

Analysys Mason – ETTelecom Report

THE NEXT GENERATION OF WIRELESS NETWORKS: 5G EVOLUTION AND ROADMAP

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This document is a report on the evolution and roadmap of 5G, globally as well as in India. It presents the characteristics of 5G, its proposed use cases, the spectrum bands it will use, the specificities of 5G network architecture, and the progress of 5G thus far, along with expected commercial launch timelines and associated socio-economic benefits.

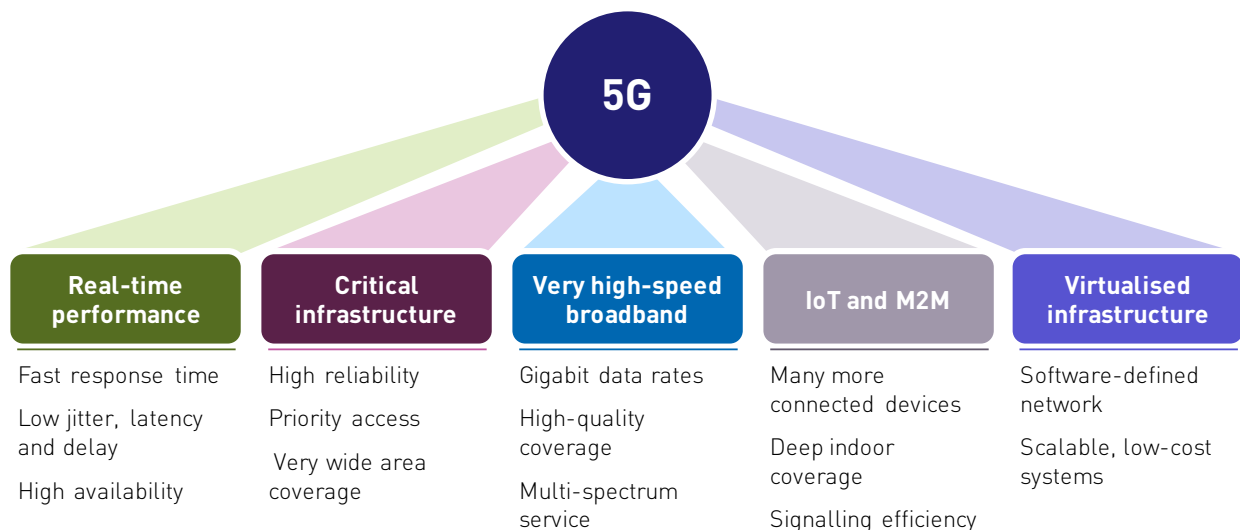
Introduction to 5G

Since the inception of digital mobile telecoms, each successive generation of technology (2G/3G/4G) has been developed to improve spectrum efficiency, coverage and capacity, and enable telecoms networks to keep pace with growth in traffic. The vision for 5G appears more revolutionary, but is also a 'wish list' for improvements to nearly all aspects of telecoms and service delivery, including:

- virtualised infrastructure, software-defined, cloud-oriented, lower-cost networks that are more flexible and scalable
- service-driven networks, driven by user experience rather than transport issues, offering telco-grade reliability
- real-time performance, supporting voice and interactive video connectivity
- everything connected, incorporating M2M and IoT as well as smartphones and other consumer devices

The key drivers for 5G are presented in Figure 1.

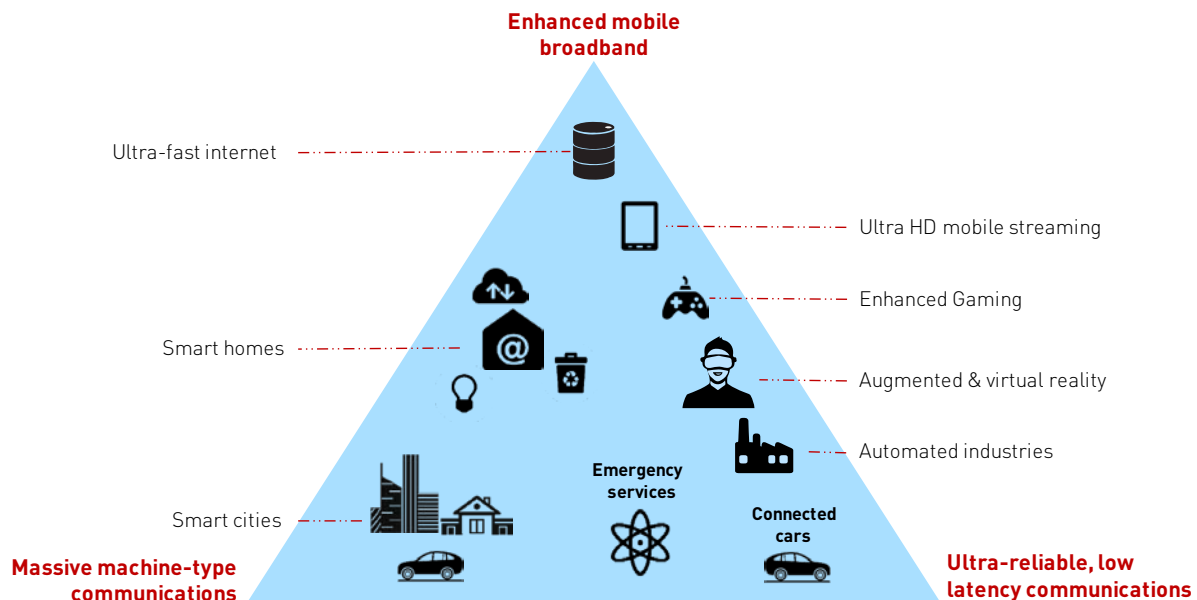
Figure 1: Key drivers and requirements for 5G [Source: Analysys Mason, 2017]



Proposed 5G use cases

Early standardisation efforts around 5G have centred around three highly publicised use cases illustrated in Figure 2.

Figure 2: 5G use cases [Source: Huawei, Analysys Mason, 2017]



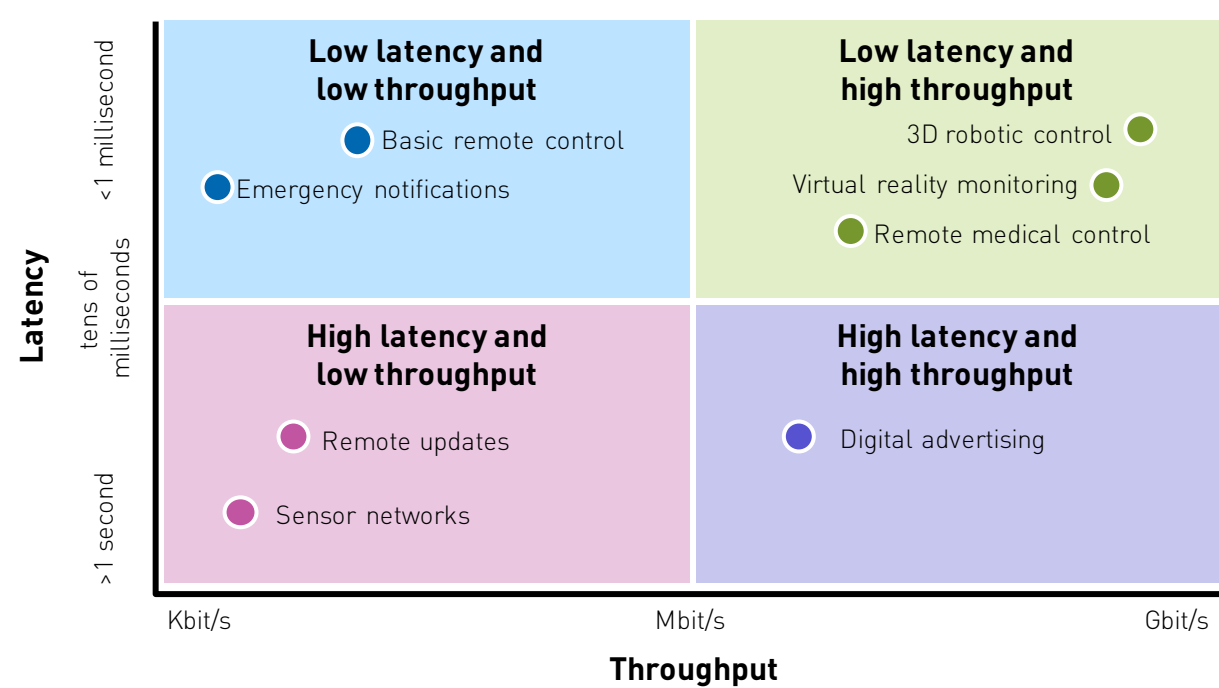
- **Enhanced mobile broadband (eMBB):** Enhanced mobile broadband is intended to deliver over 100Mbit/s to indoor and outdoor locations, with over 1Gbit/s in dense indoor locations at an end-to-end (E2E) latency of less than 5ms. Outdoor trials by Ericsson and NTT Docomo have successfully achieved 10Gbit/s in the 15GHz band. Nokia has demonstrated 2Gbit/s speeds to a high-rise complex in Tokyo using the 70GHz band, and Samsung trialled 1.2Gbit/s in a mobile test.
- **Massive machine-type connections (mMTC):** Massive IoT intends to support huge numbers of connected devices (for example, more than 1 million device connections per cell site or per km²) and enable Smart City solutions. This requires broad area coverage, usually at moderate data rates currently supported by LTE, but on a greater scale and with improved coverage. Ideally, mMTC will eventually use lower band spectrum, with sub-6GHz the most likely candidate.
- **Ultra-reliable low latency communications (uRLLC) :** Robotic manufacturing, autonomous vehicles, remote medical surgery and even gaming are the target commercial applications for low-latency (<1ms E2E delay), ultra-reliable communications. Ultra-reliable machine-type communication also targets virtual-reality applications, but in more confined spaces using wide bandwidth channels (100MHz or greater).

The three use-cases pull 5G in divergent directions. The requirements of these use-cases provide a challenge to regulators and governments looking to assign spectrum bands for 5G and to infrastructure vendors developing solutions for 5G. Vendors will be required to develop ultra-reliable solutions that operate over high frequencies and wide channels, with low latency, while also accommodating a million connections per cell (compared with the 200–400 connections typical for current networks). The equipment will also need to support a 10-year battery life and low-speed communications. To release a robust solution

in the necessary time frame is likely to force network equipment providers to choose between these options or undertake multiple development efforts – either path is likely to raise the costs of 5G.

Besides these three use-cases, industry has not been quick to develop technology applications in the IoT space, which we expect to be a key use-case driving new revenue opportunities. A number of new technologies such as NB-IoT, LoRa and Sigfox are being deployed to meet requirements of IoT-based opportunities such as smart homes, smart grids and smart cities. 5G IoT must focus on solving the problems that today’s IoT applications do not yet address. High-value IoT functions such as robotic control, virtual reality applications and remote medical procedures require very high bandwidth and/or very low latency. These solutions may be applicable to both developed and emerging markets, which further supports the need for a global approach to 5G standardisation. Figure 3 shows latency and throughput requirements of a few 5G IoT applications and their network performance needs.

Figure 3: 5G IoT applications have a variety of network performance needs [Source: Analysys Mason, 2017]

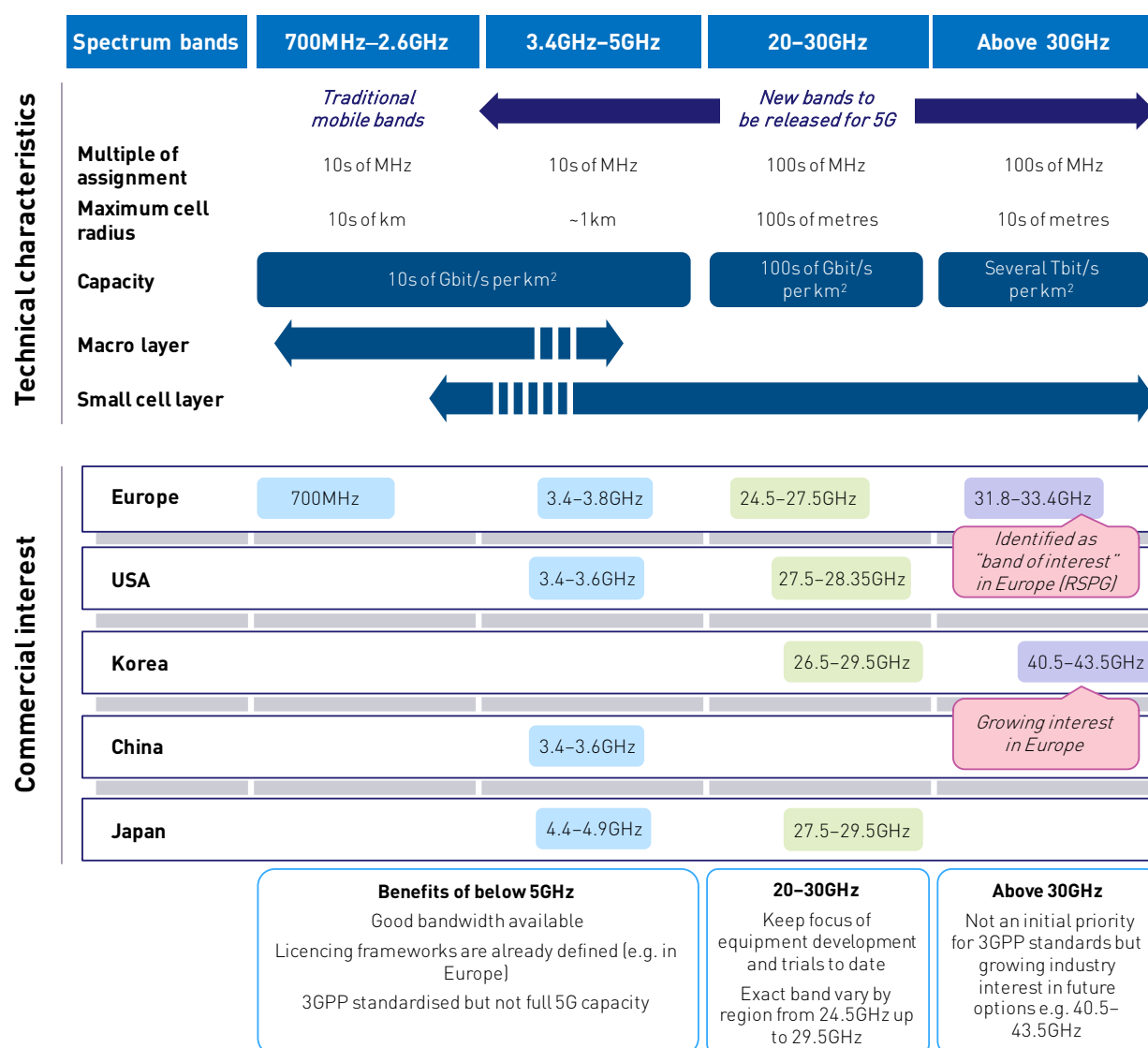


Spectrum roadmap for 5G

To enable varied use cases highlighted in previous section, 5G is expected to require spectrum in both low frequency (sub GHz) and high frequency (20 – 40 GHz) spectrum bands. While some 5G use cases like connected cars require wide area coverage to be enabled with low-frequency bands (such as 700 MHz), recent industry interest in 5G has focussed on spectrum in region of 20–40 GHz to enable very high capacity indoor and outdoor hotspot coverage.

Figure 4 shows a summary of characteristics of spectrum bands likely to be used for 5G along with an overview of recent industry interest across the world in these 5G spectrum bands.

Figure 4: Technical characteristics and industry interest in spectrum bands for 5G [Source: Analysys Mason, 2017]



The timing of the award of these 5G spectrum bands can vary significantly by country. For example, with the 700MHz band, two neighbouring countries such as France and the UK have adopted very different timelines: in France, the 700MHz band was auctioned in 2015 and spectrum is being progressively released to mobile operators, in eight stages, between early 2016 and mid-2019;¹ in the UK, Ofcom announced in October 2016 that it planned to release 700MHz spectrum in Q2 2020 (revised from its previous plans for the end of 2021).²

In India, the focus has been on spectrum bands in sub-700 MHz frequency range, which supports widespread coverage, and L band (1427–1518 MHz) and a part of C band (3.3 GHz) which offer a good mixture of coverage and capacity benefits. Operators seem interested in acquiring spectrum in these spectrum bands to enable 5G, but have expressed concerns over timing of auction, reserve prices, and in-band spectrum cap. The 700MHz band was auctioned in October 2016 but failed to attract any bids as operators

¹ In each stage their full allocation of 2x5MHz or 2x10MHz is released but only for specific areas of the country. For details (and in particular the map of release dates), see <http://www.arcep.fr/index.php?id=9199>

² See the statement from October 2016 and the consultation document from March 2016 at <https://www.ofcom.org.uk/consultations-and-statements/category-1/maximising-benefits-700mhz-clearance>

considered the reserve price too high. Recent consultation by TRAI (dated 29 August 2017) invited industry opinion on proposed first-time auction of 5G-enabling spectrum bands 3.3 – 3.4 GHz and 3.4 – 3.6 GHz along with unsold spectrum bands from 2016 auction. While the TRAI's final recommendations are awaited, operators and industry bodies have opined that any proposed timing of the auction should take into account the current phase of financial distress and consolidation in the industry, which could potentially imply postponement of proposed auction to latter half of 2018^{3,4}.

It is important for the industry, technology community and academia to work together and also participate (in auction) for getting the right amount of spectrum. We need building blocks, and the most critical element is the amount of spectrum allocation per carrier. At least 100 MHz per operator would be required for 5G enablement. The deployment would be carried over frequencies in the 3.5 GHz or less than 6 GHz range...

Mathew Oommen, President, Reliance Jio Infocomm

Six slots of 5 MHz are already available in the 700 MHz band and we have asked for a slot to be allocated to us. We are looking at it also for offering 5G services in the future. For 5G services in rural and dense urban areas, 700 MHz, sub-700 MHz and unlicensed bands such as 2.5 GHz and 5.2 GHz will be used for Internet of Things (IoT) services in India.

Anupam Shrivastava, Chairman & Managing Director, BSNL

In the short-term, India should start planning now for its spectrum needs in 2020–2025. At WRC-15 additional spectrum bands were identified by India for mobile broadband... DoT should now commit to these bands at the national level in NFAP and prepare a roadmap for the largely unused bands

Brett Tarnutzer, Head of Spectrum, GSMA

5G network architecture

5G networks will bring innovations in terms of architecture, most notably:

- **Ultra-dense networks/small cells:** Given the limited amount of sub-3GHz spectrum available, the layout of existing (2G/3G/4G) mobile networks will be insufficient to support the services expected of 5G. The poor propagation properties of high-frequency spectrum dictate that a markedly higher density of (smaller) cells will be vital if 5G is to fulfil its potential. As an illustration, mmWave spectrum delivers acceptable signal level in cell sizes of around 200–300m, making it ideal for use cases in busy city-centre streets where data demand is high. The attenuation due to heavy rainfall is 7dB/km at 28GHz,⁵ which translates to only 1.4dB of attenuation over a 200m cell size. Rain would therefore minimally affect the propagation of mmWave from 28GHz to 38GHz. By contrast, building materials such as tinted glass have high penetration losses of 40dB. This makes outdoor-to-indoor penetration of mmWave difficult,

³ See the TRAI's consultation document and responses at <http://www.trai.gov.in/consultation-paper-auction-spectrum-700-mhz-800-mhz-900-mhz-1800-mhz-2100-mhz-2300-mhz-2500-mhz-3300?page=1>

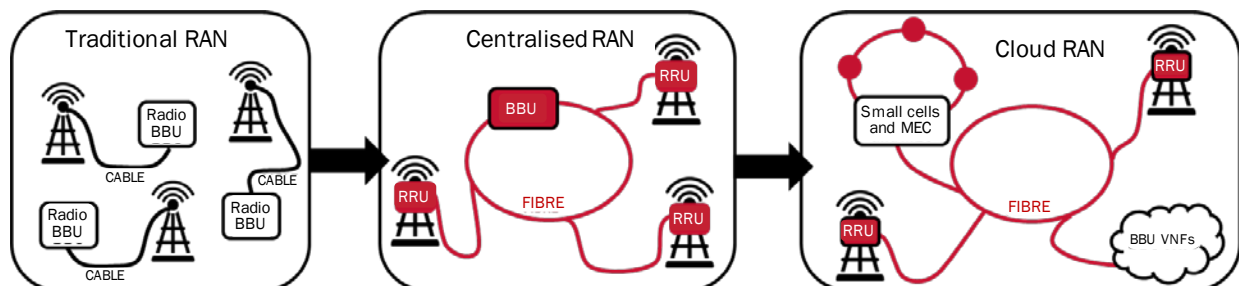
⁴ See opinion of Industry bodies and operators at <http://indiatoday.intoday.in/story/coai-for-spectrum-auction-only-in-late-2018-early-2019/1/937801.html> and <https://economictimes.indiatimes.com/news/economy/policy/no-case-for-holding-spectrum-auctions-now-big-telcos-to-trai/articleshow/61582394.cms>

⁵ Rappaport, T. (March 2013), 'Mobile Communications for 5G Cellular: It Will Work!' *IEEE Access*, Vol 1 (1), pp. 335–349.

provides high isolation between outdoor and indoor networks, giving the opportunity to further increase network density and therefore capacity by reducing the risk of interference between outdoor and indoor signals.

- **Large-scale transition to fibre:** the high throughput offered by 5G needs to be backhauled from mobile sites to the operator's core network. This will lead to the roll-out of fibre to most mobile sites, although mmWave spectrum in the E-band (70–80GHz) may also be used to provide very-high-capacity microwave backhaul.
- **Cloud RAN:** in traditional RANs, each base station has its own baseband unit (BBU), with the radio either integrated or located remotely at the top of the tower. From there, two main evolutions are possible, illustrated in Figure 5:
 - **Centralised RAN** - An evolution of the established concept of base station 'hotels', in which several remote radio units (RRUs) are connected to a single BBU, sharing its resources flexibly. The BBU may be local or remote. The primary advantages of centralised RAN relate to cost and energy efficiency.
 - **Cloud RAN** - An architecture pioneered by China Mobile, this establishes a functional split between remote and shared resources. The latter are virtualised and deployed as virtual network functions (VNFs) on a server or in the cloud. This has cost and energy advantages, but it can also support radically new network economics and a wide range of new services, and prefigures 5G network slicing.

Figure 5: The evolutions from traditional RAN to cloud RAN [Source: Analysys Mason, 2017]



Progress on 5G thus far

The time of launch and eventual success of 5G relies on adoption of common global standards. On 26 February 2017, a group of 22 mobile companies announced their collective support for the acceleration of the 5G new radio (NR) standardisation schedule to enable large-scale trials and deployments as early as 2019. AT&T, NTT Docomo, SK Telecom, Vodafone, Ericsson, Qualcomm Technologies, BT, Telstra, Korea Telecom, Intel, LG Uplus, KDDI, LG Electronics, Telia Company, Swisscom, TIM, Etisalat, Huawei, Sprint, Vivo, ZTE and DT indicated they would support a corresponding work plan proposal for the first phase of the 5G NR specification at the next 3GPP RAN Plenary Meeting on 6-9 March in Dubrovnik, Croatia. Their proposal is for work on Non-Standalone 5G NR to be completed by December 2017 and for Standalone 5G NR to be completed by June 2018.⁶

⁶ See www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_75/joint_RAN_SA_Wed_eve/Docs/RP-170741.zip for details. See <http://www.3gpp.org/dynareport/Meetings-RP.htm> for future 3GPP meetings.

A number of operators and vendors are already conducting 5G trials in different regions of the world. Figure 6 summarises the key trials that have taken place since the beginning of the year while Figure 7 provides an overview of ongoing and upcoming trials planned for future.

Figure 6: Key 5G trials in 2017 and their characteristics [Source: Analysys Mason, 2017]

Country	Spectrum band	Speed achieved	Other characteristics
Singapore	73GHz	35Gbit/s	Singapore's highest 5G transmission speeds, by M1 and Huawei
Thailand	Unknown	6Gbit/s	Latency as low as 3ms, first live 5G E2E demonstration in Thailand, by Ericsson
Turkey	15GHz	25Gbit/s	First 5G trial in Turkey, by Turkcell and Ericsson
France	Unknown	10Gbit/s	5G trial conducted by Ericsson and Orange; frequency band unknown
Hong Kong	15GHz	6Gbit/s	4x4 MIMO antenna technology, by SmarTone and Ericsson
USA	5.1–5.8GHz	450Mbit/s	Fixed wireless broadband network activated in selected areas in Maine, by wireless ISP Redzone Wireless
Czech Republic	E-band (70–80GHz)	10Gbit/s	Microwave hop of 4.85km connecting a base station to an optical aggregation site, by T-Mobile and Ericsson (commercially available 'MINI-LINK 6352')
South Korea	28GHz	4Gbit/s	Data transmission from a car driving up to 170km/h with a network made of four radio transmission points using 'beamforming and beam tracking to allow the base station to transmit signals that follow the 5G device; by Ericsson, SK Telecom and BMW
Japan	Unknown	1Gbit/s	4K video streaming in a connected vehicle travelling at 30km/h, by NTT DoCoMo, Intel, Ericsson, Denso and Toyota
Japan	Unknown	1.7Gbit/s	Successful downlink and uplink handover in a train moving at 100km/h, along with downloading of a 8K video via on-board CPE and uploading of a 4K video filmed on a camera mounted on train, by Samsung and KDDI

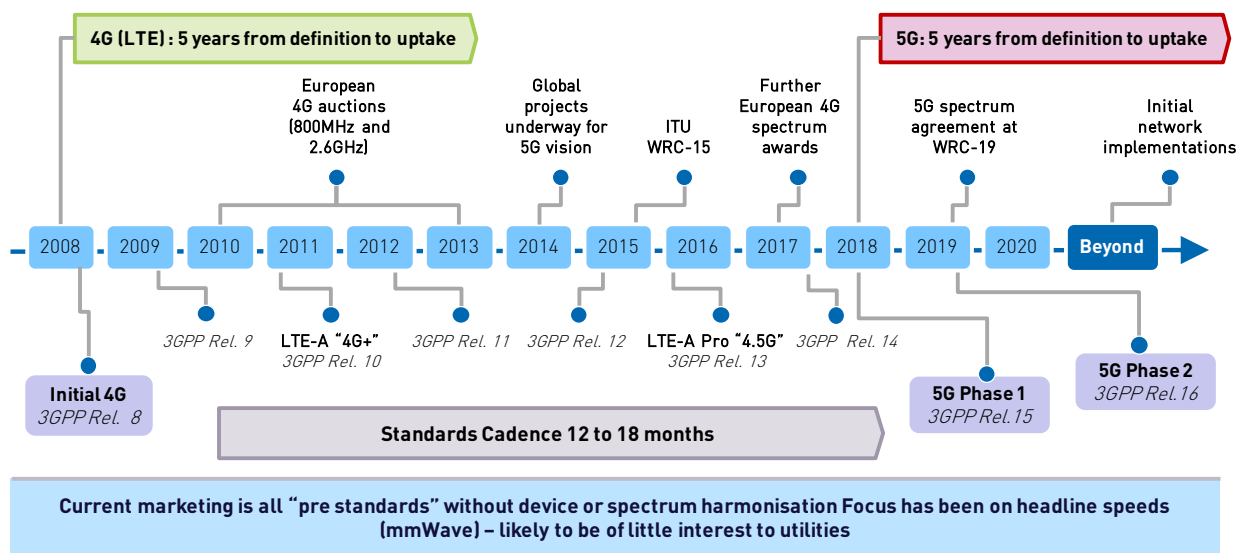
Figure 7: Ongoing and upcoming 5G trials [Source: Analysys Mason, 2017]

Country	Timeline and type of trial	Other details
Europe	2019 Pre-commercial	<ul style="list-style-type: none"> Field trials by EE, with first commercial services expected to go live the following year
China	2019 Pre-commercial	<ul style="list-style-type: none"> Field trials in 6 Chinese cities in 2019 by China Telecom
USA	2017	<ul style="list-style-type: none"> Fixed wireless customer pilots by Verizon and Ericsson with goal to launch NGN by end of decade
Japan	2020 commercial	<ul style="list-style-type: none"> Plan to provide 5G coverage in Tokyo at time of 2020 Olympics
Korea	2018 Winter Olympics, 2020 Commercial	<ul style="list-style-type: none"> Intel and KT plan to showcase 5G preview during 2018 Winter Olympics with future goal of commercial launch by 2019-20

Commercial launch

While there are commercial trials planned for 5G in the coming years, since 5G spectrum standards and protocols are not fully standardised yet, concrete commercial roll-out plans are yet to be firmed up by operators. Also, there is a 'chicken-and-egg' problem related to whether the initial investments need to come from operators or from potential commercial users of 5G applications. For example, in the case of connected cars, car manufacturers will not want to put equipment in cars (if it adds cost) unless they can be sure that networks are able to offer the services 5G could bring. On the other hand, network operators will not want to make the required network investment if there are no potential customers. Having said that, we expect 5G standards to be agreed by 2019, meaning networks will begin to be deployed in Europe from 2020 onwards, and the real impact coming after 2025. Figure 8 provides a summary of expected timeline for 5G commercial launch.

Figure 8: Expected timeline for 5G commercial launch [Source: Analysys Mason, 2017]



The GSMA forecasts that commercial 5G networks will begin to be widely deployed at the start of the next decade and, by 2025, will provide coverage to a third of the world's population. 5G connections are forecast to reach 1.1 billion by 2025, accounting for approximately one in eight mobile connections worldwide by this time

Brett Tarnutzer, Head of Spectrum, GSMA

In India, the government constituted a high-level forum on 5G technology in September 2017 with a broad target of rolling out 5G in India by 2020. However, this target may provide challenges given that 4G adoption is still in its infancy and LTE network roll-out is still under way. For commercial launch of 5G in India, both demand- and supply-side drivers need to evolve. Relevant consumer segments and specific use-cases relevant to the Indian context still need to be identified and developed. Operators, on the other hand, have made heavy investments in 4G and are only now starting to generate returns. Thus, there may still be a while before we see operators with commitment and resources take the plunge with deployment and launch of 5G.

On a brighter side however, the keenness of industry towards early 5G deployment is already visible. Operators are already bringing some of 5G technologies such as Massive MIMO and applying them into 4G. Taking into account the current rate of progress in the industry, India is likely to get ready for 5G by 2022, which is within two years of expected launch in developed markets and implies a good progress over 4G roll-out where India lagged developed markets by at least 4 – 5 years.

At Airtel, we have pioneered the rollout of 4G LTE network in India and latest technologies like LTE – Advanced and Massive MIMO... Having built a strong foundation for networks of the future as part of our Project Leap initiative, we are well positioned to usher in 5G in the coming years in partnership with our ecosystem of partners and open the doors for IoT, AI and VR

Abhay Savargaonkar, Director – Networks (India and South Asia), Bharti Airtel

We are laying the ground for 5G...We expect 5G to be launched worldwide in the developed market by 2020. By 2022, India should be ready for 5G

Himanshu Kapania, Managing Director, Idea Cellular

"The 5G technology is still a few years away, but the industry is bringing some of the 5G technologies such as massive MIMO into 4G and applying them."

Vishant Vora, Director – Technology, Vodafone India

Further reading

Analysys Mason regularly publishes reports and articles about 5G. The following reports (and more on our website, <http://results.analysismason.com/search?w=5G&af=kc:true>) are available for free (samples only for the reports):

- A spectrum roadmap towards 5G: <http://www.analysismason.com/About-Us/News/Insight/a-spectrum-roadmap-towards-5g/#16%20March%202017>
- 5G fixed-wireless: the investment case for operators: <http://www.analysismason.com/Research/Content/Reports/5g-investment-operators-Jan2017-RDNS0/#30%20January%202017>
- The case for 5G: mobile operators must move beyond smartphones and encourage connected device take-up: <http://www.analysismason.com/About-Us/News/Newsletter/The-case-for-5G-Oct2016/#25%20October%202016>
- The investment case for 5G mobile is more distant without fixed wireless: <http://www.analysismason.com/Research/Content/Comments/5G-fixed-case-Aug2016-RDTW0-RDCS0/#19%20August%202016>

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Rohan has over 15 years' experience advising Telecom and Media operators and investors across 5 continents on board-level strategy issues. Rohan has directed over 100 engagements around business planning, spectrum strategy, pricing & go-to-market strategy, M&A support and operational improvement topics



Janette Stewart, *Principal, Global expert – Spectrum regulation and valuation*

Janette has over 15 years' of strategy consulting experience in wireless technologies and radio spectrum-related issues. Her expertise spans from 2G to 5G mobile communications, as well as broadcasting technologies and short-range devices. Janette is a regular speaker at international spectrum conferences with recent focus on 5G



Vishal Kumarr Chadha, *Engagement Manager, India Practice*

Vishal has over 9 years of experience in TMT, finance and investment advisory work. He has worked on multiple demand assessment, capex and opex forecasting, pricing strategy, and M&A support engagements for operators and investors in India and globally



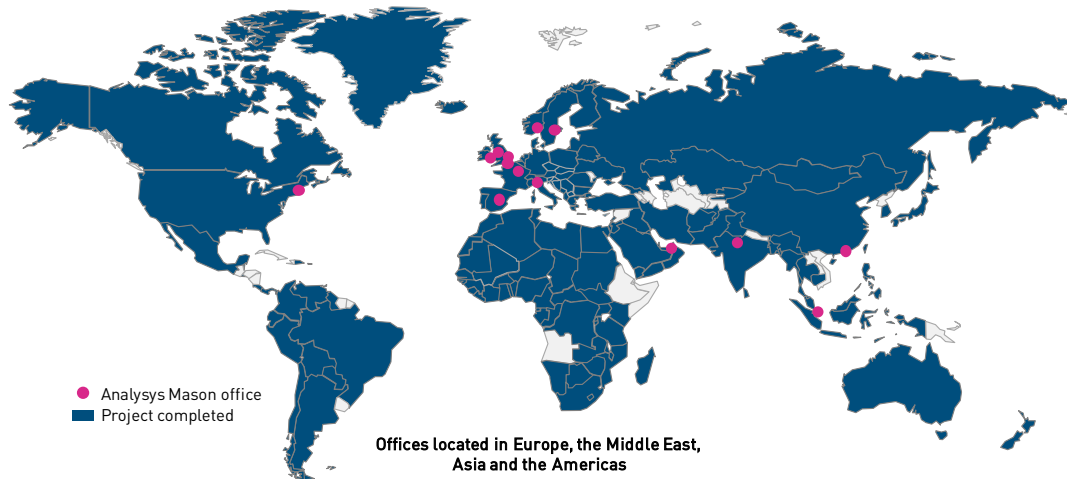
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Shreyas has experience advising leading telecom operators, internet players and private-equity investors in Asia-Pacific region

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Analysys Mason is the world's largest and most respected telecoms and digital media focused management consulting firm. Through our global presence, we deliver strategy advice, operations support and market intelligence to leading commercial and public-sector organisations in over 100 countries.

We have successfully completed over a 1000 strategy and operations advisory engagements for TMT clients in over 60 countries in the last 3 years alone



For 30 years, our intellectual rigour, operational experience and insight have helped our clients resolve issues ranging from development of operator strategy, evolution of national sector regulation and execution of major financial transactions, to the deployment of public and private network infrastructure. Analysys Mason consistently delivers significant and sustainable business benefits

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