Stimulating demand for 26 GHz in Europe

July 2021

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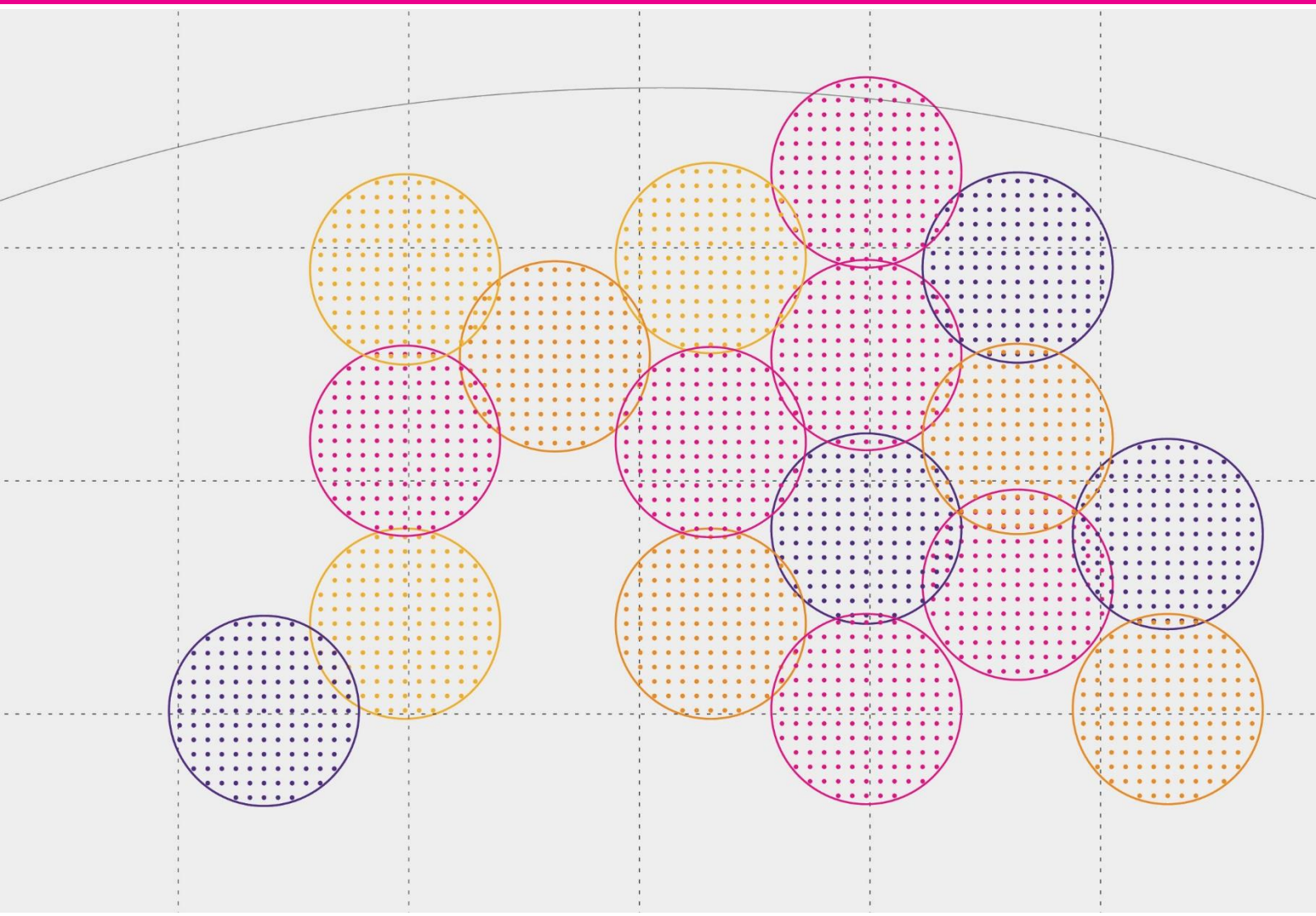

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About Plum

Plum offers strategy, policy and regulatory advice on telecoms, spectrum, online and audio-visual media issues. We draw on economics and engineering, our knowledge of the sector and our clients' understanding and perspective to shape and respond to convergence.

About this study

This study for Qualcomm / Nokia addresses the need to stimulate demand for 26 GHz spectrum in Europe for 5G.

Developments since the time of writing include:

- Croatia: Applications for 5G spectrum, including 26 GHz were open until 11th June 2021 and bidding is expected to start on 12th July 2021. The award will include 5 block of 200 MHz of 26 GHz spectrum.
- North Macedonia: The Agency for Electronic Communications closing date for applications for 5G spectrum, including 26 GHz is 5th July 2021. The award will include 800 MHz of 26 GHz spectrum.

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Summary

Mobile communication has contributed significantly to economic and social progress in Europe and other parts of the world. The opportunities created by Information and Communication Technology (ICT) are a key contributor to how society is evolving with access to services supported by mobile communication now largely indispensable. Examples include driving innovation across a diverse set of vertical sectors such as media, manufacturing, health, automotive, agriculture and mining. This trend will continue as more social, commercial and government interactions go online.

The features developed for 5G (enhanced mobile broadband – eMBB, ultra-reliable low latency communications – URLLC, and massive machine communications – mMTC) will enable the support of new devices, applications, and business models. However, delivery of the full benefits of 5G requires access to newly available mmWave spectrum with much wider RF bandwidths and small wave lengths for optimum use of adaptive antenna technology. There is some hesitancy on the part of mobile network operators arising from the different nature of 26 GHz deployment (e.g. short-range cells) but technology improvements and better understanding of deployment for specific use cases are overcoming these issues. Shorter propagation distances can turn into an advantage as they limit interference between neighbouring uses allowing more easily for local use concepts even with different UL to DL ratios tailored to the respective applications. The very wide bandwidths of mmWave spectrum facilitate support of large capacity cells and as a result can reduce the cost of infrastructure deployment making 5G services affordable for consumers and businesses.

Spectrum bands in the low, mid, and high frequencies have been identified globally for 5G and at WRC-19 several mmWave options were identified including the band 24.25-27.5 GHz (the 26 GHz band).[1] A strategic roadmap for spectrum for 5G in Europe was set out in 2016 when the Radio Spectrum Policy Group (RSPG) published its first Opinion on spectrum for next generation wireless systems. This identified three pioneer spectrum bands for 5G including 24.25-27.5 GHz, or 3GPP n258 band, to support ultra-high capacity for innovative new services, harmonised in CEPT[2] under ECC Decision 18(06).[3] The European Electronic Communications Code (EECC) set out that Member States of the European Union should allow the use of at least 1 GHz of the 26 GHz band, if there is clear evidence of market demand and of the absence of significant constraints for migration of existing users or band clearance. While progress in making available part or the whole of the 26 GHz band was slow in Europe during 2020, there are signs that momentum is picking up with about half of EU countries expected to complete spectrum awards for 26 GHz by the end of 2021.

At the time of writing the 26 GHz band (or parts of it) had been made available in Europe in Denmark, Germany, Greece, Finland, Italy, Russia, Slovenia and the UK offering different regulatory options ranging from traditional nationwide awards to local licensing. Mobile network operators need access to the spectrum to increase the scope of services offered to their customers in the consumer and enterprise sectors (including industrial). There is also likely to be entry from industrial and other players wishing to innovate with new service capabilities and these players too need access to suitable spectrum. In addition, there is a need to make more efficient use of spectrum, including through shared concepts such as neutral hosts. To unleash the full potential of the 26 GHz band, regulators need to define and implement the most appropriate regulatory framework to enable access (including use of spectrum and infrastructure sharing regimes), considering their specific national environment.

Plum's research on stimulating demand for 26 GHz identified three key areas for action.

Use cases

[1] WRC19 identified the frequency bands 24.25-27.5 GHz, 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 and 66-71 GHz for the deployment of 5G networks.
[2] CEPT – the European Conference of Postal and Telecommunications Administrations. ECC- Electronic Communications Committee.
[3] Decision 18(06): Harmonised technical conditions for Mobile/Fixed Communications Networks (MFCN) in the band 24.25-27.5 GHz.

Use cases for 26 GHz can broadly be grouped into two categories: eMBB (including Fixed Wireless Access – FWA) and enterprise (including industrial), and they are likely to be characterised by requirements for high downlink and uplink bandwidths.[4] eMBB hot spots and FWA are likely to be the first use cases deployed in the 26 GHz band and there are already commercial services in countries like Italy and Russia and trials in several EU member states such as Spain, France and Germany, as well as the UK, to name a few. Examples of eMBB use could include:

- Indoor smartphone, tablet and laptop use and evolution to e.g. augmented and virtual reality device use
- Outdoor smartphone, tablet and laptop use
- Fixed wireless access
- Hot spot high-capacity solutions
- Rural backhaul connections.

While the US has cities with large-scale commercial mmWave use for eMBB, in Europe proof of concept work is taking place for hot spot use such as at sport stadium and arena locations. Also, 26 GHz spectrum furthers the opportunity to tackle the digital divide with backhaul and FWA in rural areas together with opportunities to operate 26 GHz spectrum indoors with low risk of interference to outdoor services.

Over time industrial use cases will grow as suppliers focus on delivery of solutions provided either through public mobile networks or private systems. Plum has identified and interviewed early adopters of mmWave in the industrial manufacturing environment and in other industries. Lower latency connections for mission critical applications will be supported by smaller slot durations, and mmWave solutions will support high uplink traffic demand with the possibility to implement different uplink / downlink configurations for specific installations.[5]

The issue for mmWave is not the absence of use cases but uncertainty in Europe about access to the spectrum required to enable them. Spectrum for trials in several countries has been awarded however a clear path to market including a timeline for access to commercial spectrum licenses is required.

Ecosystem

According to the GSA, as of March 2021 there are 23 band n257 (26.5 – 29.5 GHz) devices and equipment is widely available (the bottom 1 GHz of band n257 overlaps with the top 1 GHz of band n258) and can be used for trials and commercial deployments in Europe already. That said, the ecosystem for band n258 (24.25-27.5 GHz) was raised as an area for action as currently there are relatively few n258 devices available (10 devices as of April 2021). As with use cases, the issue is not with the n258 ecosystem as such but with the slow rate at which spectrum is becoming available which reduces incentives for device OEMs to commit to production for n258 while n257 has a broad global driver in terms of spectrum already made available and thus wider eco-system support. As now 3GPP band n258 is available more widely and a device market is in sight, it is expected that device production will ramp up relatively quickly as has been seen with previous mobile generations and building on readily available technology developed for band n257. Enterprise and industrial solutions may require standalone 5G systems and the ecosystem for these is expected to grow as communications service providers have started to introduce 5G standalone.

Tax policy and incentives is another element of the n258 ecosystem that should be considered to accelerate deployments of supporting infrastructure and equipment upon spectrum becoming available. Such policy has

[4] Applications with these characteristics could include 360 and immersive video, cloud gaming and enhanced reality.
[5] The shorter-range propagation characteristics of mmWave provide better isolation between systems with different configurations than is possible with use of mid-band frequencies.

been implemented successfully in Japan in 2020 where MNOs pulled forward their planned investments in Sub-6 GHz and mmWave infrastructure to take advantage of the short tax incentive window.

Access to spectrum

The two issues considered above point to the need to advance access to spectrum in the 26 GHz band. The third issue was how access is enabled and how at a minimum the requirement of the EECC to provide access to 1 GHz of the band can be implemented. This requires National Regulatory Authorities (NRAs) to check for demand through calls for inputs, public consultations or other means and to monitor and review developments on a regular basis. For early deployments, use of 26.5-27.5 GHz with n257 equipment could provide a quick route to market, while access to other parts of the band is enabled. Spectrum management authorities have adopted multiple approaches to access to 26 GHz spectrum and there are examples of both administrative and competitive awards on localised and country wide bases. Clearly, the solution in a specific country is dependent on the circumstances of that country including potential use cases and verticals' needs, number of mobile operators, incumbent users and the amount of available (unused) spectrum. However, a general principle to consider is allowing spectrum users – mobile network operators and others – to obtain a viable amount of spectrum (ideally 800-1000 MHz but at least 400 MHz per network)[6] at locations where there is demand with the least onerous conditions of use subject to accommodating incumbent use of the band. The amount of spectrum available, the low cost of access and the wide range of uses that can be supported make the band attractive to a wide range of potential users but flexibility and innovation will be key to the availability of this spectrum as "one size will not fit all".

A further observation from Plum's research is to ensure that experiments, trials and other incentives lead to routes to market. Too often these activities demonstrate worthwhile innovation but stumble because the transition from trial to commercial service was not fully thought through at the design stage in terms of:

- What outcome is the intervention seeking to achieve?
- How will the spectrum be made commercially available?
- What are the potential business models?

Europe is not alone in deploying mmWave solutions – there are already networks supporting mmWave in North America (in 24 GHz, 28 GHz and 39 GHz), the Asia-Pacific region and LATAM where several countries have already adopted the 26 GHz band or part of it. Examples of countries using 26 GHz are China,[7] Hong Kong, Thailand, Vietnam, Korea, Japan, Taiwan, Singapore, Australia, New Zealand[8], Brazil, Chile.

Plum's conclusions

26 GHz spectrum is already awarded or otherwise available In Europe in Denmark, Germany, Greece, Finland, Italy, Russia, Slovenia and the UK. There are encouraging signs for 26 GHz in other European countries with more NRAs either looking to award the spectrum or consult in 2021 such as Spain (award announced for Q4 2021) Bulgaria (consultation ongoing), Romania (consultation ongoing), Montenegro (expected 2H 2021), Croatia (expected Q2 2021), Macedonia, Norway, Malta. When added to those that have already enabled access this will represent a significant proportion of the population of the European Union and beyond. Also, momentum is building for the 26 GHz band in other parts of the world, like Brazil, Thailand, Australia, New Zealand, Malaysia, Singapore, Hong Kong, Vietnam, Taiwan, Korea in addition to USA and Japan which will increase the addressable market for OEMs.

Having considered the research findings Plum recommends the following to stimulate demand for 26 GHz:

[6] There are some spectrum awards that have assigned less than 400 MHz (e.g. in Italy where 200 MHz was assigned to each operator with the possibility to access other spectrum through a "club" model.
[7] In China 24.75-27.5 GHz.
[8] 24 – 30 GHz use in New Zealand | Radio Spectrum Management New Zealand (rsm.govt.nz)

- Create better visibility on existing mmWave use cases, their technical and economic benefits and their promotion from proof-of-concept to commercial use.

- Promote with key European stakeholders the already wide availability of the n257 (26.5 – 29.5 GHz) ecosystem and the opportunity to quickly start mmWave services upon spectrum release pointing to commercial services already deployed in countries such as Italy.

- Create more visibility of ecosystem developments and expectations for how quickly devices (in a variety of form factors including phones, modules, other indoor and outdoor CPE) will come to market based on experience in other 5G bands and the impact of decisions made by non-European countries like Brazil, Thailand, Australia, New Zealand, Singapore, Malaysia, Hong Kong, Vietnam, USA, that will act as additional triggers for eco-system development for the n258 band.

- Regulators should review and consult on a regular basis to monitor whether there is unmet demand for access to 26 GHz spectrum – there might be cases where market demand is hidden.

- If there are no incumbents, encourage NRAs to release the spectrum to stimulate the market with the licensing conditions providing the means to take back spectrum if it is not used, and if there are incumbents, encourage NRAs to develop spectrum access possibilities where incumbent services are present in the band (including the use of the top 1 GHz of the 26 GHz band where there are the least incumbency issues).

- Promote use of the spectrum with low barriers to entry that could include lower cost of spectrum than for other mobile bands[9] and the use of award mechanisms other than auctions (including administrative and beauty contests, which may include investment commitments).

- Consider the approach to licensing to allow flexibility for localised use along with providing some certainty for those users who may want access to 26 GHz spectrum or part of it at multiple locations in a country.

- Ensure spectrum access can be realised for private networks and neutral hosts as well as MNOs to ensure spectrum efficiency and flexibility.

- Keep encouraging innovation on use cases to include use of the 26 GHz band or part of it through trials (and consider appropriate incentives). Ensure visibility of trials results to foster innovation and encourage other trials and commercial deployments. Provide a clear timeline for spectrum availability for commercial use to ensure follow through from trials.

- Implement tax incentives, such as tax deductions or special depreciation schedules, for investments by MNOs and private network developers in 26 GHz or band n258 related infrastructure and equipment. Include the use of award mechanisms that seek to encourage investment (e.g. investment commitments in beauty contests).

[9] Plum's research finds that in recent awards the average value of 26 GHz spectrum ($/MHz/pop) is $0.0033 whereas for 3.5 GHz auctions the value is $0.1087 (normalised values are 26 GHz $0.0034 and 3.5 GHz $0.1059).

1 Introduction

1.1 Background to study

This study addresses the need to stimulate demand for 26 GHz spectrum in Europe for 5G.

So far deployment of 5G using mid-band spectrum (3.3-3.8 GHz) has been the key focus of many with the notable exception of the United States (US) that launched with mmWave.[10]

Mid-band spectrum is a good starting point for 5G. It significantly increases data speeds and capacity. However, there are use cases that require mmWave that are not readily supported by mid-band spectrum. These include hot spot high-capacity solutions, fixed wireless access delivering fibre like speeds, and a range of enterprise and industry vertical solutions. Use of 26 GHz spectrum also enhances user experience and allows support of higher uplink capacity for applications. Delay to 26 GHz spectrum availability delays these use cases and full realisation of 5G concepts and associated benefits such as increased country competitiveness.

1.2 5G and 26 GHz

5G enables significant advantages over 4G and earlier generations of mobile technologies in respect of reliability, data speeds, latency and capacity.

A strategic roadmap for spectrum for 5G in Europe was set out in 2016 when the Radio Spectrum Policy Group (RSPG) published its first Opinion on spectrum for next generation wireless systems. This identified three pioneer spectrum bands for 5G including use of the frequency range 24.25-27.5 GHz, referred to as the 26 GHz band or 3GPP n258 band, to support ultra-high capacity for innovative new services, harmonised in CEPT[11] under ECC Decision 18(06). The European Electronic Communications Code (EECC) set out that Member States of the European Union should allow the use of at least 1 GHz of the 26 GHz band by 31 December 2020, if there is clear evidence of market demand and of the absence of significant constraints for migration of existing users or band clearance. While there has been progress in making available part or the whole of the 26 GHz band, there are signs that momentum is picking up in Europe with about half of EU countries expected to complete spectrum awards in the 26 GHz range by the end of 2021.

1.2.1 5G deployment

The first deployment of 5G mobile technology was in 2019, with South Korea being the first country to adopt the technology on a large scale. USA launched at around the same time, with e.g. Verizon using mmWave spectrum. Frequencies in the mid bands and mmWave bands typically provide more contiguous spectrum than low bands and thus can support situations where there is a need for capacity as shown in Figure 1.1. The lowest latencies and highest traffic densities are supported by mmWave, which provides limited reach (coverage) but is ideal where a cell radius of 500 metres is sufficient and the smaller physical network equipment size provides advantages for site acquisition and deployments. mmWave is also ideal for indoor use.

[10] See FCC auctions 101 for 28 GHz, 102 for 24 GHz and 107 for upper 37 GHz, 39 GHz and 47 GHz. Mid-band spectrum was recently auctioned in the US under auction 107 (3.7 GHz band).
[11] CEPT – the European Conference of Postal and Telecommunications Administrations. ECC- Electronic Communications Committee.

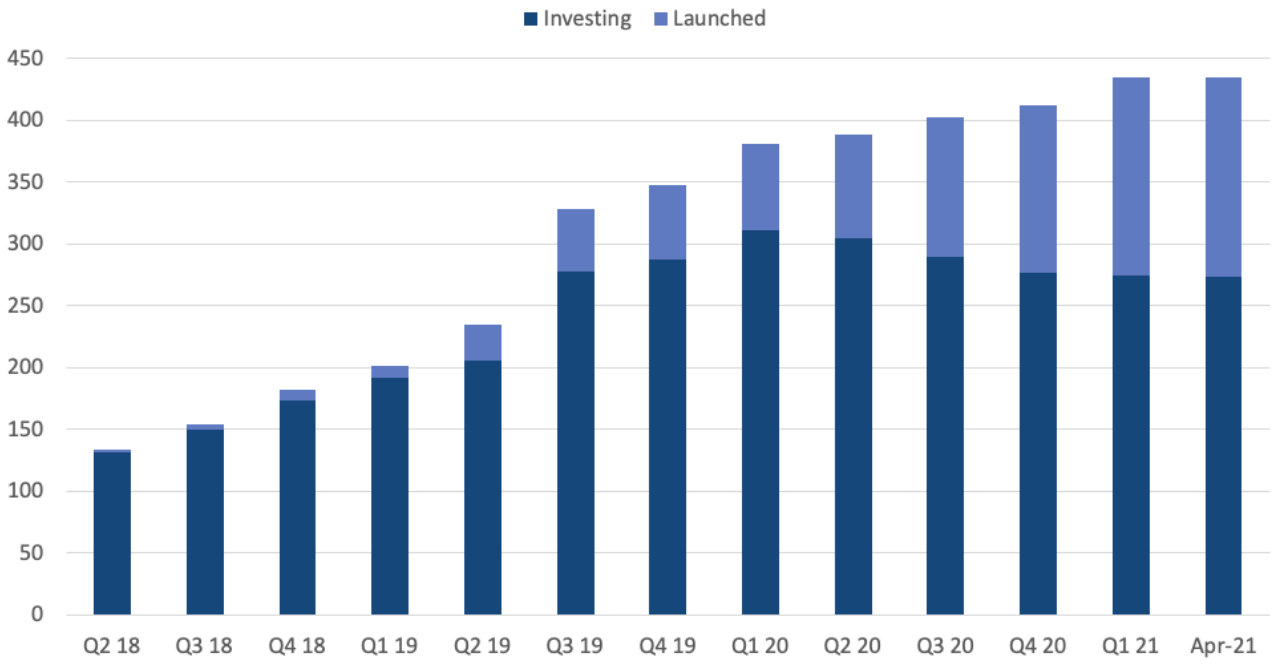
Figure 1.1: Spectrum ranges for 5G

According to the Global Mobile Suppliers Association (GSA) in April 2021[12] there were:

- 162 operators with launched commercial 5G networks in 68 countries/territories
- 435 operators in 133 countries are investing in 5G networks in the form of tests, trials, pilots, planned or actual deployments
- 68 operators in 38 countries are investing in 5G public standalone networks.

The growth in launched commercial 5G networks is shown in Figure 1.2.

Figure 1.2: Growth in launched 5G networks



Source: GSA April 2021

5G is predicted to provide benefits to consumers, transform industry and generate economic value. The GSMA estimate that 5G is expected to yield $2.2 trillion in GDP over the period from 2020-2034. mmWave applications will make up an increasing proportion of the overall 5G contribution to global GDP, achieving around 25% of the

[12] Reports - GSA (gsacom.com) NTS snapshot update April 2021

cumulative total by 2034, which amounts to $565 billion in GDP.[13] Accenture has estimated that in the 5 years (2021 to 2025)[14] the benefits from 5G for the European Union and the UK could be €2 trillion growth in sales enabled by 5G, approximately €1 trillion growth in GDP and 20 million jobs created or transformed.

In the case of the mmWave bands the GSA reported[15]:

- 106 operators in 20 countries/territories hold public licences (many of them regional) enabling operation of 5G networks using mmWave spectrum
- Twenty-four operators in 15 countries/territories are known to be already deploying 5G networks using mmWave spectrum
- Nineteen countries/territories have announced formal (date specified) plans for assigning frequencies above 24 GHz between now and end-2022
- 112 announced 5G devices explicitly support one or more of the 5G spectrum bands above 24 GHz, up from 59 at the end of November 2019 and 70 of these devices are understood to be commercially available

1.2.2 The 26 GHz band

At the World Radiocommunication Conference of 2019 (WRC-19), several new frequency ranges were identified for IMT, to be used by IMT-2020 (5G). These encompassed many of the existing 3GPP-bands plus some new spectrum ranges: 24.25–27.5 GHz, 37–43.5 GHz, 45.5–47 GHz, 47.2–48.2 GHz and 66–71 GHz.

Worldwide the 24.25–29.5 GHz range (covering the overlapping Bands n257 (26.5–29.5 GHz), n258 (24.25–27.5 GHz) and n261 (27.5–28.35 GHz)) has been the most-licensed/deployed 5G mmWave spectrum range to date. According to the GSA[16] there are one hundred and thirty-two operators in 43 countries/territories are investing in 5G in this frequency range. Also twenty-three operators are understood to be actively deploying 3GPP-compliant 5G networks in 37 – 40 GHz (n260), the majority being in the USA and its territories. Three operators in the USA have launched 5G using this band.

In Europe the 26 GHz band was identified as a pioneer band for 5G by the RSPG. The current use of the band has implications for the availability of spectrum as the band is not used in a uniform way across Europe. Examples of incumbent use are:

- Fixed links, which are used extensively across Europe in the frequency range 24.5 – 26.5 GHz (often by the mobile industry).
- A range of licence-exempt short-range devices including automotive, industrial probing and tank level probing radars.
- Satellite services including inter-satellite, fixed satellite (Earth to space), EESS (space to Earth) and Space Research (space to Earth).
- Military use in some countries mainly in upper part of the band.

[13] The WRC series: Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands. December 2018
[14] Accenture-5G-WP-EU-Feb26.pdf
[15] mmWave Bands: Global Licensing and Usage for 5G - GSA (gsacom.com) November 2020
[16] mmWave Bands: Global Licensing and Usage for 5G - GSA (gsacom.com) November 2020

Incumbent services operating in adjacent bands need to be considered. Below the 26 GHz band there are primary allocations for Radiolocation, Amateur, Amateur Satellite, EESS (passive), Radio Astronomy, Space Research (passive) and Fixed Service. Licence-exempt use is also allowed and includes ISM (Industrial, Scientific and Medical), short range devices, industrial and tank level probing radars. Above the 26 GHz band are fixed and fixed satellite (Earth to space) services.

In many countries where there is incumbent use there is still the potential to release / award 1000 MHz (26.5-27.5 GHz) without needing to refarm spectrum or accommodating incumbent use. Depending on the number of operators there is the potential for each MNO to obtain a minimum of 200 MHz bandwidth. Options like the Italian "club licensing" model allow to pool spectrum towards the recommended 800-1000 MHz operational bandwidth for a shared network. The European Commission Implementing Decision of May 2019 sets out the essential technical conditions for the availability and efficient use of the band.[17] More recently the European Commission's Connectivity Toolbox has presented a set of best practices to encourage investment in very high-capacity networks, including for the 26 GHz band.[18]

1.3 Plum's approach

Plum approach to the study was to research publicly available information on 5G and 26 GHz together with a set of targeted interviews among a selection of people from the European Commission, National Regulatory Authorities (NRAs), Mobile MNOs, equipment and other vendors, developers and use case experts from various industries.

Key research tasks were to:

- Review what has already been achieved with 26 GHz in Europe.
- Consider the nature of delays and barriers to 26 GHz deployment where progress is slow.
- Where access to the spectrum is possible the mechanisms put in place and how good these are for a range of players to access the spectrum and build business cases.
- How much the demand question (or perceived lack of it) is influencing delays.
- Whether there is consistency of approach across countries for access to 26 GHz spectrum.

26 GHz use cases and the equipment ecosystem also formed a substantive part of the research. Plum's focus was primarily on:

- Fixed Wireless Access (FWA) in dense, suburban and rural areas.
- Mobile broadband direct to mobile in dense urban areas including high traffic density areas (e.g. stadiums, transportation hubs, etc).
- Deployments for industry verticals indoors and outdoors and campus deployments and use at home for leisure and work.

[17] COMMISSION IMPLEMENTING DECISION (EU) 2019/784 of 14 May 2019 on harmonisation of the 24,25-27,5 GHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services in the Union.
[18] Common Union toolbox for connectivity. Developed under Recommendation EU (2020) 1307.

Although much of the research was focused on Europe, experience from elsewhere in the world has been considered where relevant.

Based on the information obtained recommendations are made to stimulate demand for 26 GHz.

1.4 Structure of the report

The remainder of the report is structured as follows:

- Section 2 considers use cases for 26 GHz.
- Section 3 looks at the 26 GHz equipment ecosystem.
- Section 4 reviews the state of play on access to 26 GHz spectrum in Europe.
- Section 5 presents conclusions and recommendations for measures to stimulate demand.

2 Applications and use cases for 26 GHz

2.1 Introduction

This section highlights examples of 5G use cases for 26 GHz. Applications requiring higher air interface capacity (both uplink and downlink) and low latency are good candidates for the band, but the business cases need to be validated. The same applies for the size of market required to drive access to 26 GHz spectrum and manufacture of devices.

In 2017 Bruegel in a study for the European Commission identified the following services expected to use mm-wave bands:[19]

- Enhanced Mobile Broadband (eMBB) services and high capacity FWA, for high-definition video communications, virtual, augmented and mixed realities.
- Services for vertical sectors including automotive (V2X: Vehicle-to-everything, autonomous cars), other transportation (trains and buses), manufacturing / industrial automation, energy grid communications, smart cities, and medical applications.
- Public safety.
- Fronthauling / backhauling.

The GSMA has also documented potential mmWave use cases including:[20]

- High speed broadband.
- Quick deployment / temporary connectivity.
- Industrial automation.
- Remote object manipulation.
- Virtual reality and augmented reality.
- Next generation transport connectivity.

It is likely that eMBB (including FWA) and backhaul will be the first services to be deployed with progressive rollout over the next few years. Use cases that require standalone (SA) mmWave capability are likely to follow as SA 5G implementations come to market.[21]

Trials of 26 GHz 5G use cases have been taking place, including in France where 14 projects[22] have been identified by ARCEP. Trials[23] have also been taking place in Finland, Italy, Romania, Spain, UK and Russia. Examples of these trials can be found in the European 5G observatory.[24]

[19] KK0319410ENN.en_.pdf (bruegel.org)
[20] Study on socio-economic benefits of 5G services provided in mmWave bands, GSMA, December 2018
[21] Early 3GPP Release 15 5G deployments operate in non-standalone mode.
[22] 14 projects selected end of November 2019
[23] Commercial trials involve end customers being offered products close to those anticipated for market launch.
[24] Major European 5G Trials and Pilots – 5G Observatory.

ARCEP 26 GHz experiments[25]

- Universcience, at the Cité des Sciences et de l'Industrie, in collaboration with Nokia (education and innovation)
- Saint-Quentin-en-Yvelines, at the Vélodrome National, in collaboration with Nokia, Qualcomm and France TV (sports arena)
- Bordeaux Métropole, with Bouygues Telecom (hot spots and smart cities)
- Le Grand Port Maritime du Havre, in collaboration with Siemens, EDF and Nokia (sea port)
- Paris la Défense, in Puteaux (neutral host, urban area, business center)
- Bouygues Telecom, for the Lyon Part-Dieu train station, in concert with SNCF (train station)
- Bouygues Telecom, for an industrial zone in the city of Saint-Priest (industrial area)
- Bouygues Telecom, for the cities of Vélizy (78) and Meudon (smart cities)
- Orange, for the Rennes railway station, in collaboration with SNCF and Nokia (train station)
- Orange, for the 5G Lab co-innovation space, in Châtillon (business campus, innovation, multimedia and video production)
- Franconville, with Syrtem, Orange (urban hot spots and FWA)
- Puteaux, Icade with Orange and Cisco (indoor connectivity in connected buildings)
- Nozay, Paris-Saclay Nokia Campus, with Nokia (innovation)
- Angoulême, IP Directions (rural areas)

2.2 Key features for 26 GHz deployments

Key to successful deployment of mmWave use cases is ensuring that enough spectrum is available for each operator (at least 400 MHz per network, ideally 800-1000 MHz).[26] Also, enough base stations are required at appropriate locations to support the coverage and traffic density required.

26 GHz could be deployed on existing macro sites, for example for FWA, where these are well located for delivery of service. However, in many cases, small cell technology will be deployed both indoors and outdoors to serve coverage and capacity requirements. New sites supporting 26 GHz need adequate and robust backhaul to MNO networks and / or potentially to SA networks for industrial / vertical solutions. Key to successful deployment of small cells is simplification of permission and authorisation regimes. In the European Union, an Implementing Regulation was issued in July 2020 on small cell wireless access points.[27] Small cells that meet the parameters set out in the Regulation are exempted from any individual town planning permit or other individual prior permits.

Much of the experience with rollout of mmWave solutions has been in the United States (US). There has also been test and trials activity and some limited rollout in some Asian countries. In the US, deployment has been in 3GPP bands n260 and n261. Equipment developed for the 3GPP n257 band has also been used in early deployments elsewhere, including for trials in Europe[28].

[25] https://en.arcep.fr/news/press-releases/view/n/5g-19.html
[26] There are some spectrum awards that have assigned less than 400 MHz (e.g. in Italy where 200 MHz was assigned to each operator with the possibility to access other spectrum through a "club" model.
[27] Commission Implementing Regulation (EU) 2020/1070 of 20 July 2020.
[28] Based on the information obtained recommendations are made to stimulate demand for 26 GHz.

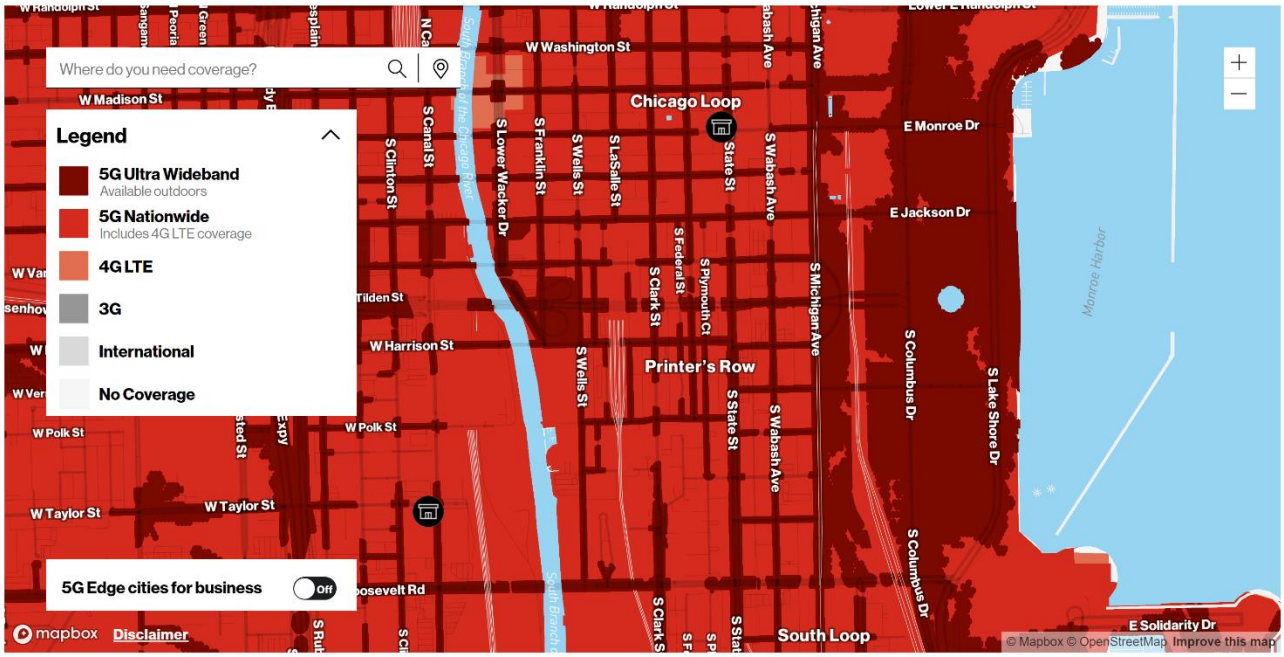
2.3 Selected use cases

Below a selection of use cases are described for the 26 GHz band.

2.3.1 Enhanced Mobile Broadband (eMBB)

eMBB is likely to comprise several variants including static (e.g. FWA – see Section 2.3.2), semi-static / nomadic consumption (e.g. seated at a venue or in a restaurant and occasionally moving around), mobility (e.g. connection while on transport or driving). An example is shown below of eMBB coverage provided by Verizon in Chicago. "5G Ultra-Wideband" denotes 28 GHz mmWave coverage which reaches street level outdoor and open areas but cannot easily reach indoors and far behind corners.

Figure 2.1: 5G coverage by Verizon in Chicago



Source https://www.verizon.com/coverage-map

A major railway station provides a good example for 26 GHz eMBB use where it can offer improved network data speed and low latency, improved business processes (e.g. selling and changing train tickets), better user experience, increased mobility, and reduced travel times. Examples are:

- Personalized travel support services:
  - Real time video with an agent (ticket purchase and exchange).
  - Navigation support service for disabled travellers (low latency).
  - 26 GHz hotspots for travellers in the station (content download before travelling).
- Augmented Reality for emergencies:
  - Assistance to a person in danger (first aid assistance).

– Direct immersion in non-attack crisis situations via an 8k 360° camera.

26 GHz trial at Rennes train station, France

In France, the Rennes railway station has been selected by the regulator to carry out trials on the 26 GHz band. The trial is testing both client services in the public zone of the station and behind the scenes for maintenance and repair of trains.

For users/travellers, improving their comfort while waiting is an objective. From 5G hotspots, various usage is envisaged, such as a service for almost instantaneous downloading of a movie or a TV series for consumption during the travel time.

For the development of business tools, 5G makes it possible to imitate applications requiring ultra-high bandwidth (training in augmented reality, remote maintenance in augmented reality, massive processing of train control data).

2.3.2 FWA

FWA delivers broadband connections to residential and business premises without the need for a fixed copper or fibre connection. It avoids civil works and other costs that would be required to deliver fibre upgrade. Today FWA is targeted at homes, buildings and offices, with the objective to deliver very high-capacity connections, enable new applications and improve user experience.

5G allows FWA to be delivered in both mid-band and mmWave spectrum. While mid-band spectrum will deliver a good service and may be well suited to longer range rural FWA use, 26 GHz is ideal spectrum for deployment of FWA in rural or suburban settings lacking fibre. Cell ranges of 500m or more are achievable and 1 Gbps download speeds and upload speeds in the 100s of Mbps are routinely possible.

At 26 GHz, FWA requires line of sight or near line of site transmission and it works best with an externally mounted antenna at the customer premises. Topology could dictate many cell sites, which could influence the scaling and economics of delivery. However, for localised fill-in or provision to small groups of rural premises, or where there are other constraints on provision of fixed infrastructure, it may well be an advantageous option. FWA and eMBB could share the same spectrum and same base station infrastructure und thus the associated cost e.g. in sub-urban areas.

FWA solutions allow cable / fibre broadband capability to be offered in many places where it is extremely costly and / or complex to deploy fixed fibre solutions. FWA solutions are unlikely to be widely adopted across all of Europe, however, even in situations where there is good, fixed broadband capability, FWA may be an economic means for facilitating interim connectivity upgrades and dealing with hard-to-reach premises.

5G FWA services in the United States

Verizon launched 5G FWA in October 2018, aiming to cover 30 million households (~23% of population) in 5-7 years. Positioned as a cable broadband alternative the 5G Home Internet service is now available in areas of 30 cities in the US (April 2021) with further expansion planned. Typical download speeds are 300 Mbps with peak up to 1 Gbps and typical upload speed is 50 Mbps.

5G FWA consumer business opportunities are cost-sensitive and location dependent and require careful selection. The pandemic and work from home trend have been seen to boost the opportunity. Generally, the enterprise opportunity is seen as very promising and Verizon provides the service in 24 cities in the US as of April 2021.

5G FWA Orange Romania

In Europe, Orange Romania plans to launch FWA services in the 26 GHz band soon. Orange has carried out numerous tests based on existing macro sites with Samsung and Cisco in 2019 and 2020, which have demonstrated a viable FWA proposition delivering service like fibre. The trials were done with band n257 technology, using MIMO 4x4 and analogue beam forming, with both indoor and outdoor antennas. Performance parameters are quite similar to fibre (1Gbps D/L and 100+ Mbps U/L) and good customer feedback has been generated by the tests.

2.3.3 Hot spot high-capacity locations (sports arena and connected venues)

26 GHz is an attractive band for high capacity, low latency connectivity over a limited coverage area. The main advantages are improved broadband access (high speed and low latency) for audiences at indoor and outdoor venues with savings on infrastructure, greater deployment flexibility and the means to deliver a richer content proposition.

Applications could include:

- Transmission of ultra-high-definition video streams for broadcast on giant screens at venues.
- Delivery of 360° 4K immersive video streams for broadcasting to the devices of venue audiences.
- Feedback and monitoring of data generated by sports participants or other performers at the venue.
- Further solutions that enhance the immersion and experience of the audience.
- Seamless access to business video calls / conferencing, presentations and data at major trade shows and events (e.g. MWC, IFA).

26 GHz trial in Vélodrome National (St-Quentin-en-Yvelines, France) – Sports arena

A broadcasting use case has been tested for indoor connectivity on the 26 GHz band by the Saint-Quentin-en-Yvelines sports arena in France and has shown positive results[29]. This open platform for 5G experiments aims to meet the challenges of this future Olympic site. The use cases will cover enhanced broadcasting of sports competitions, evolution of fixed and mobile audio and video equipment, and integration of AI into sports media: low latency and increased bandwidth will facilitate these use cases.

2.3.4 Industrial use cases and connected enterprise

Use of spectrum for industrial applications presents a wide range of opportunities. By its nature this is likely to apply to countries with a strong industrial strategy and those with a political will toward industrialisation. It could help to kick start new advanced industrial activity and increase international competitiveness.

There are many ways in which wireless might be used to drive transformation in an industrial setting and enhance delivery and competitiveness. It can assist with cost reduction, improving operational efficiency and significantly increasing the flexibility with the way in which an industrial installation is configured. Wireless could be actively deployed for machine control (Figure 2.2), maintenance management, quality assurance, stock control, safety management and incident response. 5G wireless solutions will deliver the secure radio environments necessary for industrial use. While 5G integration is at an early stage in industrial environments there are clear advantages 5G mmWave brings with quality, channel bandwidth and flexibility.

Implementation will be via many sorts of sensors, control devices, video and VR/AR capability needing the resources of large scale IoT, high bandwidth (potentially uplink as well as downlink) and ultra-reliable and low latency communications for mission critical applications (i.e. the full suite of 5G capability). Bandwidths required and the relatively short-range propagation make 26 GHz an ideal spectrum choice for many industry use cases. Metallic and other surfaces act as reflectors allowing for indirect signal paths. Where physical constraints exist, 26 GHz (e.g. building fabric, extensive metallic obstructions) 26 GHz can be used in combination with other spectrum choices (e.g. mid-band).

[29] Video of the tests available here: https://www.youtube.com/watch?v=ifnSc300pDo

Figure 2.2: Machine control and logistics operations in an industrial environment

Source: Nokia

The deployment of wireless solutions is ideal for greenfield industrial sites but 26 GHz small cells can also improve and replace legacy installations at brownfield sites to meet an increasing number of interconnected machines and devices, and deliver benefits of higher reliability, productivity and energy savings by enhancing the ability to reconfigure and removal of operation and maintenance issues associated with fibre or Ethernet connections to equipment on production floors.

The spectrum and core network / RAN aspects of industrial use cases could potentially be provided by MNOs but they could equally well be provided in SA mode by specialist providers.

26 GHz trial in Le Havre seaport, France

The port of Le Havre, associated with businesses in the port area, is exploring and testing 26 GHz applications in a port and industrial context. Siemens, Nokia and EDF (Electricité de France) are partners on this project. Applications in the field of energy are envisaged (management of smart grids, recharging of electric vehicles). Other applications will target logistics operations in the port, such as the operation of container machinery (Figure 2.3) and mobility analysis (monitoring of flows). 2.6 GHz and 26 GHz are deployed in parallel for the experiment, for the 26 GHz to use the 2.6 GHz as an anchor band. Connectivity and innovation are important in the competitive environment of seaports, and benefits are numerous on operations, mobility, and security, among others.

Figure 2.3: Port application

Source: Nokia

2.3.5 PMSE

PMSE (Programme Making and Special Events) covers radio applications used with real-time presentation of audio-visual information, including the transmission of audio, video and data signals"[30].

Visual PMSE in a 4K-8K multi-camera production environment requires very high bandwidth connections if done wirelessly. Vendors in the field can clearly see the case for 26 GHz connectivity (and this is also being explored in the 5GPPP 5G Records project) but are unable to decisively move forward without access to the 26 GHz ecosystem (5G mmWave modules needs to be integrated into the equipment). Access to spectrum is required on a localised basis, especially if PMSE is operating in a mobile production unit, which changes location day by day.

Using wireless systems eases the requirement for a significant amount of cabling and assists with rapid deployment and / or reconfiguration and thereby increases efficiency and reduces operating costs. The spectrum and core network / RAN aspects of the use case could potentially be provided by MNOs but this is a service that could equally well be provided in SA mode by specialist providers.

[30] Source : European Commission

Wireless video production

Discussion with a camera equipment vendor highlighted the need for very high uplink bitrates and the low latency supported by 5G mmWave to film high quality video content.

This is needed at studios, frequently used locations (e.g. major sports stadium, outside government buildings, etc) and other locations for either short duration for news reporting or longer duration for TV filming and movies.

Availability of suitable solutions is currently delaying realisation of wireless recording and control. The industry is concerned that the sorts of devices they require are likely to be available significantly after smartphones for the 26 GHz band.

mmWave bands allow for very high uplink bandwidth as they can implement asymmetric TDD patterns in favour of uplink transmission. The potential for isolation and the larger amounts of spectrum available in mmWave allow frequency selection for these applications with less constraints than in sub-6GHz bands (as there are likely to be less co-channel and adjacent channel users to consider).

2.4 Research feedback

The following points were raised in research regarding use cases.

- Plum's research suggests that there is good awareness of the use cases that could be deployed using 26 GHz spectrum and why this spectrum is required (e.g. high bandwidth requirements – download and upload, high traffic / user density, need for low latency).
- The research also clearly highlighted the need for using licensed spectrum and the quality-of-service assurance it provides (e.g. with outdoor industrial environments and media production locations where the risk of interference must be minimised).
- In some interviews, questions were raised about the size of the market for 26 GHz and whether this will be sufficient to drive the 26 GHz ecosystem (especially for specialist uses with devices other than smartphones).
- Although there was good awareness of the way in which 26 GHz can be used in enterprise and industrial settings, clear communication of the timeline for availability of 5G SA solutions, may be required for these settings.
- Interviews highlighted that there have been positive experiences with trials of FWA and the additional throughput that can be achieved in hot spot situations.

Overall, there appears to be a good understanding of where 26 GHz can provide solutions and concerns expressed were less about the use cases and focused more on ecosystem availability and access to spectrum, which are addressed in the following chapters.

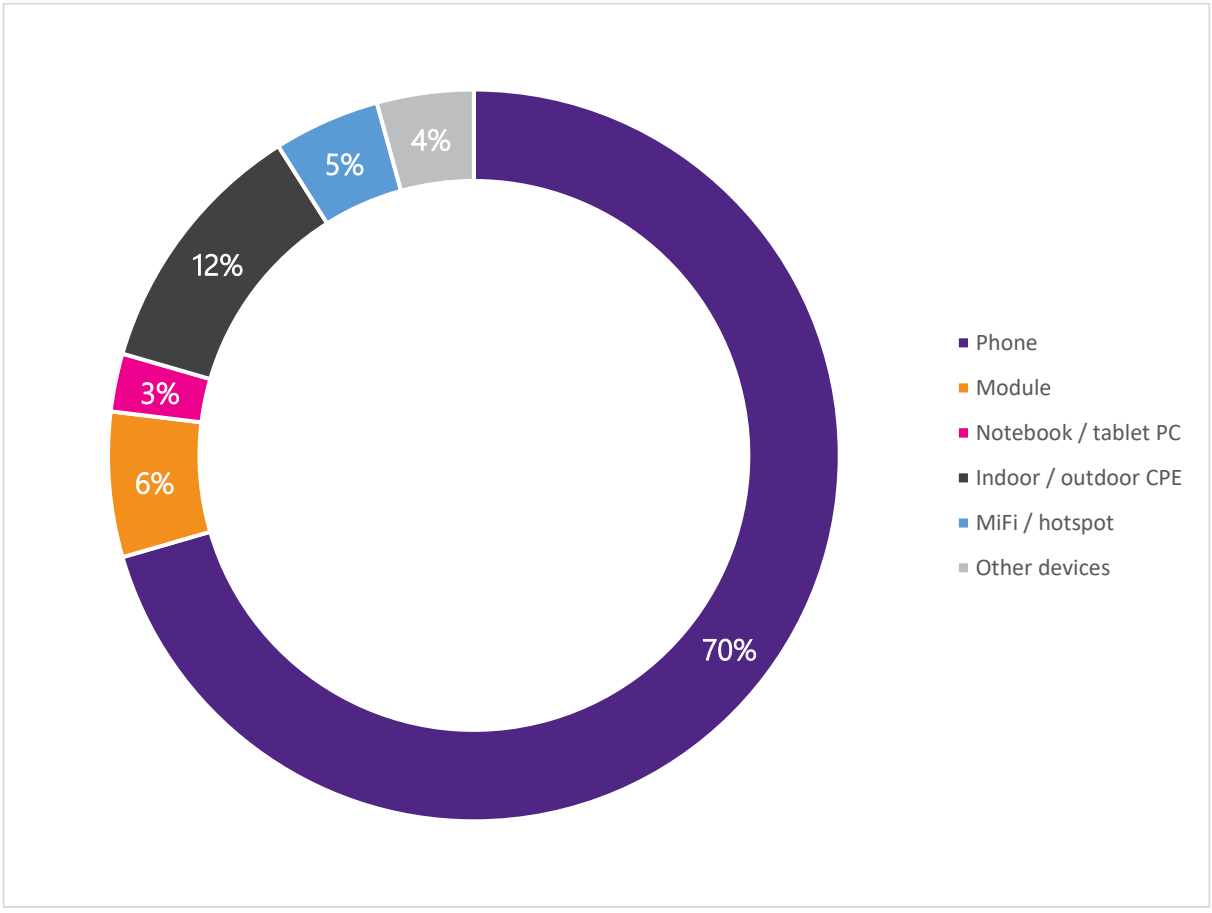
3 The 26 GHz ecosystem

3.1 Current state of play for 5G devices

A limited number of user devices were available at the start of 5G deployment. Like all new generations of mobile technology it has taken time for the device ecosystem to scale up and the number of available 5G devices is growing rapidly according to the GSA who report that "the total number of commercially available 5G devices now stands at 431, which is an increase of 28% over the past three months".[31] The GSA also report that the number of announced 5G devices continues to rise and has passed the 700 mark in April 2021.

To date most 5G devices have focused on mid-band spectrum solutions and most of these are mobile phone form factor as shown in Figure 3.1. However, it is also clear that other form factors are gaining ground such as modules and indoor and outdoor CPE.

Figure 3.1: Breakdown of commercially available 5G devices (all frequency bands)



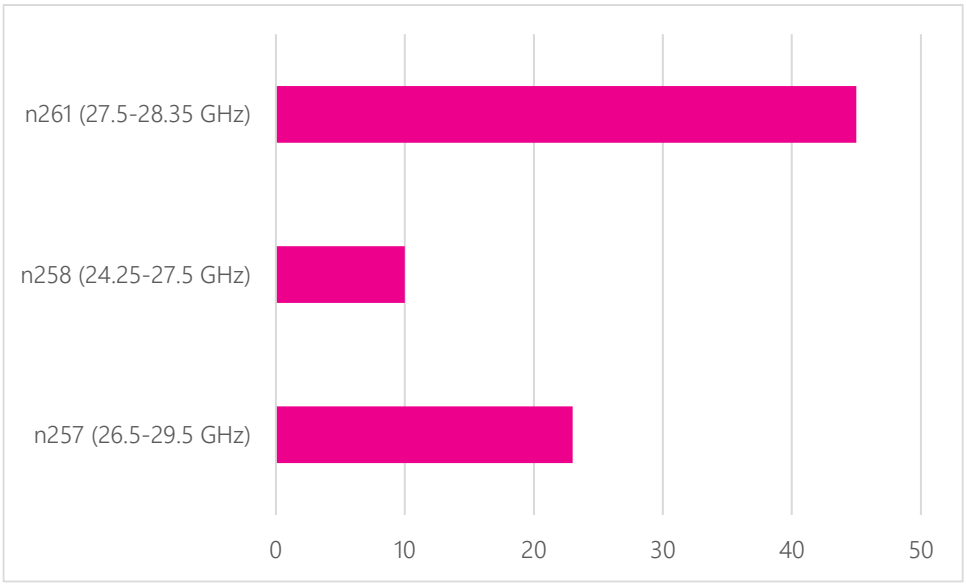
Source : GSA (Data April 2021), Plum analysis

For mmWave solutions there are fewer devices currently available. In general, deployment of mmWave lags that of mid-band but there are some notable exceptions, like the US, which put higher reliance on mmWave deployment from the start. The current position for availability of mmWave devices is as shown in Figure 3.2. Of these 27 are mobile phone form factor and 46 other form factors. The number of mmWave devices is expected

[31] GSA ecosystem report, April 2021.

to grow significantly over the next 12 months as more mmWave spectrum is made available and network deployments increase.

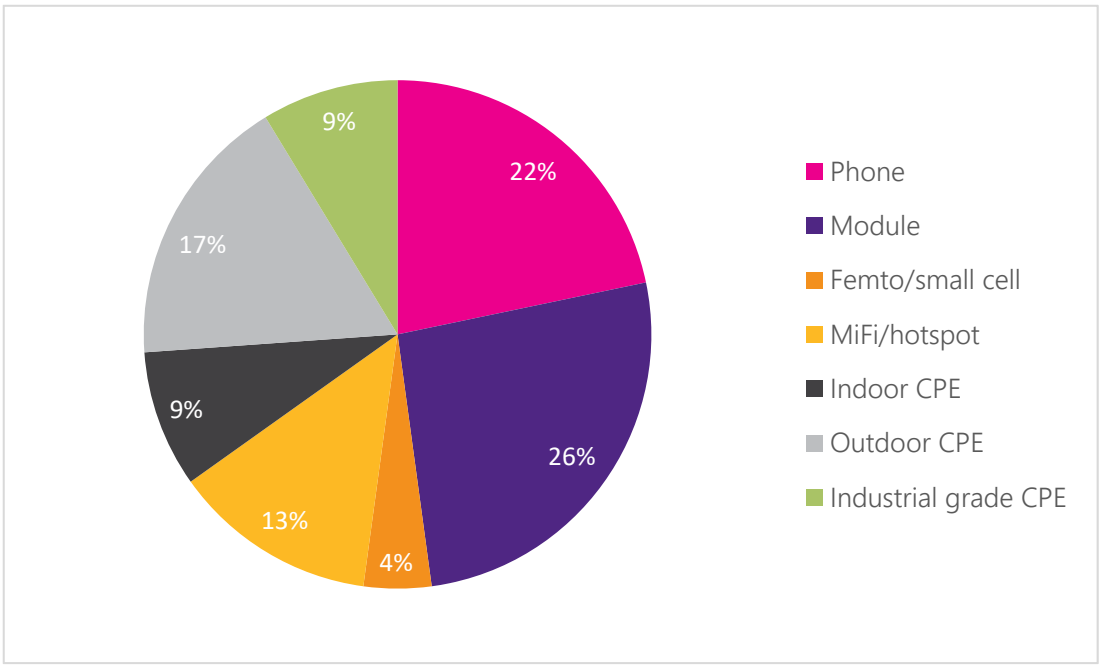
Figure 3.2: Availability of 5G mmWave devices



Source : GSA (Data April 2021), Plum analysis

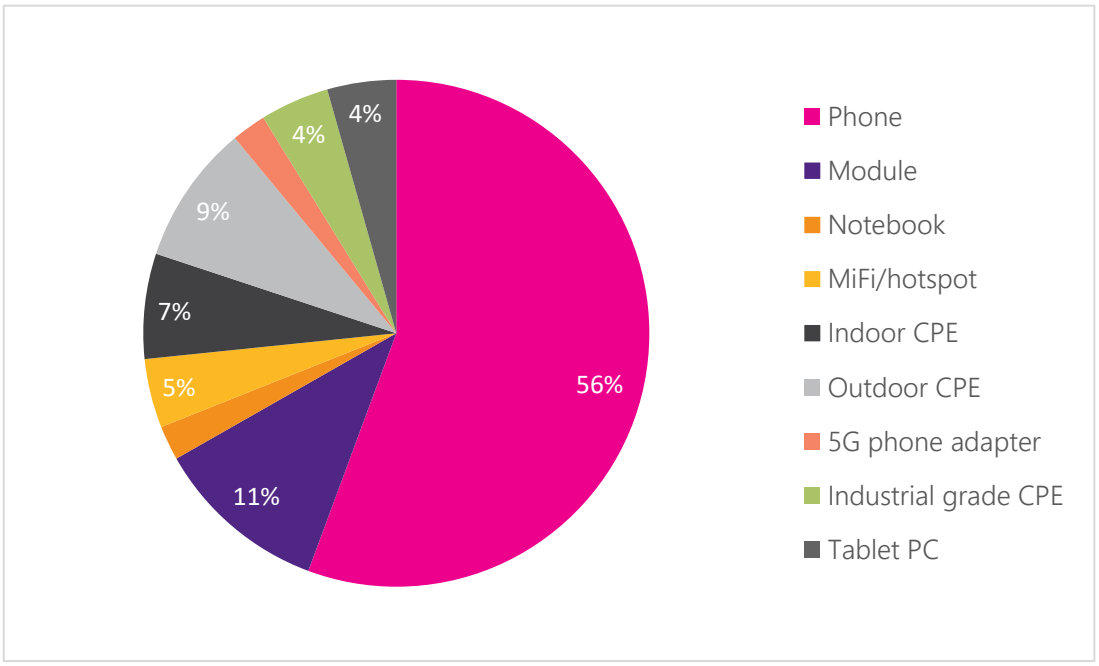
Figure 3.3 and Figure 3.4 show the breakdown of device types in the mmWave spectrum for bands n257 and n261.

Figure 3.3: N257 devices



Source GSA April 2021

Figure 3.4: N261 devices – US band



Source GSA April 2021

In general, with new mobile technology launches, it is expected that the choice of mmWave devices will grow rapidly. Indications so far are that 5G is growing faster than previous generations of mobile technologies. The Global Certification Forum (GCF) has recently said that the rate of 5G integration into devices has continued to rise, significantly outpacing the rate at which 4G was adopted in its early years.[32]

3.2 Differentiating between mmWave bands

In Europe attention is on the 3GPP n258 band (24.25-27.5 GHz). This band has been harmonised globally in WRC-19 and has been adopted elsewhere in the world including Australia, Brazil, Thailand, Malaysia, Singapore, Hong Kong and Vietnam. Together with Europe, these countries provide a strong base for OEMs to commit to development and production of devices that include the band. In many cases, chipsets and Radio Frequency (RF) modules are already available and the decision to proceed with inclusion of band n258 requires clear evidence of spectrum availability in target territories.

3.3 Interim solution using n257

A key feature of 3GPP band n257 (26.5-29.5 GHz) is the lower 1 GHz of the band overlaps with the top 1 GHz of band n258. This provides the potential for band n257 devices to assist with early mm Wave deployments in Europe.

There are already cases where band n257 equipment has been used for tests, trials and commercial deployments in Europe (e.g. for FWA). If spectrum assignment and the devices are suitable it can also be used for more early commercial deployments. Making use of these devices immediately expands the range of mmWave devices for use in the 26 GHz band. Downstream, the use of n257 devices can be reconsidered as more spectrum becomes available in the 26 GHz band and a wider range of n258 devices come to market.

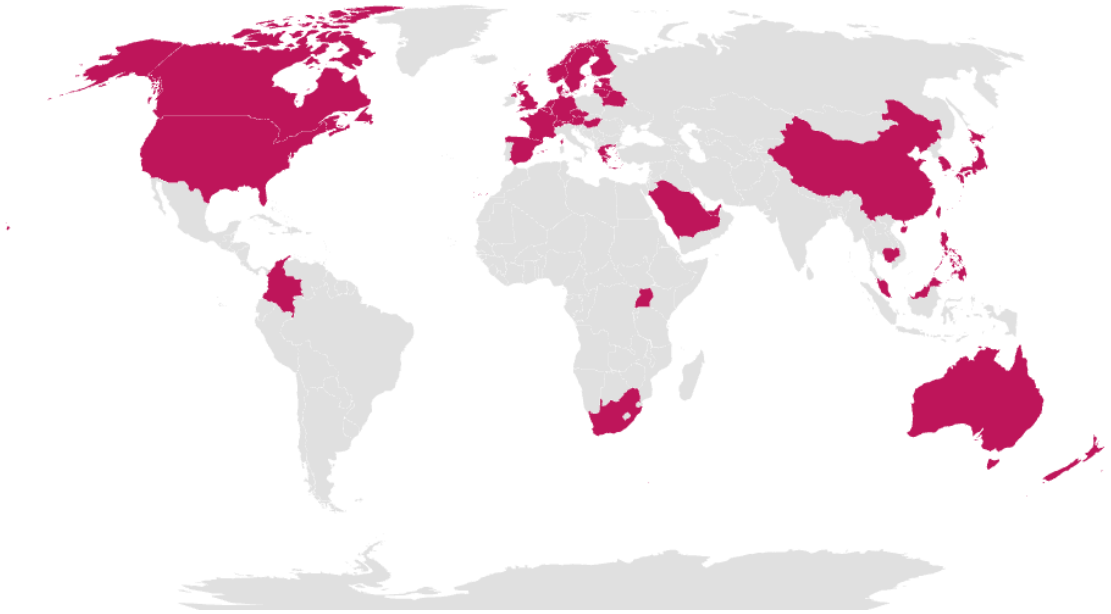
[32] GCF I Mobile Device Trends Report 2020 Published (globalcertificationforum.org).

3.4 Standalone (SA)

While MNOs have started introducing SA solutions for performance and cost reasons in their networks, 5G SA solutions will be necessary for some specific installations (these are mostly expected to be industrial). SA solutions are not yet commercially available for mmWave and are likely to be up to 1 year later than the non-SA solutions currently being deployed. For SA mmWave solutions an FR1[33]anchor is likely to be required for the foreseeable future.

Network operators have been running tests or trials of 5G SA technologies using other (non-mmWave) frequency bands. GSA has identified 68 operators in 38 countries investing in 5G standalone for public networks as shown in Figure 3.5. Vodafone has recently announced activation of a 5G standalone network in major cities in Germany – Europe's first major launch.[34]

Figure 3.5: Countries investing in 5G SA



Source: GSA 5G standalone global market status, March 2021

3.5 Research feedback

Key issues raised in the research were:

- Few comments were raised on the provision of network facilities for 26 GHz as there is an expectation that MNOs will deploy once they have a spectrum licence and see demand. Minimising the cost of backhaul was raised as a concern together with possibly a need for more suitable wholesale backhaul products for small cell deployments.

- The lack of availability of n258 devices was a frequent comment raised in Plum's research by both spectrum users and spectrum managers as a reason for holding back with deployment of the 26 GHz band. However, there are devices available, and the number is growing.

[33] FR1 anchor from spectrum in frequency range 410-7125 MHz.
[34] https://www.ericsson.com/en/news/3/2021/vodafone-partners-with-ericsson-for-europes-largest-commercial-5g-standalone-network

- There is clearly a desire to productise use cases but the perceptions around band n258 ecosystem availability are holding players back from doing this.

- There was also a surprising lack of awareness or certainty about the overlap of the 26 GHz band with band n257 and the potential for use in Europe of devices produced for band n257. However, there were some clear examples of the use of band n257 equipment for trials and commercial deployments (e.g. FWA in Italy).

- The availability of standalone 26 GHz solutions was raised as a potential inhibitor for early development of some enterprise/industrial solutions (e.g. location-based video production facilities).

Overall, there appeared to be a lack of awareness of development of the band n258 ecosystem among many of those interviewed by Plum. Also, there were some misperceptions about the potential to use band n257 equipment in Europe. Currently there is a total pool of around 30 devices able to access the top 1 GHz of the 26 GHz band.

4 Access to 26 GHz spectrum

4.1 Introduction

A strategic roadmap for spectrum for 5G in Europe was set out in 2016 when RSPG published its first Opinion on spectrum for next generation wireless systems. This identified three pioneer spectrum bands for 5G including use of the frequency range 24.25-27.5 GHz, referred to as the 26 GHz band or 3GPP n258 band, to support ultra-high capacity for innovative new services, harmonised in CEPT under ECC Decision 18(06). The European Electronic Communications Code (EECC) set out that Member States of the European Union should allow the use of at least 1 GHz of the 26 GHz band, if there is clear evidence of market demand and of the absence of significant constraints for migration of existing users or band clearance.

In this section we review the current state of play for 26 GHz spectrum in Europe and what else is required to bring this spectrum into use for 5G. Key non-European examples are presented for comparison. We also consider the spectrum required by MNOs and others likely to need access to this spectrum (e.g. neutral hosts, industrial players) and what Plum's research indicates about the terms on which spectrum is made available.

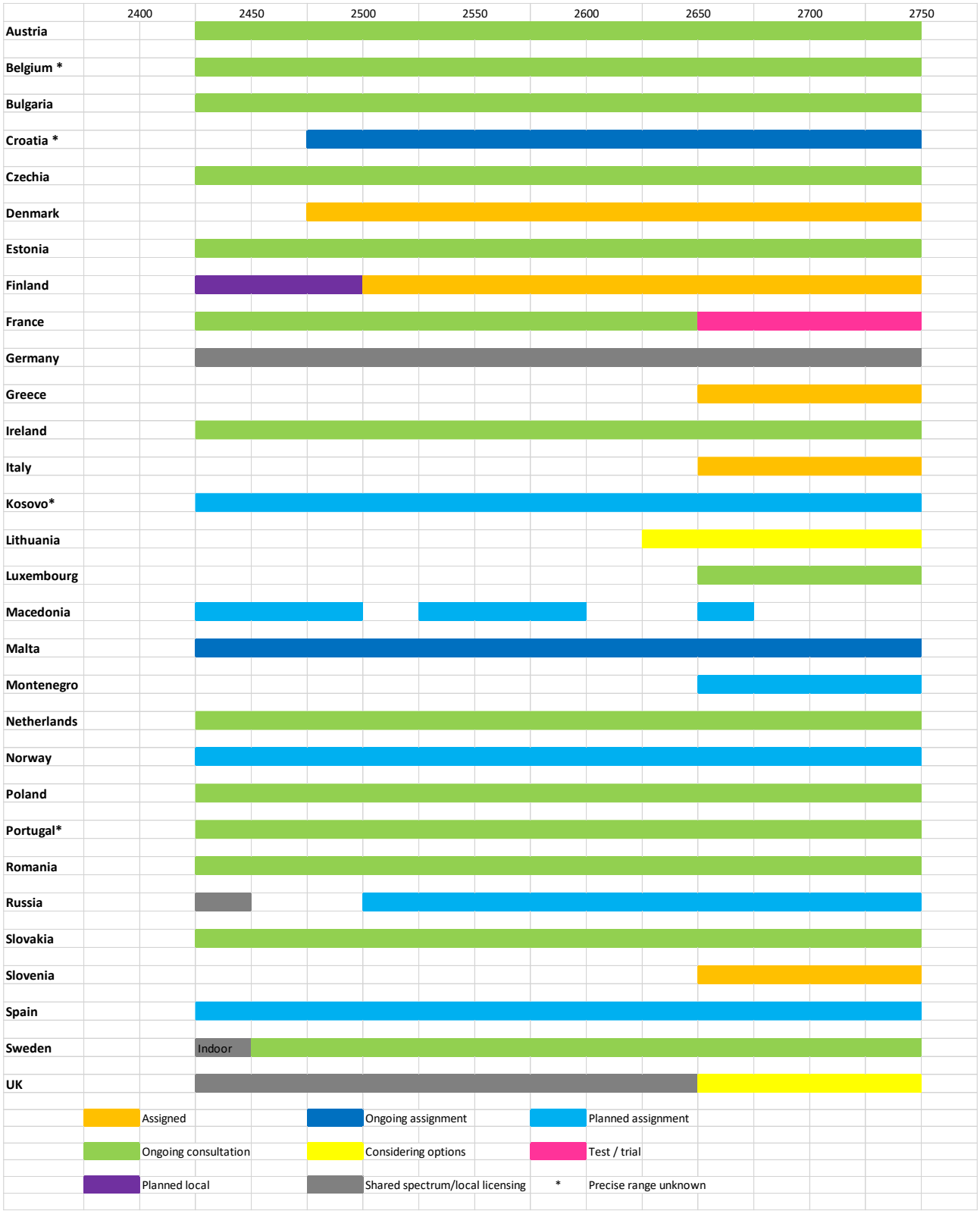
4.2 Current state of play

There is growing recognition among spectrum management authorities that the 26 GHz band is a priority band and that it should be made available when demand occurs. So far, 26 GHz spectrum has been made available in Europe in Denmark, Germany, Greece, Finland, Italy, Russia, Slovenia and the UK and there are many consultations and proposals ongoing elsewhere as shown in Figure 4.1. [35] There is no single approach that has been adopted for the award of this spectrum or a consistent amount of bandwidth made available.

In Europe, the sub-band below 26.5 GHz is more problematic to make available in the near term due to both the presence of incumbent services and the requirement to protect space sensors of the EESS[36]. This means that access to this part of the band requires equipment that meets the relevant protection criteria and that sharing mechanisms could be needed. This has led some countries to propose only awarding the upper 1 GHz (26.5-27.5 GHz). This approach allows some 26 GHz band spectrum to be made available quickly and provides the benefits of overlapping with the 3GPP n257 band[37] and enables access to a larger equipment ecosystem.

[35] To the end April 2021
[36] Earth Exploration Satellite Service (EESS).
[37] 26.5 – 29.5 GHz

Figure 4.1: 5G spectrum situation in Europe for the 26 GHz and 28 GHz bands



Source: GSA and Plum Consulting

Outside Europe there is also progress with access to mmWave spectrum (e.g. US, Hong Kong, Japan, Thailand, Australia etc.). In some countries, like Japan, specific measures (incentives) have been taken to promote the adoption of the mmWave bands.

4.3 Details of completed spectrum awards

Below are brief summaries of awards of 26 GHz spectrum both within Europe and elsewhere. While the term spectrum award is used here it should not be taken to imply that in all cases 26 GHz is being treated in the same way as sub 6GHz spectrum where competitive awards (auctions) were generally used. A wider range of mechanisms are being employed including competitive awards and administrative procedures.

4.3.1 Europe

Denmark

Denmark auctioned the 26 GHz band in conjunction with 1500 MHz, 2100 MHz, 3.5 GHz and part of 2.3 GHz starting in March 2021. The auction results were announced on 21 April with Hi3G being awarded 1,000 MHz (26.5 – 27.5 GHz), TDC 1,250 MHz (24.65-25.9 GHz) and TT Network 600 MHz (25.9 – 26.5 GHz).

Finland

26 GHz spectrum was auctioned in June 2018. Each of the three current MNOs were assigned 800 MHz of spectrum between 25.1 – 27.5 GHz at the starting price of 7 million EUR. 850 MHz of the band (24.25-25.1 GHz) has been reserved for local/regional vertical players and R&D or educational usage. The regulator, Traficom, expects there to be both local private and public networks deployed in the band.

The strategy behind the award was to make spectrum available as soon as possible, then let the market plan and implement use cases. There were no major barriers encountered with making the spectrum available in Finland.

The definition of local network and conditions to be applied to use are currently being worked on by the regulator and are expected to be published in 2021. New regulation is also being considered for small scale public mobile use with simpler licensing requirements.

Germany

In Germany it was decided to issue local licences in the 24.25 – 27.5 GHz band as a general assignment approach was not considered feasible based on incumbent use and protection requirements. The Bundesnetzagentur published the Administrative Regulation on Frequency Allocations for Local Broadband Frequency Uses in the 24.25 - 27.5 GHz Frequency Range[38] in December 2020. Applicants need to submit applications describing the intended frequency usage information including a description of the area (no maximum size is stipulated) and justification for the requested bandwidth. It is expected that a typical user bandwidth will be 800 MHz - the more bandwidth requested, the more detailed the justification must be for the need. No spectrum cap or maximum bandwidth has been set based on the expectation of further spectrum becoming available in the 40.5 – 43.5 GHz band[39]. Applications for specific frequency sub-ranges in the 26 GHz band must also be justified. Operator agreements between neighbouring users are required to manage use of the local broadband frequencies (indoor and outdoor). Allocation of frequencies requires interference free co-existence with existing radio applications for other services.

Frequencies may be fully or partially revoked after 12 months ("use-it-or-lose-it"). Frequencies for wireless network access can only be allocated if the interference-free operation of the existing radio applications of other radio

[38] Bundesnetzagentur - Regionale Netze
[39] A mandate has been issued by the European Commission to CEPT to develop harmonised technical conditions for the band.

services is also ensured. Licences are awarded on a First Come First Served (FCFS) basis and have been available since the beginning of January 2021. Fees are determined in line with a formula and depend on the parameters of each application.

Greece

In Greece, the 700 MHz, 3.5 GHz and 26 GHz bands[40] were awarded by auction in December 2020 for 5G services[41]. The 26.5 – 27.5 GHz band was assigned to the three existing MNOs with two obtaining 400 MHz each and the third a single lot of 200 MHz.

Fees paid were 6.5m EUR for each of the two 400 MHz blocks and 3.2m EUR for the 200 MHz block[42]

It is understood that up to 25 per cent of the auction revenues will be used to support research projects and there are plans to reserve frequencies in the three priority 5G bands including 200 MHz at 26 GHz for 5G research and experimentation.

The Greek government has already drafted legislation that aims to boost 5G private networks. It also plans to reserve frequencies in the low, mid and high bands for R&D[43].

Italy

Italy was the first country in Europe to auction 5G mmWave spectrum. The multi-band auction that included the 700 MHz and 3.5 GHz bands ended in October 2018 with 1000 MHz in the 26 GHz band being assigned to five MNOs. The licences are valid until 2037 and licence fees are due in instalments between 2018-2022.

The five lots were allocated, raising a total of 167.3 million EUR. Telecom Italia paid 33 million EUR for its 200 MHz block, Illiad received another lot for a little less at 32.9 million EUR, while Fastweb, Wind and Vodafone paid 32.6 million EUR each[44]

The Italian regulator AGCOM has adopted an innovative regulatory framework based on a "Club Use" model[45]. Under this framework:

- Licensees can share 26 GHz spectrum on a geographical basis when frequencies are not being used, and each licensee would still have priority access to its own block.
- Licensees can stipulate reasonable commercial agreements combining spectrum sharing and infrastructure sharing policies.
- Licensees could also make agreements with a trusted third party ("Neutral Host") to manage concurrent installations or develop the physical network's infrastructures.
- Licensees can lease spectrum to vertical players.

[40] The expiring 2.1 GHz licences were also part of the award
[41] Greece auctions 5G spectrum as EU clock ticks down - PolicyTracker: spectrum management news, research and trainingPolicyTracker: spectrum management news, research and training
[42] Greek 5G auction exceeds targets, builds innovation kitty | Network & Infrastructure | TelcoTitans.com
[43] Source: Policy Tracker
[44] Italian 5G spectrum auction – 5G Observatory
[45] This is a variant of the classic "club use" formula, as the club members and the access criteria are decided by the regulator, while the club "members" decide on their own rules of coexistence and management.

Work is ongoing to finalise the rules and processes for Club Use. Similarly, rules are also still under development for provision of access to 26 GHz spectrum by other players (non-telecoms operators) for the development of 5G services.

UK

In the UK, the lower 26 GHz band (24.25-26.5) has been added to Ofcom's spectrum sharing framework for indoor use from the end of 2019[46]. This enables deployment of new low power 5G indoor local access applications with little to no impact on existing services and without prejudice to future outdoor use of the band. Licensees can deploy the required number of indoor base stations in a circular area with a 50-metre radius without requiring further individual base station authorisations. Licences are available on a FCFS basis and it is possible to apply for multiple licences to cover a larger area. The licence will also cover terminal stations and a licence fee of £320 is applicable per licence. Anyone intending to operate a 26 GHz system within the parameters set by Ofcom can apply for a licence under the scheme.

More generally for mmWave, Ofcom carried out a call for inputs exercise in 2017 on the 26 GHz band. While the above localised shared arrangements are now in place there is still no other access to the 26 GHz band for 5G. It is understood that Ofcom is developing a consultation for the 26 GHz band, which is expected to be published in 2021.

Russia

In March 2020, Russia's State Commission for Radio Frequencies (SCRF) allocated a 400 MHz block of mmWave spectrum in the 24.25—24.65 GHz range for a wide range of users, including industries and MNOs. A further block of spectrum from 24.65-27.5 GHz is also understood to have been made available for studying 5G capabilities.

A large number of players have conducted trials using 26/28GHz spectrum in Russia using trial licences. For example, in March 2020, SCRF awarded a test licence in the 24.65–27.5GHz band to New Digital Solutions (a joint venture between MegaFon and Rostelecom) for trialling 5G capabilities in partnership with state corporation Roscosmos.[47] A selection of recent mm-wave 5G trials conducted in Russia are:

- In March 2021, MTS, Ericsson, Motorola and Qualcomm announced that they had achieved download 5G speeds exceeding 4Gbit/s in an indoor trial using 800MHz of spectrum (aggregating eight 100MHz carriers) in the 24.25–27.5GHz band. The trial used a Motorola smartphone with Qualcomm modem[48].

- In August 2020, Beeline, Nokia and Qualcomm launched a 5G pilot network at a port in St Petersburg using a trial licence in the 26/28GHz band. The network will enable VR/online gaming via the Beeline Gaming cloud service.[49]

- In August 2019, Tele2 and Ericsson launched a 5G pilot zone in central Moscow on Tele2's commercial network. The 5G pilot zone uses the 28GHz band in a non-standalone (NSA) configuration (using the 2600MHz as an LTE anchor). 5G pocket routers are used as end-user devices for mobile broadband services with ultra-high speeds.

[46] Shared access licences - Ofcom
[47] See https://www.comnews.ru/content/205070/2020-03-18/2020-w12/promyshlennye-predpriyatiya-poluchat-chastoty-dlya-5g-bez-aukcionov
[48] See http://ir.mts.ru/ir-blog/mts-blog-details/2021/MTS-Ericsson-Qualcomm-Set-European-5G-Speed-Record-for-Commercially-Available-Smartphones/default.aspx
[49] See https://www.broadbandtvnews.com/2020/08/18/beeline-launches-5g-network/

In terms of commercial deployments, in July 2020, MTS announced that it had received the country's first licence for commercial 5G operations in the range made available by the SCRF's decision. The licence is for the full 24.25–24.65GHz range, covers 83 Russian regions and expires in July 2025.[50]

In August 2020, MTS launched trial 5G mm-wave networks at two locations in the Tomsk region: the Tomsk State University of Control Systems & Radioelectronics (TUSUR) and a factory of Micran (a telecoms equipment manufacturer).[51]

Slovenia

In Slovenia the 26 GHz band was awarded by auction in April 2021 as part of an award of 700, 1500, 2100, 2300 and 3600 MHz bands. Telekom Slovenia has obtained 400 MHz, Telemach 200 MHz and A1 Slovenia 400 MHz of 26 GHz spectrum.

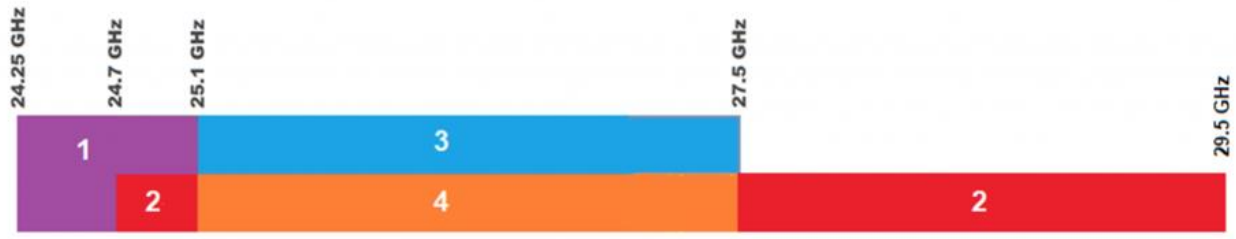
4.3.2 Outside Europe

Below is a brief overview of some early mover territories with mmWave spectrum[52].

Australia

In Australia a mix of licensing arrangements have been implemented in the 26 / 28 GHz bands as shown below.

Figure 4.2: Licensing arrangements to be implemented in the 26-28 GHz band



Key:
1 – Class licensed Australia-wide
2 – Area wide apparatus licences (AWL) Australia-wide (available no earlier than Q4 2020)
3 – Spectrum licensed in major population centres (auction Q1 2021)
4 – AWL outside major population centres (available shortly after spectrum licence auction)

Source: ACMA

The AWL licences[53] allow users to aggregate frequencies area blocks in a single licence. Areas are based on pre-defined HCIS cells. There were two planned rounds for licence applications:

- Round 1: 24.7 – 25.1 GHz, Australia wide between 4 and 17 November 2021 with restrictions on number of base stations to manage interference by preventing wide and dense deployments, and

[50] See http://ir.mts.ru/news-and-events/news/news-details/2020/MTS-Receives-Russias-First-5G-License/default.aspx
[51] See https://www.riatomsk.ru/article/20200820/the-first-5g-test-zones-in-tomsk-open-on-the-basis-of-micran-and-tusur/
[52] There are further countries, such as Brazil, planning to award the 26 GHz band in 2021
[53] https://www.acma.gov.au/area-wide-apparatus-licensing-26-and-28-ghz-bands

- Round 2: 25.1 – 27.5 GHz in all areas other than those designated for spectrum licensing in first half of 2021.

- After these two rounds will use FCFS.

The ACMA announced in December 2020 that a total of 15 companies had secured new spectrum in the 26GHz and 28GHz bands[54]. The ACMA noted that a number of the successful applicants intend to provide wireless broadband services across all states and territories and across urban, regional and rural areas, while highlighting the fact that there had been 'considerable uptake from fixed satellite service providers across Australia, including from existing providers and new entrants to the Australian satellite market'.

The auction for the spectrum licences in major population centres took place in April 2021. There were 360 lots available, each of 200 MHz bandwidth, and 358 were sold for a total revenue of AUD 647,642,100. There were 5 winning bidders for the 34 cities and major regional centres. These are towns or cities with a population over 50,000 as well as small towns or cities, which, due to them being holiday centres or having university campuses, are expected to require the deployment of high-density wireless broadband services. No bidder could acquire more than 1,000 MHz.

Chile

The 26 GHz process ended in February 2021 without an auction as was the case for the other 5G bands. Entel, Claro and WOM each received 400 MHz free of charge. The licences are regional with one, two, or three licensees per region (9 out of 40 regions with three competitors, 16 regions with only one licensee).[55]

Hong Kong

The 26.55 – 27.75 GHz band was awarded by the Communications Authority in Hong Kong in March 2019 for 5G services with three MNOs each receiving 400 MHz of spectrum for the provision of large scale public mobile services.

In April 2019, OFCA invited applications for assignment of spectrum in the 26 GHz band (24.25 – 27.5 GHz) and 28 GHz band (27.5 – 28.35 GHz) on a geographically shared basis, for the provision of 5G or other advanced mobile technologies. The shared spectrum is specifically identified for geographic areas up to 50 square kilometres such as university campuses, industrial estates, technology parks and the airport. These licences are not available to the MNOs who already have spectrum. Initially 400 MHz of shared spectrum is being made available. So far one shared licence has been issued to the Hong Kong Airport Authority.

There are currently no spectrum utilisation fees applied for either MNO or shared licences.

Japan

In March 2019, MIC awarded four blocks of 400 MHz to the MNOs in Japan (27 – 28.2 GHz and 29.1 – 29.5 GHz). The spectrum was assigned via a beauty contest.[56] The 28.2-28.3 GHz band is reserved for private 5G networks

[54] ACMA offers 15 applicants 26GHz/28GHz spectrum (commsupdate.com)
[55] Chile completes first 5G spectrum auction in Latin America – 5G Observatory
[56] The outcome was: NTT Docomo: 3.6-3.7 GHz, 4.5-4.6 GHz and 27.4-27.8 GHz; KDDI: 3.7-3.8 GHz, 4.0-4.1 GHz and 27.8-28.2 GHz; Softbank: 3.9-4.0 GHz and 29.1-29.5 GHz; Rakuten: 3.8-3.9 GHz and 27.0-27.4 GHz. MNOs committed to cover the following percentage of population within 5 years: NTT Docomo: >90%; KDDI: >90%; Softbank: 64%; Rakuten: 56%. MNOs also committed to the following network investments: NTT Docomo: 7 billion USD; KDDI: 4.1 billion USD; Softbank: 1.8 billion USD; Rakuten: 1.7 billion USD (Source 5G Observatory).

and applications were opened in December 2019. In the future further spectrum (28.3 – 29.1 GHz) may also be made available for this use.

Japan is providing time limited new incentives for start-ups and 5G investments through new legislation. Specifically, there is a 25% tax deduction for Japanese companies investing in start-ups and 15% tax credit for Japanese network development available to MNOs and private network developers (e.g. building networks for smart factories and smart agriculture in rural areas).

Figure 4.3: 5G Tax Incentive (April 2020)

Year	Year 1 – 2020	Year 2 – 2021	Year 3 - 2022
Tax Credit Available	15%	15%	0%
Scope	All Sub-6 GHz & mmWave bands	All Sub-6 GHz & mmWave bands	All Sub-6 GHz & mmWave bands

Source: METI

Korea

In South Korea, 2400 MHz in the 28 GHz band was awarded to 3 MNOs in June 2018 with a licence duration of 5 years. The fees for the spectrum were 549m US$ (622,300,000,000 KRW).

Each of the three South Korean MNOs (SKT, KT and LGU+) won 800MHz of spectrum.[57] Licences started on 1 December 2018 and last five years. Licences are national and include a coverage obligation to build a certain number of base stations within a given timeframe. The auction consisted of a principal stage and an assignment stage (clock auction and sealed bid respectively). Spectrum sold at the reserve price in the principal stage; the total price paid across all MNOs was USD560m (EUR470m).

In November 2019, MSIT launched its "5G+ spectrum plan" which aims to "secure the world's largest 5G spectrum supply" by releasing an additional 2640MHz of 5G spectrum by 2026. This includes assigning 2000MHz in the 24GHz band (1400MHz by 2021 and a further 600MHz by 2026).[58]

Singapore

In June 2020, the IMDA awarded the two mobile-network operators' national spectrum packages, comprising 100 MHz of 3.5 GHz frequency, each paired with one lot of 800 MHz of millimetre wave (26GHz and 28GHz), to Singapore Telecommunications Limited and joint-bidders StarHub and M1 - based on their network security designs, network rollout and financial standing[59].

Taiwan

The Taiwan government awarded the 3.5 GHz and 28 GHz bands via auction in February 2020 to four out of the five MNOs. The bids totalled 54m US$ (1,648,000,000 TWD) – around 0,0014 US$/MHz/pop. Not all the spectrum available in the 27.0 – 29.5 GHz band was sold with 900 MHz remaining.

[57] See http://www.msit.go.kr/web/msipContents/contentsView.do?cateId=mssw311&artId=1386500
[58] See https://www.msit.go.kr/web/msipContents/contentsView.do?cateId=mssw311&artId=2360371
[59] https://www.fitchratings.com/research/corporate-finance/singapore-presses-ahead-with-5g-driving-telecoms-capex-29-04-2020

In February 2020, the NCC announced a 5G first-wave programme and targets to accelerate the rollout and take-up of 5G. This aimed to encourage MNOs to deploy 5G in particular areas and hubs within a specific timeframe (1.5 years, 2.5 years or 3.5 years). The areas and venues identified are either high density areas to provide capacity to subscribers (e.g., in shopping centres or at sporting venues) or industrial use cases (e.g. for smart transport or telemedicine use).

In October 2020, the NCC published its proposals for subsidising the rollout of 5G in Taiwan. The proposed subsidy would offer NT$26.65 billion to operators with the purpose to accelerate and increase construction of base stations for 5G in both the 3.5 GHz and 28 GHz bands. It is understood that this would support the cost of additional base stations (those not originally included in MNOs business plans). Figure 4.3: summarises the proposed subsidy and its allocation over five years.

Figure 4.3: Proposed 5G subsidy (October 2020)

Year	Year 1 – 2021	Year 2 – 2022	Year 3 - 2023	Year 4 - 2024	Year 5 – 2024
Funding available	NT$9.92 bn	NT$5.57 bn	NT$ 5.56 bn	NT$2.59 bn	NT$3 bn
Outcome within period	Up to 50% coverage of non-rural population	Up to 60% coverage of non-rural population	Up to 70% coverage of non-rural pop	Up to 80% coverage of non-rural pop; 40% of new network (including base stations) to be sourced locally	Up to 80% coverage of non-rural pop; 40% of new network (including base stations) to be sourced locally

Source: NCC

United States

In the US award by auction of mmWave spectrum commenced in July 2016 with the 28 GHz (27.5 – 28.35 GHz), 37 GHz (37 – 38.6 GHz) and 39 GHz (38.6 – 40 GHz) bands. Also, spectrum between 64 and 71 GHz was made available on an unlicensed basis. Additional high band spectrum has since been awarded in the 24 GHz, upper 37 GHz, 39 GHz, 42 and 47 GHz bands. These mmWave bands have been made available for 5G in advance of mid-band spectrum, which has contributed to the initial rollout of 5G in the higher bands.

- The FCC's auction of residual 28 GHz (27.5-28.35 GHz) frequencies began in November 2018. The auction closed in January 2019. Bids reached 703 million USD.
- FCC's 24GHz auction[60] ended in May 2019, generating total bids of 2.02 billion USD (1.77 billion EUR). Twenty-nine bidders won 2904 licences.
  - AT&T obtained 831 of the 2,909 available licences, paying USD982 million (862.1 million EUR).
  - T-Mobile US paid USD803 million (705 million EUR) for 1,346 licences.
- Auction 103, which comprised spectrum in the upper 37 GHz, 39 GHz and 47 GHz bands, started in December 2019 and concluded in March 2020. The auction generated gross proceeds of USD7.57 billion.
  - Verizon offered 3.417 billion USD for a total of 4,940 licences.

[60] Lower segment (24.25 – 24.45 GHz) licensed as two 100-megahertz blocks (Blocks A and B) and upper segment (24.75 – 25.25 GHz) licensed as five 100-megahertz blocks* (Blocks C – G)

- AT&T offered 2.379 billion USD for 3,267 concessions.
- T-Mobile US committed to pay 931.609 million USD for 2,384 spectrum permits.

In December 2019, the Federal Communications Commission unveiled plans to establish a new "5G Fund" of up to 9 billion USD (8 billion EUR) in Universal Service Fund to support mobile operators to contribute with the deployment of 5G services across rural America.

Auction 107 in the US has recently concluded bringing access to mid-band spectrum for mobile operators (3.70-3.98 GHz).

4.4 Summary of award approaches

It is evident from the examples above that a range of different approaches have been adopted for access to mmWave spectrum, with the combinations of bandwidths, award types and other conditions seen:

- Bandwidths in the range 100 MHz to 1250 MHz per operator, often meeting or exceeding 400 MHz, have been awarded.
- Auctions, beauty contests and administrative (FCFS) awards have been seen.
- Fees have ranged from effectively zero (e.g. in Hong Kong) to millions of dollars / Euros, leading to very affordable cost per MHz per subscriber compared to other mobile spectrum bands.
- There are both local and national licenses awarded.
- Terms like licence durations can differ widely.

The GSMA has highlighted that ideally operators should be assigned at least 800 MHz contiguous spectrum per operator in initial millimetre wave (mmWave) bands (e.g. 26/28 GHz).[61] This position is also proposed by some equipment vendors in their literature though it is generally accepted that 400 MHz per network should be an acceptable minimum for a number of use cases.

The European Union Common Toolbox for Connectivity[62] has set out guidance for award of 26 GHz spectrum. Key points are:

- An individual authorisation scheme for the 26 GHz band.
- Member States are encouraged to promote flexible licensing of the band.
- Focus on local licensing and infrastructure sharing.
- Authorisation to take future use cases into account.
- Authorisation should enable different network solutions and topologies to ensure efficient use of spectrum.

[61] 5G Spectrum: GSMA Public Policy Position – March 2021.
[62] Common Union Toolbox for Connectivity - Connectivity Toolbox | Shaping Europe's digital future (europa.eu). The toolbox address aspects of implementation of very high capacity networks, including use of 26 GHz spectrum.

- The situation for local authorisations, including FCFS, depends on the national situation and spectrum availability.

- Member States "should avoid revenue maximisation" when setting reserve prices and provide incentives for investment in the networks.

For 26 GHz, the toolbox encourages Member States to consider use of both nationwide and local licenses where possible. Member States are also asked to consider whether it is more efficient to dynamically re-assign at least parts of the band on a local basis, as well as to encourage the sharing of infrastructure. The toolbox effectively leaves options open on how to achieve access to spectrum to those wishing to use it on a local basis.[63] It also refers to the Club Use model already considered in Italy as a possible approach.

Each Member State should provide the Commission with a roadmap for the implementation of the Connectivity Toolbox by end April 2021.

4.5 Research feedback

When the totality of the awards of 26 GHz spectrum in Europe is taken together with plans for release of spectrum in 2021, good progress is being made. The 26 GHz band (or part of it) is already available in Denmark, Germany, Greece, Finland, Italy, Russia, Slovenia and the UK, all EU countries have consulted on the 26 GHz band and further awards are planned in 2021. Awards are currently ongoing in Croatia and Malta and announced in Spain. However, there appears to be a need to speed up access to spectrum in the 26 GHz band to ensure that players in currently unserved countries have the ability to access the spectrum to unlock demand.

Key issues raised in the research were:

- Different approaches are being taken by spectrum managers in different countries ranging from requiring evidence of demand before assignment to anticipating demand and making spectrum available so that demand can be served as it arises.

- Spectrum made available in the 26 GHz band must be sufficient to support MNOs and others wanting to offer services. Support of several operators at a given location could require large amounts of spectrum in the band.

- More work is required to accommodate incumbent users of the spectrum and the need to share to make spectrum available for 5G, including examination of the least onerous conditions to make the spectrum available. ECC has considered these issues.

- While experiments and trials have been conducted and other incentives considered, these must lead to a route to market. Too often these activities demonstrate worthwhile innovation but do not go forward into commercial service.

- Mobile network operators are likely to need access to the 26 GHz spectrum to increase the scope of services offered to their customers in the consumer and enterprise sectors (including industrial). However, there is also likely to be entry from industrial and other players wishing to innovate with new service capabilities, including neutral hosts and service providers / integrators. Authorisation mechanisms must be able to cater for both.

[63] Through leasing, local licensing or access via a third party.

- There should be particular focus and attention to the positive role of incentives or subsidies to encourage development of mmWave applications and use of 26 GHz spectrum.

Overall, the research suggests a lack of consistency with the way 26 GHz spectrum is being authorised for 5G. The spectrum and use cases have some commonality with previous spectrum releases but there are also key differences including localised use and support for private (industry vertical) standalone operation. Also, flexibility is required to balance the desire to offer innovative 5G services in mmWave with the need to meet protection requirements for incumbent users. The circumstances of every country will be different and "one size will not fit all".

5 Conclusions and measures to stimulate demand

5.1 Findings

From the desk research and interviews carried out there is awareness of the factors that lead to a choice of mmWave spectrum for 5G use cases and what the 26 GHz band could support. This includes clear recognition of the bandwidth and latency characteristics of use cases and why other spectrum choices are less advantageous, including the quality of service benefits of use of licensed spectrum.

The key feedback from the research is that developments in Europe have been slowed down by the rate at which 26 GHz spectrum is being made available. This leads to a lack of confidence in the availability of the ecosystem for 3GPP band n258, which has gone slower than that for bands n257 and n261, where there were stronger incentives for the spectrum and ecosystem to come to market.

However, there also seems to be a lack of awareness of the opportunity offered by the crossover of the lower end of band n257 and the upper end of band n258 (i.e. 26.5-27.5 GHz). This allows the use of equipment developed for the n257 ecosystem in Europe as has been seen with some trials and early commercial developments of mmWave in places like Italy. If the top 1 GHz of the 26 GHz band is available, there is potential to stimulate demand through use of this route.

While use of the top 1 GHz of the 26 GHz band and n257 equipment can help to get things moving, to fully stimulate demand for 26 GHz in Europe requires access to band n258 equipment, which in turn requires access to more spectrum in the 26 GHz band. When this will happen is the key uncertainty we identified. While there is more to do there are a number of positive signs:

- There is progress with making the spectrum available in Europe with eight countries so far assigning the spectrum for 5G.
- Many countries are developing plans and / or have the intention to award or otherwise make the spectrum available in 2021.
- Developments elsewhere in the world with adoption of band n258 and making spectrum available increase the incentives for its inclusion in devices by OEMs.
- Low research and development barriers to n258 deployment with experience from the n257 and n261 ecosystems.

Specifically on spectrum it is clear that there are differences of approach from spectrum management authorities ranging from waiting to see if access is demanded (this only works if there is regular monitoring to detect demand) through to those anticipating demand for a variety of use cases, including industrial, and are making spectrum available in anticipation of this.

It is also clear that provision of access to the 26 GHz band can be more complex than for other bands where clearance has occurred. More work is required to accommodate incumbent users of the spectrum and the need to share to make spectrum available for 5G, including examination of the least onerous conditions to do this. This is a key part of the good practice that must be developed for access to this band and mmWave spectrum in general, which should also include dealing with a wider range of potential spectrum users (not just MNOs), ensuring that spectrum is available where it is needed on reasonable terms (including duration and cost), and with the recognition that flexibility and innovation will be key to the availability of this spectrum as "one size will not fit

all". The European Union Common Toolbox for Connectivity[64] and the guidance if sets out for individual authorisation of 26 GHz spectrum provide advice in this respect.

While access to spectrum is key, together with measures to encourage investment like the connectivity toolbox and small cells Regulation, consideration should continue to be given to other incentives to encourage trials, network deployment and further innovation. Examples have been provided for Japan and Taiwan, and there are many other examples of public funds being used for stimulating tests and trials (e.g. in the UK).

5.2 Recommendations

Having considered the research findings Plum recommends the following to stimulate demand for 26 GHz:

- Create better visibility on existing mmWave use cases, their technical and economic benefits and their promotion from proof-of-concept to commercial use.
- Promote with key European stakeholders the already wide availability of the n257 (26.5 – 29.5 GHz) ecosystem and the opportunity to quickly start mmWave services upon spectrum release pointing to commercial services already deployed in countries such as Italy.
- Create more visibility of ecosystem developments and expectations for how quickly devices (in a variety of form factors including phones, modules, other indoor and outdoor CPE) will come to market based on experience in other 5G bands and the impact of decisions made by non-European countries like Brazil, Thailand, Australia, New Zealand, Singapore, Malaysia, Hong Kong, Vietnam, USA, that will act as additional triggers for eco-system development for the n258 band.
- Regulators should review and consult on a regular basis to monitor whether there is unmet demand for access to 26 GHz spectrum – there might be cases where market demand is hidden.
- If there are no incumbents, encourage NRAs to release the spectrum to stimulate the market with the licensing conditions providing the means to take back spectrum if it is not used, and if there are incumbents, encourage NRAs to develop spectrum access possibilities where incumbent services are present in the band (including the use of the top 1 GHz of the 26 GHz band where there are the least incumbency issues).
- Promote use of the spectrum with low barriers to entry that could include lower cost of spectrum than for other mobile bands[65] and the use of award mechanisms other than auctions (including administrative and beauty contests, which may include investment commitments).
- Consider the approach to licensing to allow flexibility for localised use along with providing some certainty for those users who may want access to 26 GHz spectrum or part of it at multiple locations in a country.
- Ensure spectrum access can be realised for private networks and neutral hosts as well as MNOs to ensure spectrum efficiency and flexibility.
- Keep encouraging innovation on use cases to include use of the 26 GHz band or part of it through trials (and consider appropriate incentives). Ensure visibility of trials results to foster innovation and encourage

[64] Common Union Toolbox for Connectivity - Connectivity Toolbox | Shaping Europe's digital future (europa.eu). The toolbox address aspects of implementation of very high capacity networks, including use of 26 GHz spectrum.
[65] Plum's research finds that in recent awards the average value of 26 GHz spectrum ($/MHz/pop) is $0.0033 whereas for 3.5 GHz auctions the value is $0.1087 (normalised values are 26 GHz $0.0034 and 3.5 GHz $0.1059).

other trials and commercial deployments. Provide a clear timeline for spectrum availability for commercial use to ensure follow through from trials.

- Implement tax incentives, such as tax deductions or special depreciation schedules, for investments by MNOs and private network developers in 26 GHz or band n258 related infrastructure and equipment. Include the use of award mechanisms that seek to encourage investment (e.g. investment commitments in beauty contests).