Millimetre Wave Spectrum for 5G

October 2019

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Executive Summary

GSA's view on spectrum is that a range of frequencies in the low-band (e.g. 600, 700 MHz etc.), mid-band (2.3, 2.6, 3.3-4.2, 4.4-5 GHz etc.), and high-band (24.25-29.5, 37-43.5 GHz etc.) need to be made available and harmonised globally as much as is possible to ensure mobile broadband can meet the expanding services both industry and consumers are expecting in the coming years.

GSA supports the industry forecast that by 2024 over 130 Exabyte (one hundred and thirty quintilion bytes) of data will be transmitted globally every month and the mobile industry will need to massively deploy 5G technology in a broad range of frequency bands to meet this demand.

Applications that will drive this massive data usage include 8k mobile video, Augmented and Virtual Reality, HD video, industrial automation and robotics, drone and aeronautical networks and the industry of things.

Spectrum for 5G should ideally be made available in contiguous blocks of 80-100 MHz from the mid bands and 1 GHz of spectrum from the high mmWave bands to ensure the most effective delivery of 5G services.

Spectrum Vision for Mobile Broadband Services & Applications

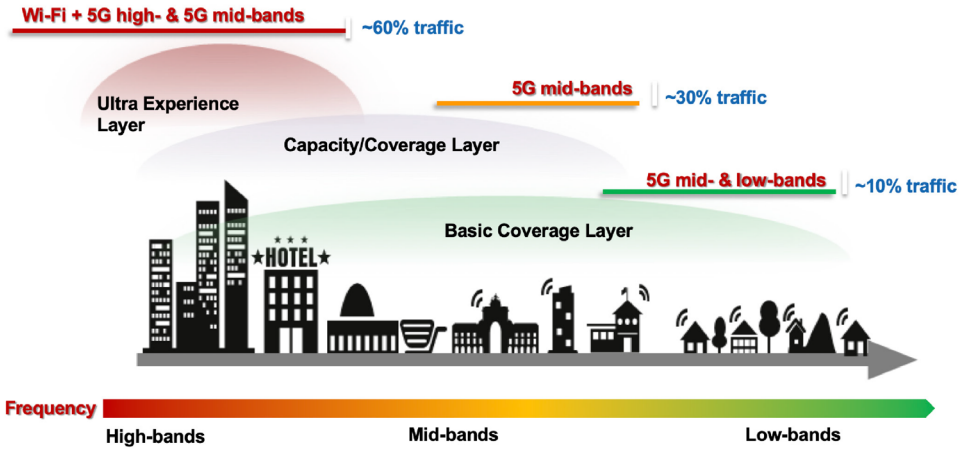
A broad range of low- to mid- to high-band spectrum should be made available to deliver mobile services across a broad range of applications with coverage and capacity that meets the public, private, business and consumer needs in the majority of geographical locations. In addition, spectrum should be made available in a way that utilizes this finite resource in the most effective and harmonious way without unduly restricting the provision of mobile services in locations where those services are required.

Spectrum should be made available for 5G New Radio within the low-band, mid-band and high-band frequency ranges, with the appropriate amount of contiguous spectrum per network, as well as provide regulatory conditions that facilitate cost-effective 5G NR usage in a timely manner. Making spectrum ranges available within the 2020-2022 time-frame with appropriate regulatory conditions will facilitate the vision of IMT connecting almost 7+ billion people globally, in addition to the 100 billions of devices and things, by 2030.

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Spectrum Requirements

Access to a broad range of spectrum resource one of the main growth drivers for the deployment of wireless services; conversely spectrum can also be a limiting factor for the expansion of wireless broadband into new markets and industries. GSA therefore advocates a range of frequency bands should be made available for mobile broadband from the low, mid and high-bands.



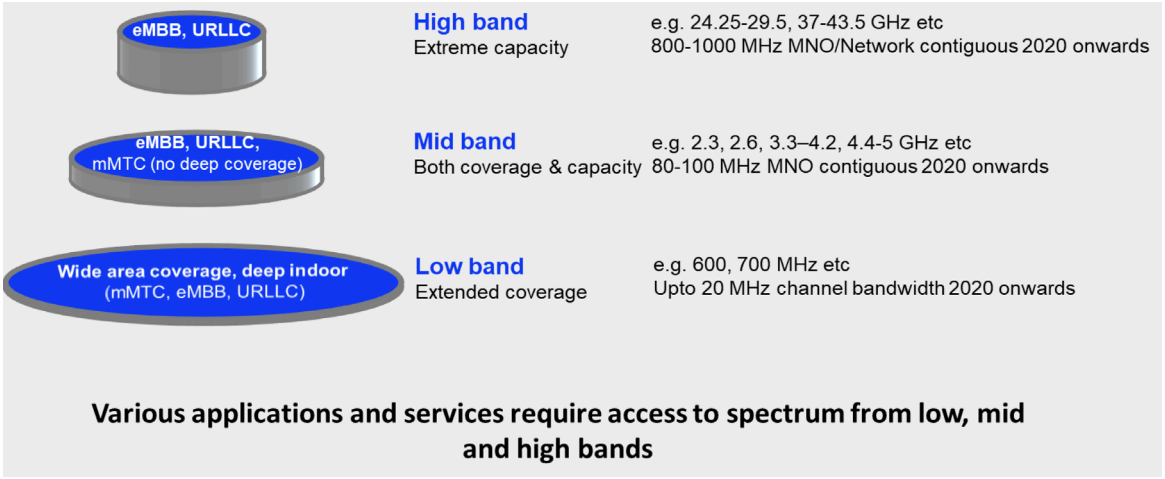
Low-band spectrum

The propagation characteristics of low-band spectrum forms the backbone of the mobile industry due to its wide area coverage and is vital to provide economical deployment of mobile services. The digitalisation of services, in many instances, is freeing up low-band spectrum and provides for the re-purposing of underutilized spectrum to be more effectively provisioned and allocated for mobile.

Mid-band spectrum

The propagation characteristics of mid-band spectrum, while not as coverage beneficial as low-band spectrum, does support the extended wide area delivery of mobile services with the added advantage of wider spectrum bands being available to deliver high data throughput applications. Combined with low-band spectrum, good outdoor and some indoor coverage needs can be met.

GSA will publish an update C-Band spectrum report before the end of 2019.



Various applications and services require access to spectrum from low, mid and high bands

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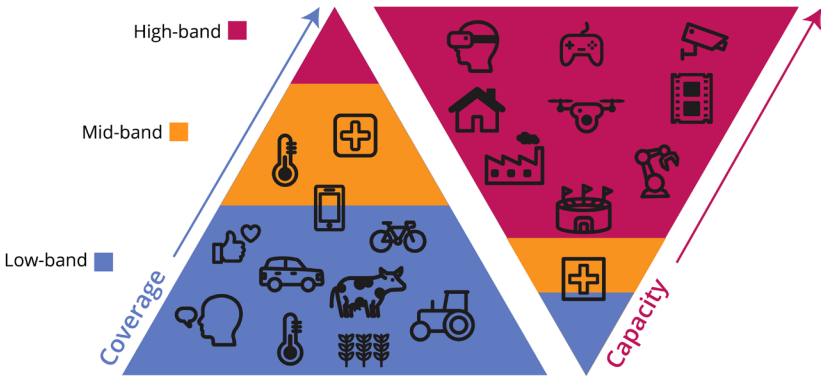
Applications

High-band spectrum

High-band spectrum, especially spectrum above 20 GHz, with large amounts of bandwidth, is ideally suitable for high data throughput applications such as video communications, video animations and data hungry applications such as virtual and augmented reality which are expected to grow rapidly over the coming years. High-band spectrum is suited to local area hot-spot coverage and supports applications in places where high data throughput is required – video surveillance for instance. The short-range propagation characteristics of high-band spectrum requires multiple cells to be deployed using range extending techniques such as Massive-In Massive-Out (MIMO) antenna configurations and these deployments are expected to be concentrated in city-centres high traffic areas and high capacity arenas for example.

High-band spectrum is also ideally suited to deployment in-building due to this band's propagation characteristics. Lower power high-band spectrum can be efficiently deployed in-building to supplement WiFi and provide seamless 5G coverage.

Spectrum Coverage Capacity Comparison



Mass market mobile network operations cannot be economically provided with only High-band spectrum and requires a combination of low and mid-band spectrum to make the mobile services business case viable. Access to all three bands, low- mid- high- will enable outdoor and indoor coverage needs to be fully met and the full range of 5G services to be provided.

Spectrum recommendations

GSA therefore recommends that at least 1 GHz of contiguous high band spectrum is made available per network to support the full range of coverage and capacity needs that are and will be demanded by public, private, businesses and consumers.

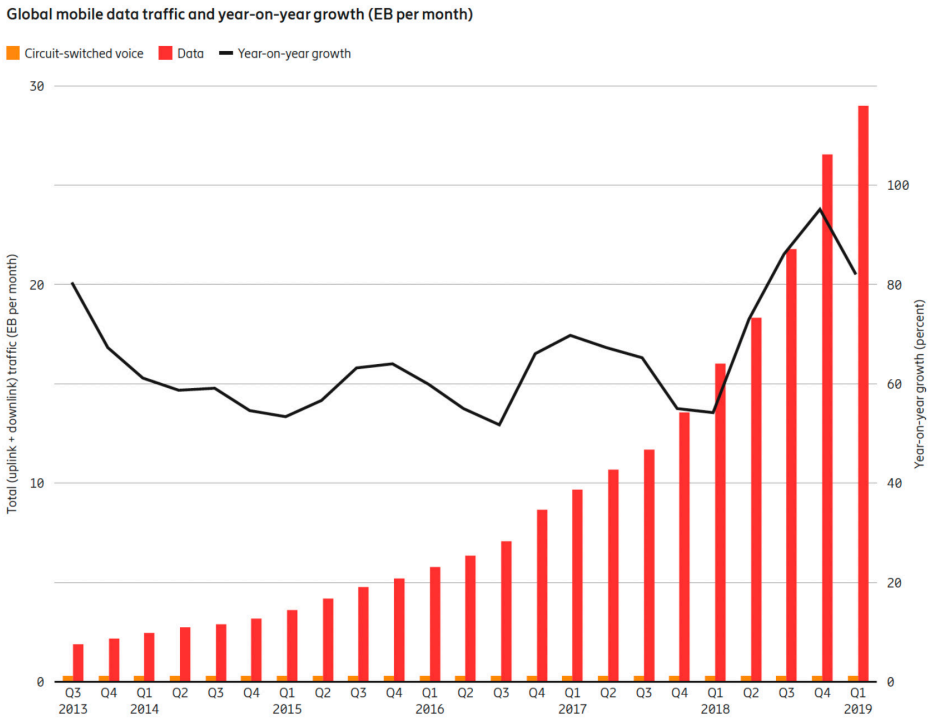
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5G and the mmWave Business Case

5G is a step-change in the delivery of mobile broadband and will support the next phase of global industrialisation, often referred to as Industry 4.0. Global mobile subscriptions were 7.9 billion by the end of Q1 2019 growing 2% since Q1 2018. Mobile broadband subscriptions grew 15% year-on-year in the same period, increasing by 140 million and now account for 76% of all mobile subscriptions. There is little evidence to suggest this adoption of mobile broadband is declining while data usage is widely reported to be on an exponential growth curve. The mobile industry is therefore driving the introduction of 5G at a pace that is outpacing 4G roll out with 321 operators in 103 countries investing in 5G and 62 operators announcing the deployment of 3GPP compliant 5G live networks. The majority of these trials and deployments have been in the high-band or mid-band spectrum ranges.

The growth in global mobile data traffic shows no sign of slowing down as new data hungry applications are coming to market.

The evidence has been clear for some time; mobile networks will eventually become capacity choked unless large blocks of new spectrum are made available for mobile broadband use.



Source: Ericsson traffic measurements (Q1 2019)
[1] Traffic does not include DVB-H, Wi-Fi or Mobile WiMAX. VoIP is included in data traffic

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5G mmWave requirements

Low-band spectrum is ideal for mobile coverage, but is limited in bandwidth to deliver on all the future capacity needs.

Mid-band spectrum plays a vital part in extending mobile coverage and meeting some of the increasing capacity needs, but will not satisfy the complete demand for the full range of high quality mobile broadband local area services in the near future.

High-band spectrum is the obvious answer to the capacity conundrum facing the mobile industry and if access is wisely managed a significant amount of spectrum could be made available for mobile and home broadband. High band spectrum such as 26 GHz (24.25-27.5 GHz) and 40 GHz (37-43.5 GHz etc.) is being sought for IMT/5G at the WRC-19 meeting in November 2019. GSA supports an agenda item to consider additional spectrum, particularly in the low and mid band frequency ranges, as part of the WRC-23 cycle.

Availability of new spectrum in bands such as both the 3.5 GHz, 26 GHz & 40 GHz bands is key to unlocking the full potential associated with 5G and as the promises of 5G will be delivered through the combination of Gigabit LTE and 5G New Radio (NR). GSMA recently released a very informative study on 5G mmWave. It concludes that mmWave spectrum will have a significant positive impact on the economy contributing to an increase of $565 billion in global GDP, producing 25% of the value created by 5G with Europe having the highest percentage of GDP growth attributable to mmWave 5G than any other region (2.9%). Asia and Americas are expected to generate the greatest share of the total contribution of mmWave 5G to the GDP, $212 billion and $190 billion, respectively.

Releasing high band spectrum, (26 GHz & 40 GHz) will enable the development of new services and applications; 5G for enterprises, industrial IoT and fixed wireless access (FWA) and very high-speed mobile broadband. 5G NR mmWave outdoor deployments will be predominantly driven by mobile operators initially focusing on providing local area services in dense urban areas and traffic hotspots using smartphones, whereas indoor deployments will complement wireless services provided by Wi-Fi on new device types such as tablets, always connected laptops bringing multi-Gigabit, low latency and virtually unlimited capacity. Deployments will leverage existing infrastructure (Wi-Fi or Cellular) by co-siting small cells for enhanced user experiences. The introduction of breakthrough performances will be game changers for users' experience and in a number of industries.

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Mobile operators around the world are racing toward rolling out commercial 5G services in their networks, with commercial 5G NR network launches in the U.S., South Korea, United Kingdom, Italy, Switzerland and other countries. Without a doubt, 5G momentum is continuing to build, as more commercial networks come online in the next few weeks and months.

To date, not only have we seen multiple 5G NR mmWave smartphone announcements, but many global mobile operators are also expected to support mmWave in their networks starting this year, with U.S. leading the way with live commercial networks today. We anticipate mobile operators prioritizing mmWave service roll-outs at metropolitan cities that need more network capacity to address the growing mobile data demand. For example, Verizon as of October 2019 has launched in 20+ cities including Chicago and Minneapolis and will gradually expand their mmWave footprint to smaller cities. Verizon's deployments inside sports stadiums is an interesting example of using mmWave spectrum to provide local area ultra fast quality services to many thousands of people at the same time.

What to expect from mmWave deployments starting in 2019

GSA expects initial use cases to focus on enhanced Mobile Broadband (eMBB) and Ultra Reliable Low Latency Communications (URLLC) usage scenarios for indoor hotspots in enterprises and factories and outdoor mobile broadband in dense urban and urban areas as well as FWA in suburban and rural scenarios. Applications such as Mobile Virtual/Augmented Reality and Ultra High Definition Video, 5G fixed wireless access services and smart home, smart manufacturing, autonomous vehicle, Health care will all benefit from 5G deployments.

The multi-Gigabit data rates possible with mmWave technology and the wide bandwidths available in high bands such as 26 & 40 GHz will likely enable new use cases benefiting from high instantaneous data rates. On one hand, end users, who could be individual consumers and machines, will be able to download large amounts of data very quickly: e.g., a movie before boarding a flight, fibre optic like services on always on laptops, or a high definition map update to a vehicle. On the other hand, the network will be able to serve an IoT network's more highly demanding end points as the high instantaneous peak rates combined with Massive MIMO (M-MIMO) will dramatically increase network capacity and hence facilitate traffic off-load to the existing 4G networks.

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It is important to point out that capacity will be an important metric for 5G, as the amount of traffic will be burgeoning in the coming years with the more widespread adoption of competitive data plans comprising unlimited use of popular apps, video streaming or even full unlimited data usage. The capacity increase, however, will not be uniform across the network; it will rather be concentrated in specific local area hotspots (cafés, venues, public squares, city centres, etc.) and aligned with the strategic deployment of high-capacity small cells covering the hotspot area.

mmWave technology brings the benefits of Massive MIMO down to a small-cell scale, hence maximizing small cell capacity and hotspot coverage. Deployments will encompass venues (e.g., stadiums) and locations within city centres.

Several tests and simulations based on over the air testing and channel measurements on 5G NR mmWave deployments at both in outdoor and at indoor locations.

Taking 5G NR mmWave indoors

With more than 80% of mobile data traffic originating or terminating indoors, one enormous opportunity for mobile operators and service providers is to bring mmWave services to indoor locations. GSA member Qualcomm have analysed potential deployment scenarios in various dense urban cities.

Their studies have found that mmWave does not propagate well from the outside to inside so is beneficial for deploying mmWave indoors as well as outdoors, since the same mmWave spectrum can be reused indoors with limited coordination with the outdoor deployment. This benefit opens new possibilities for mobile operators to offer private indoor mmWave networks, in addition to expanding mmWave indoors as part of their public networks.

Complementing existing indoor Wi-Fi services, 5G NR mmWave can elevate user experiences to new heights by bringing multi-Gigabit speed, ultra-low latency, and virtually unlimited capacity to a wide range of devices such as smartphones, tablets, XR (extended reality) headsets, and always-connected laptops. Qualcomm has been working with indoor venue owners and operators to understand how 5G NR mmWave will perform in a wide range of indoor environments.

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For indoor enterprises

One exciting opportunity for 5G NR mmWave is indoor enterprises. Today, most offices have Wi-Fi connectivity for computers and other enterprise devices. With 5G NR mmWave private networks, enterprises can realize the vision of "mobile office of the future", bringing enhanced performance, convenience, security, and user experiences not possible with today's connectivity solutions.

To understand how 5G NR mmWave performs in enterprise settings, Qualcomm have studied a few different office layouts and performed comprehensive system-level simulations. As an example, the company has been looked at one office floor at their San Diego headquarters and simulated coverage and performance with 5G NR mmWave small cells placed at the same locations as existing Wi-Fi access points. The rationale behind co-siting is that both power supply and wired back-haul connectivity are already available at these locations, and it is the most efficient way to start any 5G NR mmWave deployments. With 1-to-1 co-siting, Qualcomm were able to achieve ~98% downlink coverage and ~99% uplink coverage. The median throughput achieved with this setup was 5 Gbps.

For dense venues

Large venues, such as convention centres, concert halls, and stadiums, are often plagued with wireless connectivity issues. As the venues are packed with large number of visitors during events, many users will be accessing the wireless network at the same time. The key challenge is for the wireless network to have enough capacity to sustain reasonable performance. While LTE and Wi-Fi network densification helps, they are still limited by the amount of available bandwidth. With 5G NR mmWave, venue networks can now have access to 100's of MHz of mmWave bandwidth that can satisfy the growing data demand.

Bringing enhanced venue experiences with 5G NR mmWave.

Similar to previous analysis, Qualcomm have simulated 5G NR mmWave coverage and performance for a wide range of venues. One such simulation happened at the Las Vegas Convention Centre, where co-sited 5G NR mmWave small cells with existing 3G/4G cellular DAS (distributed antenna systems) was tested. The results were very encouraging — ~95% downlink and uplink coverage and a median downlink burst rate of 5 Gbps.

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For transportation hubs

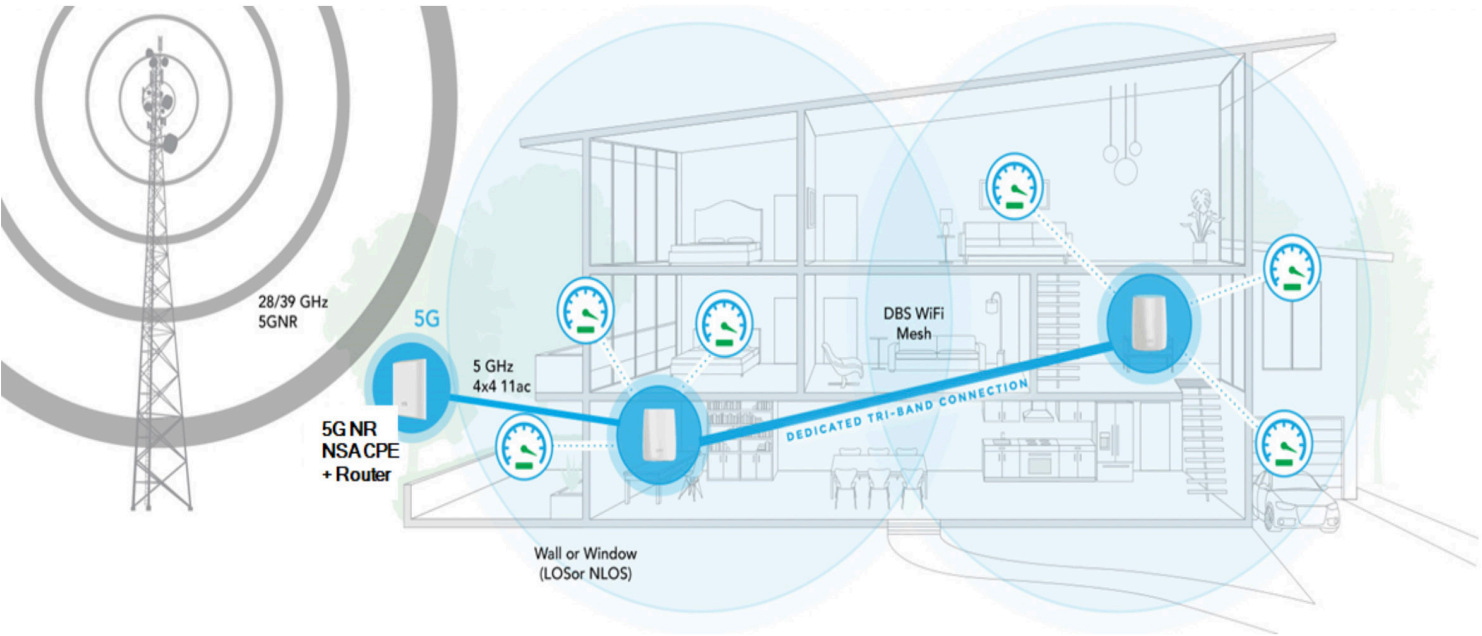
Finally, Qualcomm looked at various transportation hubs, such as airports and train stations. For an airport concourse that is about 160 thousand square feet in size, comprehensive coverage and a median throughput of ~4.2 Gbps could be achieved using just ten co-sited 5G NR mmWave small cells.

Eco-system readiness

5G equipment

Unlike in previous generations of mobile market developments equipment availability is not an inhibitor to rapid market deployments. 5G base stations that cover 26/28 & 40 GHz are available, chip-sets and terminals (CPE's & Phones) are available. The industry just need spectrum to be made available with appropriate regulatory conditions. GSA produces regular reports on 5G networks and the devices ecosystem.

For example, 5G NR equipment supporting the 26.5 – 29.5 GHz band (3GPP TDD band n257) is already available since 2019. Testing of 5G end-to-end system at mmWave is currently ongoing in Europe in a number of European Member States with commercial 5G devices (smartphones, CPE, tablets etc.) supporting 26.5-27.5 GHz expected to be released in Europe in 2019 - these will benefit from a wide and global eco-system driven by commercial deployments in the US, Korea, Japan, Russia and Italy planned from 1H 2019.



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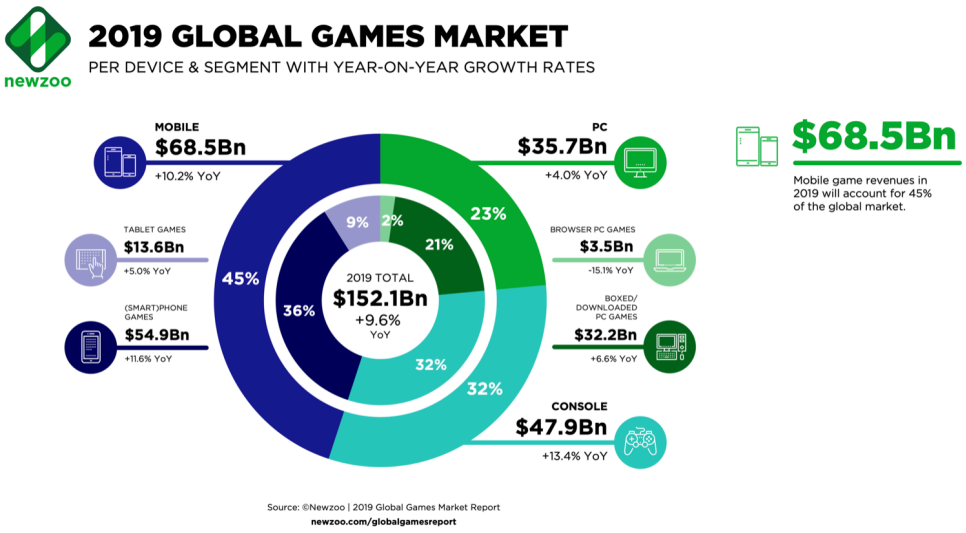
5G Service Examples

Video usage

Video traffic in mobile networks is forecast to grow by some 34% annually over the next five years increasing from 60% of mobile data traffic in 2018 to 74% in 2024. The forecast in the latest Ericsson Mobility Report suggests a total of 131 Exabyte of data traffic per month in 2024. To put this into context, that is the equivalent of more than 6 billion hours of compressed 4K video being downloaded every month.

Video applications

Mobile applications these days often incorporate video into their solution, whether it is Facebook, Instagram or video blogging, and mobile video marketing has created a new industry of content providers. Vloggers – video bloggers – have increased their presence and the top players like PewDiePie and Logan Paul have tens of millions of followers and earn anything from $10-30 million per year. Ryan Kaji, (Ryan ToysReview), is just 7 years old, has 21 million followers and earned $22m in 2018. This is just one example out of thousands reflecting the power of video. Consumption of this media will continue to dominate mobile as this youth phenomenon grows in size, relevance and influence.



Mobile video communications

The video telephone touted by many fixed telephone operators 40 years ago is now with us in the form of the smartphone and mobile tablets with their high definition camera and screens. Video calling is built into Facebook and WhatsApp, while Skype and Zoom video conferencing is setting new expectations for business conference calls.

Mobile Gaming

Mobile gaming has come a long way since the Finn Taneli Armanto put a version of Snake on Nokia's 6110 mobile phone in 1997. There are now more than 2.5 billion gamers across the world. Combined, they are expected to

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spend $152.1 billion on games in 2019, representing an increase of +9.6% year on year. Mobile gaming on smartphones and tablets is the largest gaming segment growing 10.2% year-on-year to $68.5 billion – accounting for 45% of the market.

Multi-party games require low latency and 5G will accelerate the growth in this gaming segment due to the low latency it delivers. In addition, multi-party mobile gaming usually has video or animation content which will also require high bandwidth – another benefit of 5G high-band spectrum.

Virtual and Augmented Reality – Gaming and more

GSA fully expects Virtual Reality (VR) and Augmented Reality (AR) to follow similar adoption paths to mobile video and impact mobile network capacity and throughput requirements. VR gaming is already mainstream and the user experience will improve dramatically over the next five years as will the size of the market. By 2026 Report Ocean predict the VR gaming market to grow at a CAGR of 26% to reach $48.2 billion.

Visualisation is 5G mmWave

Speech and words are abstract and are somewhat difficult for the brain to retain. Alternatively, visuals are easier to remember since the brain is mainly an image processor. Visualisation, whether it is video, animation VR, AR, images and infographics, is driving the mobile broadband data explosion. It is not clear when, or even if, this will slow down.

The mobile industry with the support of regulators and policy makers need to ensure enough spectrum in the mmWave high-band spectrum range is made available to deliver the 5G mobile visualisation experience subscribers will demand. A lack of enough suitable harmonised spectrum could have the impact of stagnating the industry when it is poised to enter a new phase of growth.

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5G Internet of Things

At the end of 2018 there were estimated to be 8.6 billion Internet of Things (IoT) connections growing at a CAGR of 17% to 22.3 billion by 2024. Industries (verticals) using massive IoT include utilities with smart meters, healthcare companies looking at wearable medical devices, transport with tracking sensors, the oil & gas industry and agriculture with remote sensors and insurance companies considering how to use IoT devices to gather relevant data form home, business and transport insurance evaluations.

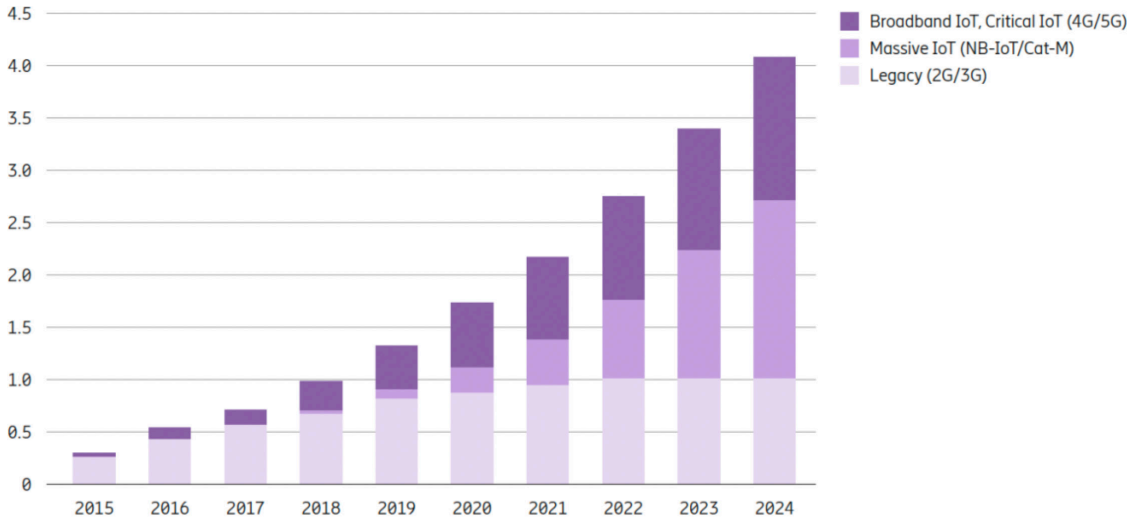
IoT connections (billion)

IoT	2018	2024	CAGR
Wide-area IoT	1.1	4.4	27%
Cellular IoT[2]	1.0	4.1	27%
Short-range IoT	7.5	17.8	15%
Total	**8.6**	**22.3**	**17%**

5G IoT capacity

While IoT devices on the whole do not individually impact data usage, the huge number forecast to be mobile connected, 75.44 billion by 2025, will require masses of 5G capacity. Some vertical application needs – remote sensors for instance – will need to be served by low- or mid-band spectrum. Other applications such as for smart-city sensing and traffic flow control will be served with mid- and high-band spectrum while many in-building IoT applications will require a dedicated indoor high-band spectrum network to ensure adequate coverage and capacity.

Cellular IoT connections by segment and technology (billion)



[1] Cat-M includes both Cat-M1 and Cat-M2. Only Cat-M1 is being supported today
[2] These figures are also included in the figures for wide-area IoT

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Summary

5G will be a major step change in mobile broadband connectivity and creates new industries and services on condition that sufficient spectrum is made available, with favourable licensing conditions, for wireless services from low-mid-high frequency bands.

National mobile operators will need at least 1 GHz of high band spectrum, ideally in contiguous blocks, to deliver the hot spot and home broadband services, speeds, coverage and capacity 5G will require.

Ubiquitous outdoor and in-building coverage will be a key aspect of 5G deployments and will require complementary business models.

5G is the fastest roll out of a new generation of IMT technology with over 321 operators committed to invest in 5G networks and over 350 commercial networks anticipated by end of 2020.

There is an accelerating ecosystem where GSA has identified 172 announced 5G devices from 71 vendors, with 40 devices supporting mmWave frequency bands. The bands known to be most supported by announced 5G devices are n78, n41, n79 and n77.

The identification of high band spectrum, such as 26 GHz and 40 GHz, for IMT/5G at WRC-19, together with appropriate regulatory conditions, is essential to enable the full 5G vision to be realised.

An agenda item at WRC-23 supporting consideration of additional spectrum in the mid and low band spectrum ranges will help ensure the ongoing success of mobile broadband.

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About GSA

GSA (the Global mobile Suppliers Association) is a not-for-profit industry organisation representing companies across the worldwide mobile ecosystem engaged in the supply of infrastructure, semiconductors, test equipment, devices, applications and mobile support services.

GSA actively promotes the 3GPP technology road-map – 3G; 4G; 5G – and is a single source of information resource for industry reports and market intelligence. GSA Members drive the GSA agenda and define the communications and development strategy for the Association.

Membership of GSA is open to any supplier of products; systems or services related to the mobile industry and brings many benefits including access to the GAMBoD database. The range of benefits includes enhanced discussion, networking and influencing opportunities on the key industry topics, and unique promotional/visibility opportunities for your company name, capabilities, positioning and messages. More details can be found at:

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Contact

GSA Secretariat

Email: info@gsacom.com

Spectrum related feedback email: research@gsacom.com

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