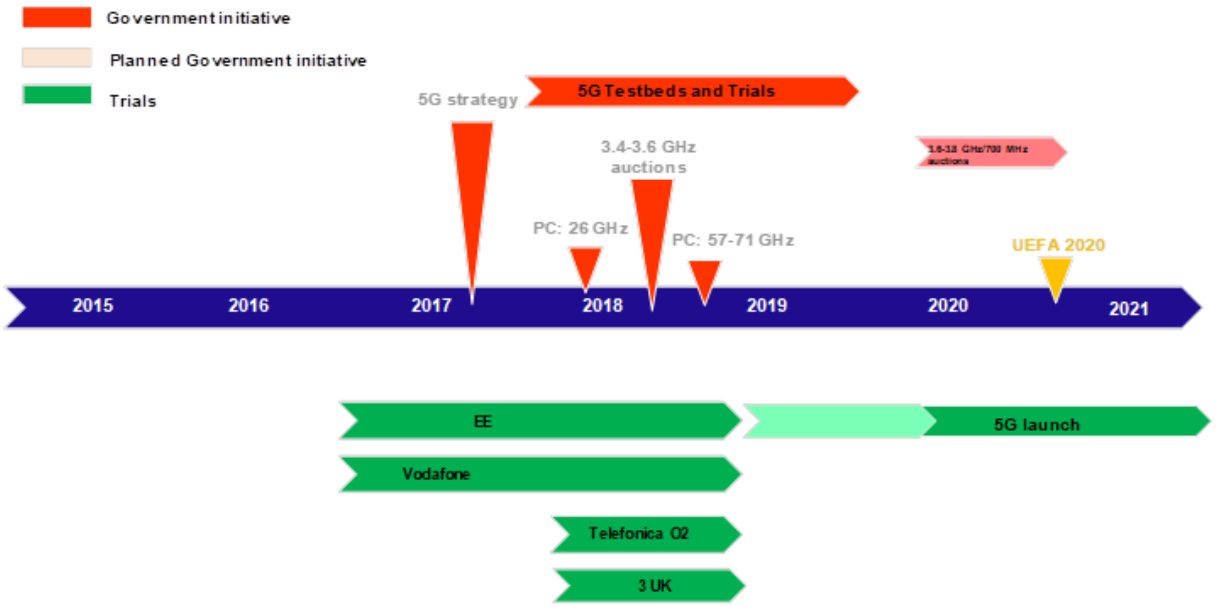
Statement on the review of spectrum used by fixed wireless services published in July 2018.

5G was initiated in 2016 when the Government announced its National Productivity Investment Fund (NPIF) worth in total of 23 BGBP, of which 740 MGBP funded by the government aiming at 5G trials and full fiber deployment across the UK by 2020-2021. Projects must complete all grant-funded activities by 31 March 2019.
In July 2018, Ofcom decided to change the authorization approach for fixed wireless systems in the 64-66 GHz band to license 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 license 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 license 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.

Figure 21: 5G timeline in the UK



Source: IDATE DigiWorld, as of December 2018

3.4-3.8 GHz band

3400-3600 MHz auctioned in April 2018.

3.2. 5G strategy and pioneer bands follow-up

Table 12: 5G strategy and pioneer bands follow-up for EU-28 most advanced countries

Country	Frequency band	5G strategy published	Spectrum assigned	Availability for 5G use	Channel width	Coverage obligations	License duration
Finland	700 MHz	✗	✓	✓			
	3.4-3.8 GHz	✗	✓	January 2019	130 MHz		15 years
	26 GHz	✗	✗				
France	700 MHz	✓	✓	✓	5 and 10 MHz duplex	✓	15 years
	3.4-3.8 GHz	✓	✗ 2019	✗			
	26 GHz	✓	✗ 2020	✗			
Germany	700 MHz	✓	✓	✓		✓	
	3.4-3.8 GHz	✓	in April 2019	✓		✓	31/12/2040
	26 GHz	✓	✗	?			
Italy	700 MHz	✗	✓	✗ July 2022	5 MHz duplex		15.5 years
	3.4-3.8 GHz	✗	✓ 200 MHz (3.6-3.8 GHz)	✓	20 MHz		19 years
	26 GHz	✗	✓ 1 GHz (26.5-27.5 GHz)	✓	200 MHz	✗	19 years
Spain	700 MHz	✓	✗				
	3.4-3.8 GHz	✓	✓	✓			
	26 GHz	✓	✗				
Sweden	700 MHz	✓	✓	✓	5 and 10 MHz duplex	✓	21 years
	3.4-3.8 GHz	✓	✗				
	26 GHz	✓	✗				
United Kingdom	700 MHz	✓	✗				
	3.4-3.6 GHz	✓	✓	✓	20, 40 and 50 MHz		Indefinite term
	26 GHz	✓	✗				

Source: IDATE

3.3. International developments/trials

USA, Japan, South Korea and China are the leading countries in terms of 5G readiness. A number of Gulf countries claim to the firsts to have launched 5G mid-2018:

- **China:** China Mobile is currently trialling 5G. It plans commercial launches by 2020. China Unicom and China Telecom are targeting 2020 for commercial services.
- **USA:** AT&T and Verizon launched mobile commercial services in early 2019. T-Mobile plans to start deployments in 2019 with a nationwide deployment by 2020. Sprint is suggesting a commercial launch late in 2019.
- **Japan:** KDDI, Softbank and NTT DoCoMo are targeting commercial launch by 2020 (Tokyo Summer Olympics).
- **South Korea:** South Korean MNOs displayed 5G at the Winter Olympic Games. KT has brought forward plans for a commercial launch to 2019. Full commercial launch took place in April 2019.
- **Europe:** Commercial large-scale introduction is targeted for 2020. 5G coverage in main urban areas and transport routes is scheduled for 2025.
- **Gulf Countries:** Qatar and UAE both claim to be the world firsts to have launched 5G. Without any 5G device available, it appears to be a 5G infrastructure green light rather than a full commercial launch.

3.3.1. USA

The United States is a well advanced country in terms of 5G. The Federal Communications Commission (FCC) is pursuing a comprehensive wireless strategy. Clearing 11 GHz of high-band spectrum for 5G was one of its first action in favour of 5G as early as 2016. In 2016, it announced a 400 million USD funding dedicated to research on 5G. It now intends to make more mid-band spectrum available.

Concerns about cyberattacks from China resulted with an attempt from the Trump administration to build a secure 5G network (possibly under government control). The FCC and the wireless industry have pushed these attempts back.

5G Americas is the strong arm of 5G at regional level (partnership agreements with major standardisation bodies and wireless entities).

Spectrum issues

The FCC voted in 2016 for the release and development of nearly 11 GHz of high-frequency spectrum intended to be used for fixed and mobile broadband bandwidth uses: 3.85 GHz to be assigned under licenses 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[10] (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.
  - Winning parties for the 28 GHz auction will be announced when the 24 GHz auction will be over.
- 24 GHz spectrum (24.25–24.45 GHz + 24.75–25.25 GHz) auctions started in March 2019. 24 GHz frequencies are auctioned in 100 MHz blocks and sold by partial economic areas (PEAs). PEAs are larger than counties.

3.3.2. China

Spectrum issues

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

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

MIIT identified other bands for 5G:

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

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

3.3.3. South Korea

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

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

The South Korean carriers agreed mid-2018 to build single 5G network to save money and time. The government sees a 5G common launch in March 2019.

Spectrum issues

The government assigned 280 MHz of the 3.4-3.7 GHz spectrum in June 2018 at 3.3 trillion KRW (2.4 billion EUR). Prices raised very high levels (more than 16 EUR per MHz per pop for 10 years).
At the same time, the South Korean government assigned 2400 MHz (800 MHz for each player) of 28 GHz spectrum. Each player paid 160 million EUR for the 28 GHz spectrum.

3.3.4. Japan

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

Spectrum issues

Japan mainly supports the 28 GHz (27.5-29.5 GHz) band for 5G.The MIC has also approved the 3.6-4.2 GHz and the 4.4-4.9 GHz frequencies.

3.3.5. Other countries

Apart from the countries described above and the EU, other countries started planning 5G deployments such as India, Australia, Canada, South Africa, and the Gulf Countries (UAE, Qatar, Saudi Arabia, Bahrain).

India

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

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

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

A reasonable target for 5G launch is 2022.

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

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

Qatar

Ooredoo announced it launched its 5G commercial network in July 2018. Considering 5G mobile devices are not ready yet, it states it is waiting for manufacturers to produce 5G capable devices.

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.

Saudi Arabia

The SA Kingdom has 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.

Bahrain

The Ministry of Transportation and Telecommunication announced in March 2019 that commercial launch of 5G services is planned for June 2019 in the country.

3.4. 5G commercial launch dates

Table 13: 5G commercial launch dates in EU28 (as planned in March 2019)

Country	Operator	5G commercial launch date
Austria	T-Mobile Austria	03/2019
	A1 Telekom Austria	01/2020
	Hutchison 3G Austria	n/a
Belgium	Proximus	2020
	Orange Belgium	Q4 2020/H1 2021
	Telenet Belgium	2021
Bulgaria	A1	2020
	Telenor	2020
	Vivacom	Q4 2020/H1 2021
Croatia	A1 Croatia	n/a
	T-Hrvatski Telekom	2020
	Tele2 Croatia	n/a
Cyprus	MTN	n/a
	CYTA	n/a
	PrimeTel	n/a
Denmark	TDC	2020
	Telenor Denmark	2020
	Telia Denmark	n/a
	3 (Hi3G)	n/a
Estonia	Telia Estonia	2019
	Tele2 Estonia	2020
	Elisa Estonia	2020
Finland	Elisa Finland	06/2018
	DNA	H1 2019
	Telia Finland	H1 2019
France	Orange France	2020
	SFR	2020
	Bouygues Telecom	2020
	Free Mobile	2020
Germany	Deutsche Telekom	2020
	Telefonica Germany	n/a
	Vodafone Germany	H2 2019
Greece	Vodafone Greece	n/a
	Cosmote	n/a
	WIND Hellas	n/a
Hungary	Telecom (T-Mobile Hungary)	n/a
	Telenor Hungary	n/a
	Vodafone Hungary	n/a
Ireland	Vodafone Ireland	Q4 2019
	EIR	End 2019
	Three Ireland	H2 2019
	Virgin Mobile	n/a
Italy	TIM	H2 2019
	Wind Tre	H2 2019
	Vodafone Italy	2019
	Iliad	n/a
Latvia	Tele2 Latvia	n/a
	Bite	n/a
	LMT	2019
Lithuania	Bite	n/a

Country	Operator	5G commercial launch date
	Tele2	n/a
	Telia (Omnitel)	2020
Luxembourg	POST	2020
	Tango	2020
	Orange	2020
Malta	Melita	2019
	Vodafone Malta	n/a
	GO	n/a
Netherlands	T-Mobile	2020
	VodafoneZiggo	2020
	KPN	2020
Poland	T-Mobile	12/2018
	Orange Poland	H2 2019
	Plus	n/a
	Play	n/a
Portugal	Altice (MEO)	2019
	NOS	n/a
	Vodafone	End 2019
Romania	Orange	n/a
	Telekom	n/a
	Vodafone	n/a
Slovakia	Orange	n/a
	T-Mobile	n/a
	O2	n/a
Slovenia	Telekom Slovenije	2020-2022
	A1	n/a
	Telemach	n/a
Spain	Orange Spain	2020
	Telefonica (Movistar)	2020
	Vodafone Spain	H2 2019
	Yoigo	n/a
Sweden	Telia	2020
	Tele2	2020
	Telenor	2020
Switzerland	Sunrise	03/2019
	Salt	2019
	Swisscom	April 2019
United Kingdom	EE	H2 2019
	Telefonica UK	End-2019
	Vodafone UK	H2 2019
	Three UK	H2 2019

Source: IDATE

3.5. 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.

Table 14: Number of cell sites/base stations for 5G trials and networks

Country	Operator	Number of 5G cell sites	Announcement date
Austria	T-Mobile	Commercial launch with friendly customers. 25 base stations installed in rural areas.	March 2019
Australia	Optus	Signed a partnership with Ericsson to deploy 50 5G sites across the cities of Sydney and Melbourne	February 2019
China	China Mobile	China Mobile announced plans to deploy more than 10,000 5G base stations by 2020	December 2018
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
Germany	Deutsche Telekom	Deutsche Telekom currently maintains about 28,000 towers across Germany, but the operator has formerly suggested that figure could even double with the rollout of 5G technology in the 2020s	February 2018
Germany	Deutsche Telekom	Wants to build over 2,000 new mobile sites every year along with 10,000 smaller radio cells to improve coverage at high-demand locations or inside buildings	October 2018
Italy	Vodafone	The 5G network in Milan covers 80% of the city's population via 120 active sites	December 2018
Kuwait	Viva	Viva is rolling out a nationwide 5G network with over 1,000 5G NR-based radio sites in 2019	March 2019
South Korea	KT	Around 1500 5G base stations deployed in January 2019. 30,000 base stations by April 5, 2019 (including 15,000 in Seoul)	January 2019 March 2019
South Korea	LG Uplus	5,500 5G base stations deployed in January 2019 18,000 base stations deployed in March 2019. The operator plans to install 50,000 base stations within the first half of the year	January 2019 March 2019
South Korea	SK Telecom	Around 1500 5G base stations deployed in January 2019 34,000 5G base stations	January 2019 April 2019
UK	Vodafone	In 2018, will test 5G at more than 40 sites in Birmingham, Bristol, Cardiff, Glasgow, Liverpool, London and Manchester Extension to 1000 sites by 2020	June 2018 December 2018
UK	EE/BT	Nine 5G trial sites are now live across East London. 1500 cell sites will be operating in 2019 covering 15% of the population (25% of total traffic)	November 2018

Source: IDATE

3.6. 5G network equipment –main manufacturers

3.6.1. Ericsson

Ericsson as well claim to offer the "Market first global 5G access and transport portfolio", having created its Radio System as the basis for its future 5G offering including a transport and access solution. Ericsson put the stress on the smooth transition from 4G to 5G that its solution enables with notably a support for spectrum sharing between 4G and 5G. This solution brings increased flexibility for spectrum asset usage since it enables to deploy both 4G and 5G in the same spectrum, something particularly interesting at the beginning when 4G devices still account for the majority of the data traffic. With its 5G radio dot offering, Ericsson also emphasize the importance of indoor coverage and how its tiny base station fulfils the challenge of bringing 5G capacity indoor. A street macro solution and RAN compute portfolio has been announced for launch in the second half of 2019.

Figure 22: Presentation of Ericsson 5G solution

Source: Ericsson

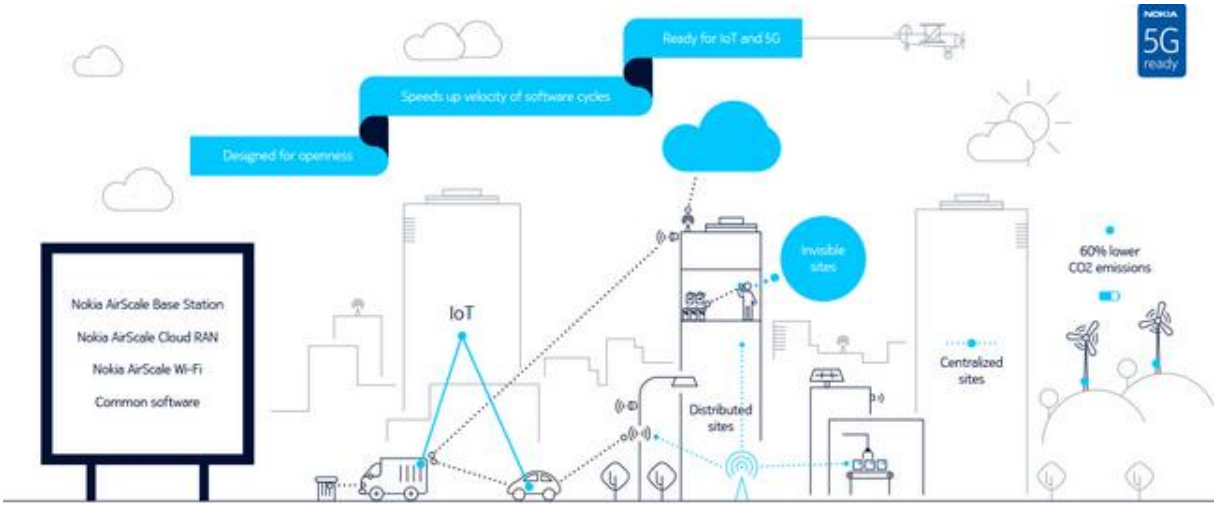
3.6.2. Huawei

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

3.6.3. Nokia

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

Figure 23: Nokia AirScale Radio Access for 5G



Source: Nokia

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

3.6.4. Samsung

Figure 24: Samsung 5G products evolution

Source: Samsung

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

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

Figure 25: Displaying of Samsung 5G FWA solution for the American market

Source: Samsung

3.6.5. ZTE

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

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

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

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

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