Outlining the Roadmap to 5G

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Abstract

This paper provides an overview of the background to the roadmap and evolution to 5G and the path the industry is taking to realise the benefits that will come from a mass industry deployment of this standardised mobile technology. 4G LTE network rollouts are continuing and new LTE features are being deployed to support both industry and user expectations for what 5G will deliver once the technology has been deployed.

Keywords: 3GPP, 5G, 4G, Trials, LTE, Ecosystem.

1 Introduction

Of all the technologies that have created the widest impact over the past thirty years, mobile communication could be argued to be the most prominent. 2017 was a breakthrough year for the mobile industry with mobile connections, including licensed cellular Internet of Things, passing 8.5 billion and the number of net mobile subscribers surpassing 5 billion globally [1].

Operator revenue exceeded 1 $trillion in 2017 and mobile technologies and services generated 4.5% of GDP, a contribution that amounted to $3.6 trillion of economic value. According to the Global mobile Suppliers Association (GSA) expectations and predictions across the mobile industry forecast 4G will continue to be a leading technology and that 5G will herald a shift to

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massive connectivity, massive bandwidth, massive user experiences, as the amount of data we all consume continues to rise exponentially [2].

This level of growth brings its own challenges, and the mobile industry is not taking a back seat in dealing with the economics of delivering more and more data per user. New harmonized spectrum is needed for 5G and GSA – via is Spectrum Group – and in cooperation with the GSMA (GSM Association), is working to promote the global benefits of freeing up spectrum in different frequency bands for early 5G deployments, the first of which will happen in 2018.

The ecosystem is also mobilizing. Chipsets and devices supporting Category-16 (Cat-16) are now appearing [3] and Cat-18 capability will emerge in 2018. Gigabit LTE will be a common theme as more operators roll out Release 14 and Release 15 features [4].

5G is probably the most ambitious mobile generation technology envisaged to-date. Expectations on what 5G will deliver are high – suggesting new levels of performance, efficiency, and connectivity as well as better user experiences. There is however alignment in the industry on the potential solutions for 5G and agreement on the immense impact 5G will have across all aspects of industry and society.

2 LTE to LTE-Advanced Pro

The mass adoption of the 3GPP standard known as LTE (Long Term Evolution), has been the first globally accepted mobile technology, and arguably the fastest adopted mobile technology ever. It took just 5 years for LTE to cover 2.5 billion people, compared to 8 years for WCDMA/HSPA. By the end of 2017 there were 2.8 billion LTE subscriptions globally, as seen in Figure 1, with 832 million new subscriptions added during the year [5]. This equated to a 42.4% Year-on-Year growth with LTE now accounting for 35.7% of all global subscriptions. GSA forecasts LTE will account for more than 50% of all subscriptions by 2020 and 60% by 2022. By comparison GSA estimates 5G subscriptions will reach 400 million by 2022 [6].

There are currently very few countries that do not have at least one LTE network deployed [7] and these countries are mostly in Africa or are islands. According to GSA data in its Networks, Technologies & Spectrum database (GAMBoD), as of 10$^{\text{th}}$ April 2018 there were 855 operators investing in LTE as detailed in Figure 2. 667 LTE networks have been launched, according to data published by GSA with a further 127 networks either in deployment, planned, are in a testing/trialling phase or a license for LTE deployment has been granted. 59 LTE networks still need confirmation of their status.

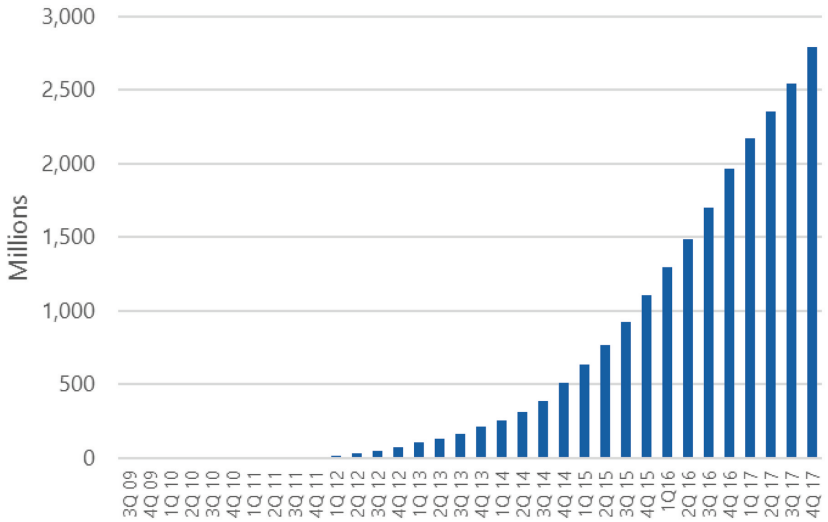

Figure 1 LTE Subscription Growth.

Source: Ovum WCIS.

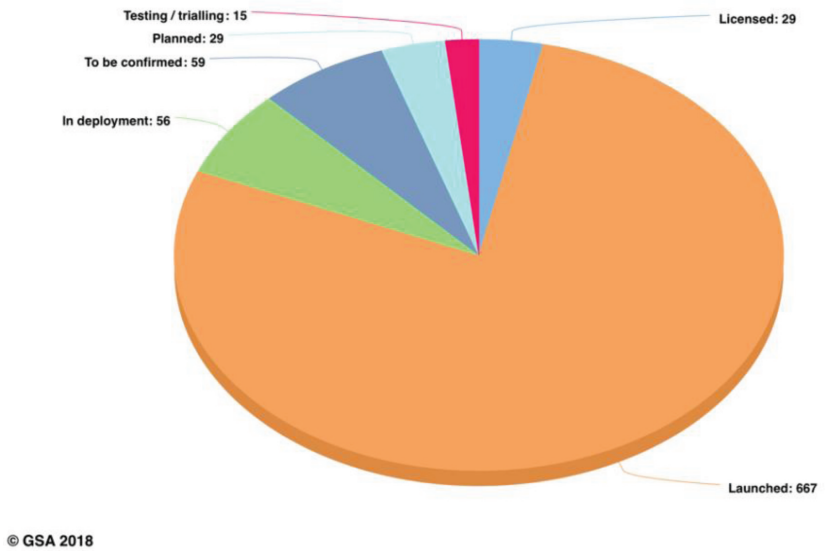

Figure 2 LTE network investments and launches.

Source: GSA NTS database.

The progress of the LTE standard to LTE-Advanced and LTE-Advanced Pro has also brought new features such as Carrier Aggregation, VoLTE, Mission Critical Communications, 4x4 MIMO and support for unlicensed frequency bands.

As of 10th April 2018 the following LTE deployment facts have been reported by GSA:

• LTE-Advanced	239 networks launched
• LTE-Advanced Pro	123 networks launched or trailling
• LTE-TDD	109 networks launched
• Carrier Aggregation	290 networks launched or trialling
• 4x4 MIMO	114 networks launched or trialling
• 256QAM	96 operators have launched or using in DL
• eMBMS	LTE Broadcast – 45 operators evaluating – 3 have launched
• VoLTE	221 investing – 143 launched

As is evidenced by the figures on the deployment of LTE features, LTE has enabled the mobile telecommunications industry to deliver a totally new mobile user experience with 88 operators in 55 countries investing in a Gigabit LTE service and 39 deployed or commercial network in 29 countries using Carrier Aggregation and 4×4 MIMO or above and 256QAM in the downlink [8].

There has been rapid deployment of the three key enabling technologies for Gigabit LTE networks, and many operators are deploying them in combination. Commercial network peak downstream speeds are dependent to a great extent on the maximum aggregated bandwidth available, and for users, very high (near-Gigabit, or above-Gigabit) speeds can only be realised with devices meeting downlink User Equipment (UE) Cat-16 specifications. Nonetheless, momentum is building strongly behind these advanced network technologies. Figure 3 shows the number of networks GSA has tracked using Carrier Aggregation (any number of aggregated carriers, including those in unlicensed spectrum), 4x4 MIMO (or higher-order), and 256QAM.

3 Ecosystem

The LTE ecosystem of devices has continued to expand over the GSA tracking period of the past 8–9 years [9]. As of February 2018, there were 10,655 LTE user devices including frequency and operator variants from 602 suppliers [10], – a 12% increase over the previous 3-month period.

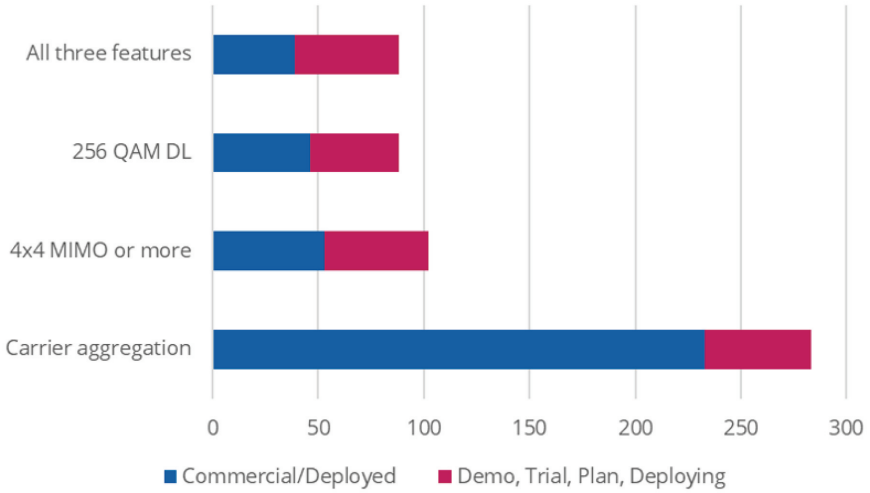

Figure 3 Commercial and demo/trial/planned networks using three core LTE-Advanced features.

Source: gsacom.com

The phone form factor has the largest ecosystem with 7,038 phones announced, including operator and frequency variants, giving a 66.1% share of all LTE devices. The LTE-connected tablet PC segment (761 devices) is also large, and the module segment (703 devices) is growing fast. See Figure 4. Most devices operate in the FDD mode while the number of terminals that support LTE TDD (TD-LTE) continues to grow and gain market share: 4,371 (41%) of LTE devices support the LTE TDD (TD-LTE) mode.

There has been a clear move from the ecosystem suppliers to bring higher order devices to market. This can be seen in the increase in devices supporting Cat-12 and above and the number of Cat-16 devices now available. The following data is extracted from the GSA LTE Ecosystem report – February 2018:

- 96 Cat-9 devices are launched (450/50 Mbit/s)
- 2 Cat-10 devices launched (450/100 Mbit/s)
- 53 Cat-11 devices are launched (600/50 Mbit/s)
- 72 Cat-12 devices launched (600/100 Mbit/s)
- 37 Cat-13 devices are launched (390/150 Mbit/s)
- 4 Cat-15 devices are launched (up to 750 Mbit/s DL)
- 42 Cat-16 devices are launched (up to 1 Gbit/s DL), up from 26 in November 2017.

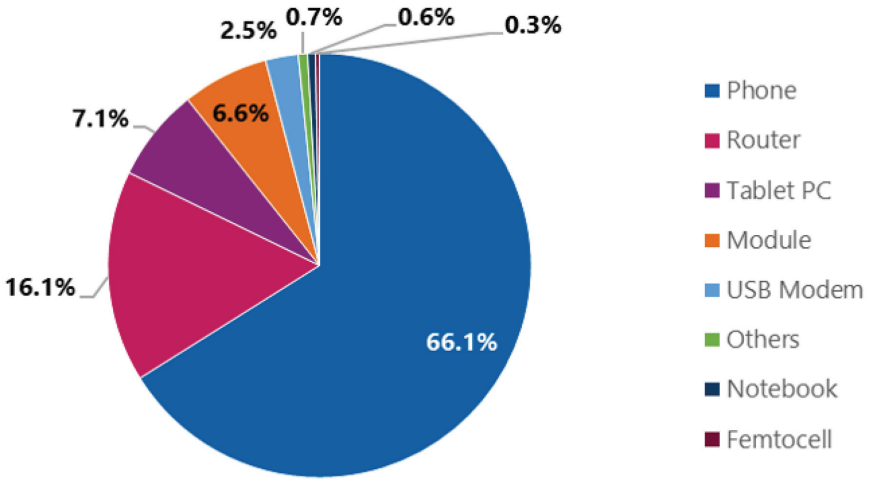

Figure 4 LTE Ecosystem by form factor February 2018.

Source: GSA LTE Ecosystem Report February 2018 – gsacom.com

Note to the above figures – that not all vendors publish details of UE category or up/downlink speeds.

The first Cat-18 devices (up to 1.174 Gbit/s DL) are starting to appear and will be tracked by GSA during 2018.

4 Chipsets

The ecosystem is dependent on the silicon vendors bringing chipsets to the market in a timely manner. There are at least 22 cellular LTE modem chipsets available separately [11], from six vendors: Hi-Silicon, Intel, Qualcomm, Samsung, Sanechips (formerly ZTE Microelectronics) and Spreadtrum. Other modems are MediaTek's WorldMode modem integrated within many of MediaTek's platforms.

The largest category of chipsets is mobile processor platforms: GSA has counted 101 commercially available mobile processors/platforms (other than those specifically designed for IoT applications) from 13 vendors. The total includes some market-specific variants such as chipsets designed to meet automotive industry standards.

Higher order chipsets (supporting Cat-20 and above) have been announced that are pre-empting the move to 5G. The chipset status is shown in Figure 5 and is taken from the GSA Chipset report – February 2018.

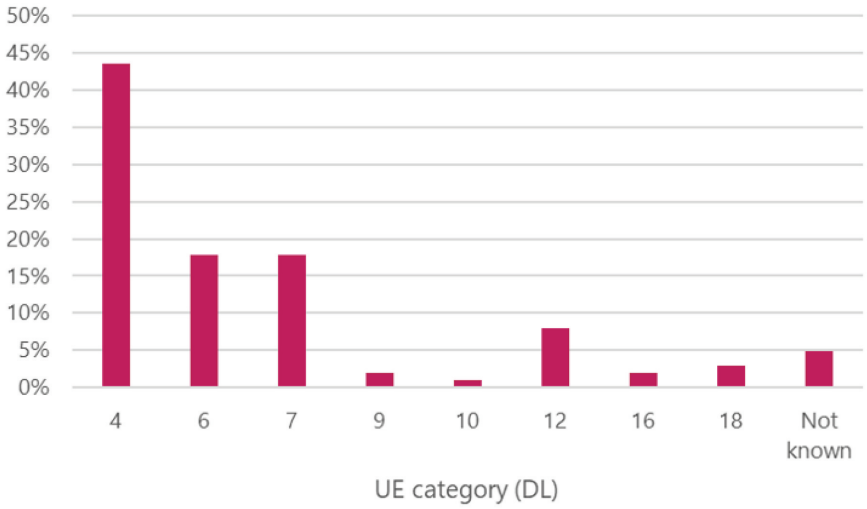

Figure 5 Percentage of mobile processors/platforms supporting specific UE categories.

Chipsets are increasingly coming to market supporting the latest 3GPP features that enable device manufacturers to meet the market need for more capacity and higher speeds. Smartphones are now more like media centres and applications like Augmented and Virtual Reality will push the boundaries of LTE technology to where 5G will be needed to achieve the required level of user experience.

The unlicensed bands are also a prime focus for LTE and technologies like MulteFire are due to impact the market in 2019 with Qualcomm and Nokia both promoting the technology.

At the other end of the chipset spectrum is the narrow-band segment. As of February 2018, there were 24 chipsets (modem chipsets and integrated processors/platforms) designed specifically to address M2M and IoT applications and supporting LTE Cat-1, Cat-M1 and Cat-NB1 user equipment. In the last quarter there were chipsets announced from Nordic Semiconductor, CEVA and ARM, and a second chipset from Neul (Huawei).

5 The Need for 5G

Mobile data increased by 65% in the 12 months between 3Q 2016 and 3Q 2017 [12], and the forecast is that global mobile data traffic as shown will grow from 14 ExaBytes per month in 2017 to110 ExaBytes per month with video accounting for 75% of data traffic. See Figure 6.

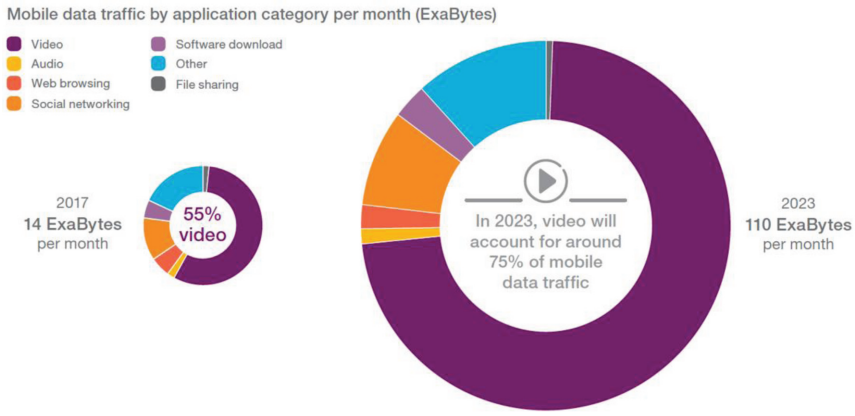

Figure 6 Mobile data traffic forecast.

Source: Ericsson Mobility Report – November 2017[12]

The need for 5G is driven by multiple factors, not least by what is often referred to as the Fourth Industrial Revolution (Industry 4.0); depicted as a fusion of technologies that is merging the physical, digital, and biological worlds. 5G will bring enhanced capabilities to support Industry 4.0 some of which are already being deployed or are planned, including The Internet of Things (IoT), factory automation, robotics, smart cities, connected drones and autonomous vehicles.

Worldwide monthly data traffic per active smartphone is predicted to increase from 2.9 GB to 17 GB [12]. This will only be realised with new spectrum – and lots of it. This means spectrum bands below 6 GHz need to be utilized as well as mmWave bands. 3GPP has defined a number of 5G/NR (New Radio) frequency bands and these can be seen in Tables 1 to 3 [13].

Table 1 5G/NR – mmWave bands

5G/NR – mmWave			
Band	Frequencies [GHz]	BW [MHz]	Duplex mode
n257	26.5–29.5	50–400	TDD
n258	24.25–27.5	50–400	TDD
n260	37.0–40.0	50–400	TDD
TBD	37.0–43.5	50–400	TDD

Table 2 5G/NR – spectrum below 6 GHz

5G/NR – Below 6 GHz			
Band	Frequencies [MHz]	BW [MHz]	Duplex mode
n77	3300–4200	10–100	TOD
n78	3300–3800	10–100	TOD
n79	4400–5000	40–100	TOD
n80	1710–1785/N/A	5–30	SUL
n81	880–915/N/A	5–20	SUL
n82	832–862/N/A	5–20	SUL
n83	703–748/N/A	5–20	SUL
n84	1920–1980/N/A	5–20	SUL

Table 3 5G/NR – re-farmed spectrum

5G/NR – Refarmed			
Band	Identifier	Frequencies [MHz]	BW [MHz]
n1	IMF Core Band	1920–1980/2110–2170	5–20
n2	PCS 1900	1850–1910/1930–1990	5–20
n3	1800	1710–1785/1805–1880	5–30
n5	850	824–849/869–894	5–20
n7	IMF Extension	2500–2570/2620–2690	5–20
n8	900	880–915/925–960	5–20
n13	US 700 Upper C	777–787/746–756	tbd
n20	CEPT800	832–862/791–821	5–20
n25	PCS1900G	1850–1915/1930–1995	tbd
n26	E850 Upper	814–849/859–894	tbd
n28	APT 700	703–748/758–8035–20	5–20
n34	TDD 2000 Upper	2010–2025	tbd
n38	IMF Extension Gap	2570–2620	5–20
n39	China TDD 1900	1880–1920	tbd
n40	TDD 2300	2300–2400	tbd
n41	TDD 2600	2496–2690	10–100
n50	TDDL-band	1432–1517	5–80
n51	TDDL-band, local	1427–1432	5
n66	AWS Extension	1710–1780/2110–2200	5–40
n70	AWS-3/4	1695–1710/1995–2020	5–25
n71	US 600	663–698/617–652	5–20
n74	FDDL-band	1427–1470/1475–1517	5–20
n75	Extended SDL L-band	N/A/1432–1517	5–20
n76	Extended SDL L-band, local	N/A /1427–1432	5

6 5G Use Cases

5G will usher in a new level of use cases as bandwidth requirements, latency, coverage, capacity and the economics of mobile deployments deliver a better user experience. A number of use cases have been discussed in the industry and some of them are covered briefly here [14].

Cloud Virtual and Augmented Reality: The bandwidth requirements needed for VR/AR to operate effectively are considerable and rendering can take up a huge amount of processing power in the device. Much of this rendering could be carried out in the cloud, but there is still the need to deliver high quality imaging with some applications needing in excess of 100 Mbps.

Connected Automotive: The automotive industry is moving quickly to support and test autonomous driving and in some cases autonomous cars will require ultra-low latency communications (ULLC) to support V2X (Vehicle to Everything).

Smart Manufacturing – including Robotics: Smart robotics and lean engineering are at the heart of Industry 4.0 and mobility is taking a foothold in the workplace in areas such as manufacturing, supply and asset management/tracking. Mobility is enabling real-time access to mission critical data and Artificial Intelligence is being used to speed up processes, improve industry performance and increase productivity.

Connected Energy: Understanding energy needs and distribution is paramount for the energy companies to effectively manage their business. Outage management and even video surveillance of sub-stations will all be part of the 5G network energy solution.

Connected Drones: Unmanned Aerial Vehicles (UAV) are ideal products for 5G with often a need for real time video to support traffic surveillance, crime prevention or emergency support – in case of a major fire for instance. UAVs will need a 5G connection to validate parcel deliveries, potentially using facial recognition to ensure delivery to the right location and person.

Smart Cities: A 5G connected city will without doubt be highly efficient and able effectively manage parking, lighting, traffic flow, refuse collection, floods, pollution monitoring and fly tipping. High megapixel IP cameras will be at the heart of the Smart City and many will need the bandwidth of 5G to deliver high resolution imaging.

7 Network-as-a-Service

Mobile architecture is becoming more IT centric with virtualisation, cloud native software, including a virtualised evolved packet core (EPC).

The need to improve scalability, resource utilisation and the economics of Radio Access Network operation means the mobile industry is also considering ways to reduce network operating expenditure, including reducing energy consumption, which can account for up to 15% of network OPEX in mature markets [15]. The by-product of this initiative will also have a positive impact on CO_2 emission reduction.

By virtualizing the EPC functionality, mobile networks can be customised to satisfy the different requirements of each customer by creating a tailored service solution either fully in the cloud, partially in the cloud with some local component – to ensure low latency for instance – or as a fully deployed private mobile network. Virtualisation is enabling the deployment of compact stand-alone 4G networks on oil rigs or in mining sites and 5G will further extend the -as-a-service capabilities from the full 5G network-as-a-service into areas like IoT-as-a-service or drone-as-a-service type solutions. As an example of the scale virtualisation can enable, Telefonica have demonstrated a complete mobile network on a drone [16].

8 5G Trials

Telecom operators from all continents have announced involvement with 5G demonstrations, lab tests and field trials. GSA has identified 134 operators, in 62 countries that have demonstrated, are testing or trialling, or have been licensed to conduct, field trials of 5G-enabling and candidate technologies [17]. Over 326 separate demonstrations, tests or trials have been announced confirming the high interest in bringing 5G technology to market.

At least 61 projects have involved testing Massive MIMO in the context of 5G (i.e. MIMO trials involving 64 or more transmitters, or lower order MIMO used on new high frequency spectrum bands or involving some other 5G aspect such as New Radio characteristics). This figure is up from 54 at the end of 2017.

There have been at least 73 demos, tests or trials of New Radio technologies (up from 42 during the last three months of 2017). GSA has also identified 19 projects that have explicitly featured network slicing.

One use case that has gained prominence is use of 5G to delivery fixed wireless broadband services. At least 15 tests so far that have specifically focused on the fixed wireless access (FWA) use case.

A variety of spectrum bands have been used for 5G Trials and the main bands are shown in Figure 7.

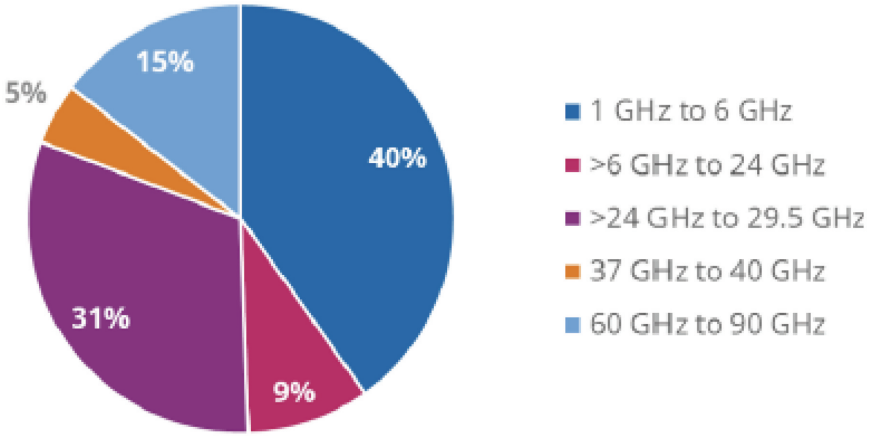

Figure 7 Distribution of 5G demonstrations and trials by broad spectrum ranges.

9 Conclusion

The road to 5G is clearly defined by the impact and success of 4G/LTE in the mobile industry over the past nine years – specifically in the last 5 years as LTE has dominated the growth in mobile devices and networks. Many of the features of 5G are being tested in LTE-Advanced Pro networks around the world creating a strong foundation for 5G to grow out of.

New spectrum for 5G will bring in massive capacity and the capability to deliver bandwidth intense services to meet the ongoing explosion of data usage that is being predicted. Video and VR/AR will reside at one end of this spectrum, but ULLC and lower bandwidth IoT services will reside at the other end of the services mapping. Gaming though may need both ULLC and high bandwidth.

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Biography

Joe Barrett is President of the Global mobile Suppliers Association (GSA), the leading industry association representing industry mobile suppliers worldwide. GSA promotes and advocates the family of 3GPP technologies covering the evolution of 3G, 4G/LTE and 5G technologies as well as standardised Low Power Wireless Access technologies. The GSA Spectrum Group advocates the harmonisation of spectrum for mobile use. Prior to becoming President of GSA, Joe worked at both Nokia and Qualcomm representing each company on the GSA Executive Board and helped drive the mobile technology agenda to position GSA as the trusted global supplier's voice in the industry.