ETTelecom
From The Economic Times

analysys mason

Analysys Mason – ETTelecom Report

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

8 December 2017

Rohan Dhamija, Janette Stewart, Vishal Kumarr Chadha, Shreyas Sharma

## Contents

This document reports on the evolution of, and roadmap for, 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 the 5G network architecture, along with the progress on 5G thus far and the expected commercial launch timelines.

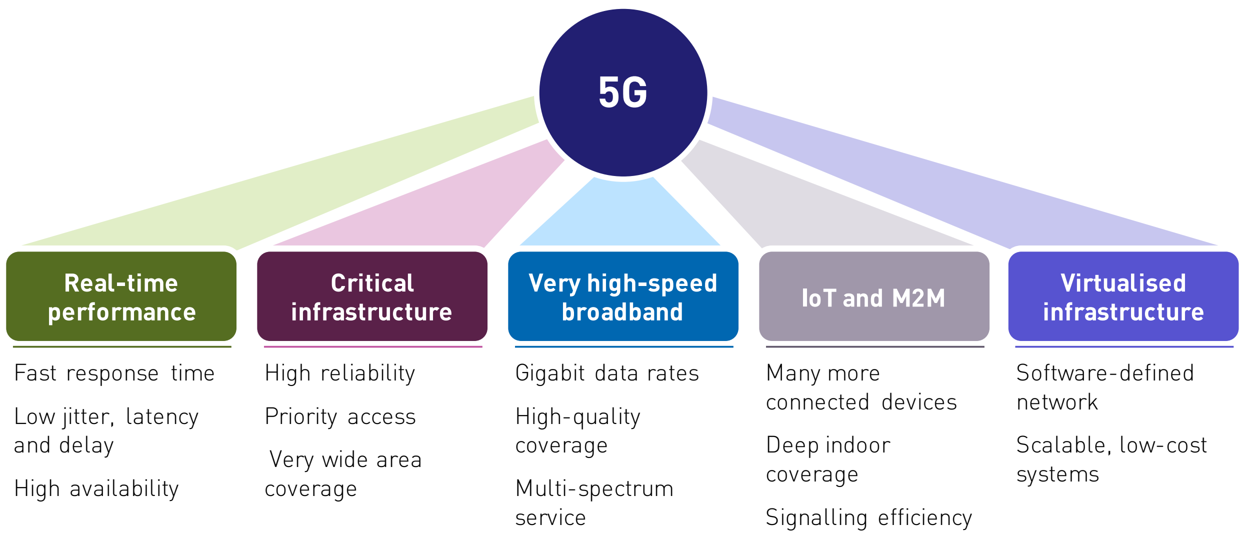
## Introduction to 5G

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 it 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, and offering telco-grade reliability
- real-time performance, supporting voice and interactive video connectivity
- 'everything connected', incorporating machine-to-machine (M2M) and the Internet of Things (IoT) as well as smartphones and other consumer devices.

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

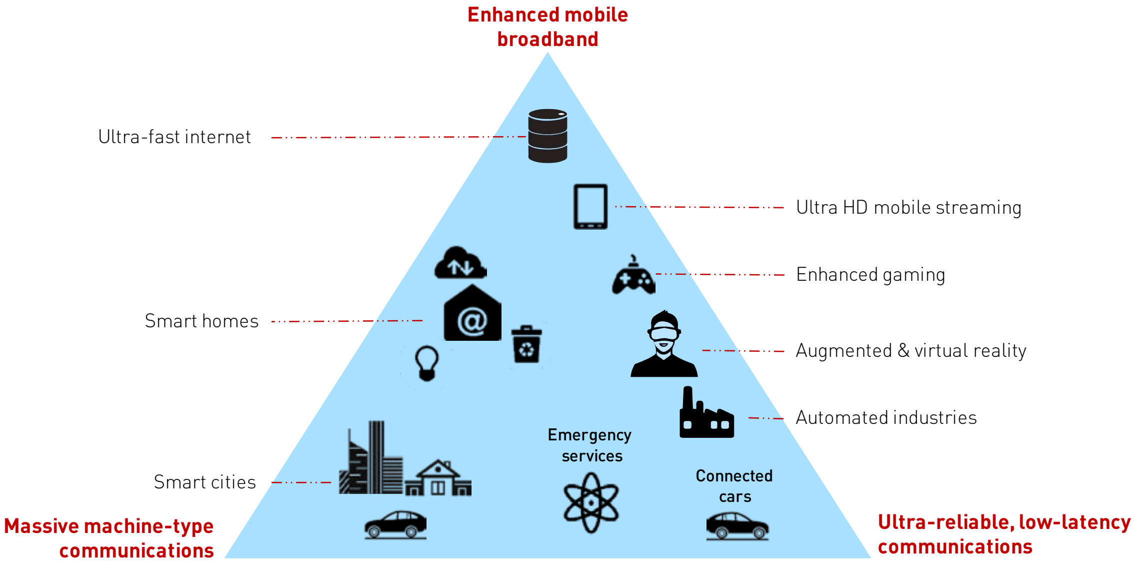
*Figure 1: Key drivers and requirements for 5G [ Source: Analysys Mason, 2017]*



# Proposed 5G use cases

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

*Figure 2: 5G use cases [Source: ITU-R, Analysys Mason, 2017]* [1]



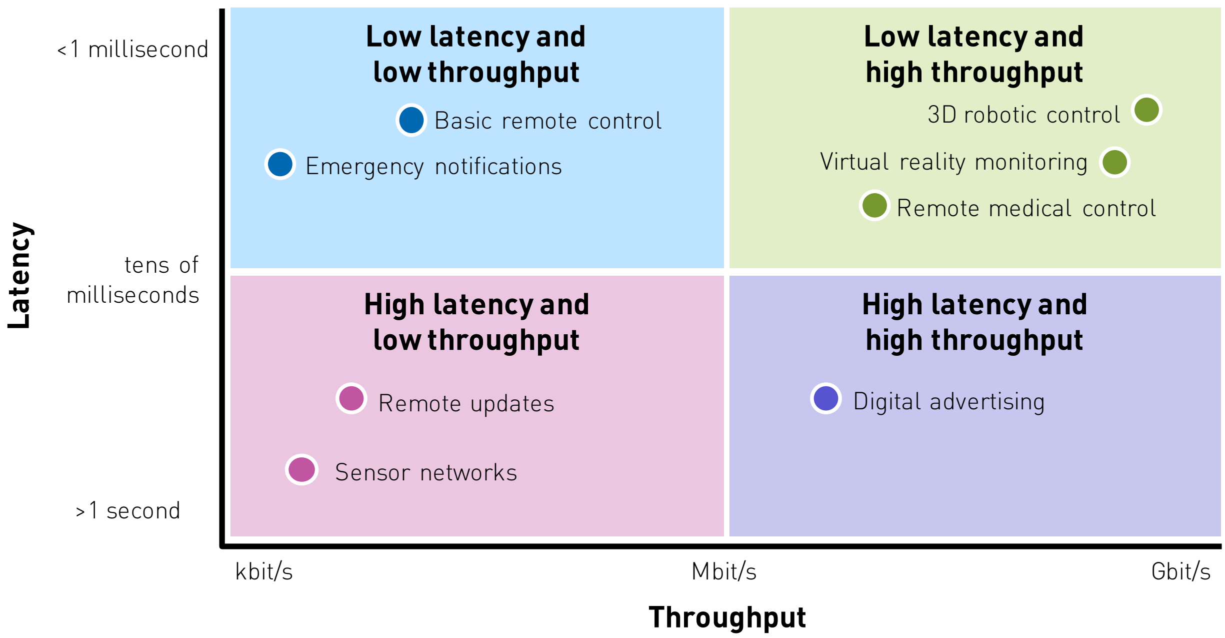

- **Enhanced mobile broadband (eMBB)**: Enhanced mobile broadband is intended to deliver over 100Mbit/s to indoor and outdoor locations, with over 1Gbit/s in dense indoor locations at an end-to-end (E2E) latency of less than 5ms. Outdoor trials by Ericsson and NTT DoCoMo have successfully achieved 10Gbit/s 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 km$^2$) 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 ultra-reliable, low-latency (<1ms E2E delay) communications. uRLLC also targets virtual-reality applications, but in more confined spaces using wide-bandwidth channels (100MHz or greater).

These three use cases pull 5G in divergent directions. The requirements of these use cases pose a challenge to regulators and governments looking to assign spectrum bands for 5G and to infrastructure vendors which develop 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 1 million connections per cell (compared with the 200–400 connections typical for current networks). The equipment will also need to support a ten-year battery life and low-speed communications. If network operators are to release a robust solution in the necessary timeframe, they will likely have to choose between these options or else undertake multiple development efforts – and either path is likely to raise the costs of 5G.

[1] Based on ITU-R Rec. M.2083. Link: http://www.itu.int/rec/R-REC-M.2083

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 provides further evidence that a global approach to 5G standardisation is required. Figure 3 shows the latency and throughput requirements of a few 5G IoT applications and their network performance needs.

*Figure 3: Illustration of varied network performance needs of 5G IoT applications [Source: Analysys Mason, 2017]*

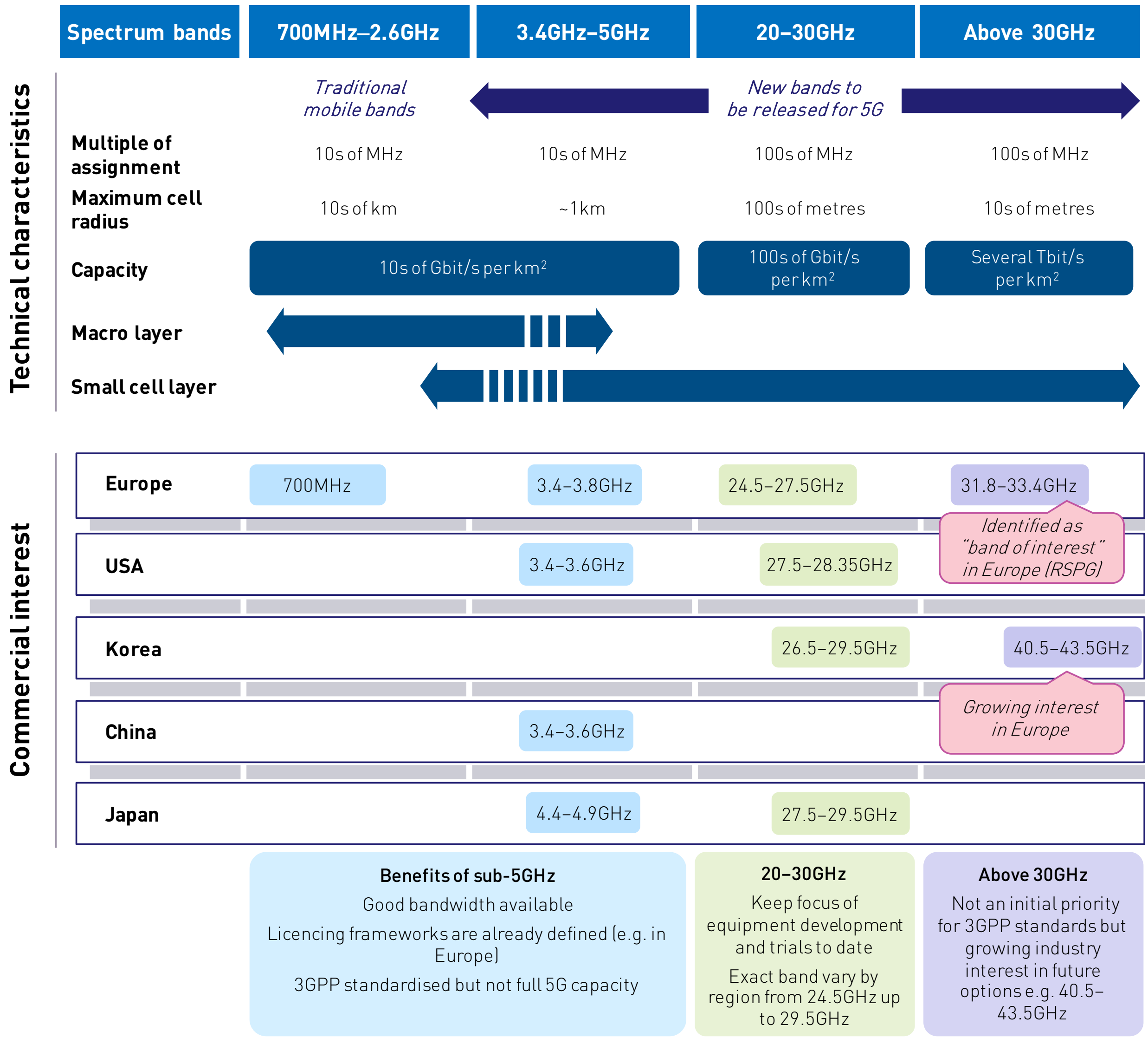



## Spectrum roadmap for 5G

To support the varied use cases highlighted in the previous section, 5G is expected to require spectrum in both low-frequency (sub-1GHz) and high-frequency (20–40GHz) bands. While some 5G use cases like connected cars require wide-area coverage to be enabled with low-frequency bands (such as 700MHz), recent industry interest in 5G has focused on spectrum in the 20–40GHz range, which will enable very-high-capacity indoor and outdoor hotspot coverage.

Figure 4 summarises the characteristics of spectrum bands which are likely to be used for 5G, and provides an overview of recent industry interest in these 5G spectrum bands around the world.

*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, neighbouring countries France and the UK have adopted very different timelines: in France, the band was auctioned in 2015 and spectrum is being progressively released to mobile operators in eight stages, between early 2016 and mid-2019;[2] in the UK, communications regulator 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).[3]

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

2 At each stage the full allocation of 2×5MHz or 2×10MHz is released, but only for specific areas of the country. For details (including a map of release dates) see **http://www.arcep.fr/index.php?id=9199**

3 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**

reserve price too high. A recent consultation by TRAI (dated 29 August 2017) invited industry opinion on the proposed first-time auction of 5G-enabling spectrum bands 3.3–3.4GHz and 3.4–3.6GHz, along with unsold spectrum bands from the 2016 auction. While the TRAI's final recommendations are awaited, operators and industry bodies have opined that the timing of the auction should take into account the ongoing financial difficulties and consolidation in the industry, which could potentially delay the auction until the second half of 2018.[4,5]

*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 100MHz per operator would be required for 5G enablement. The deployment would be carried over frequencies in the 3.5GHz or less than 6GHz range [...]*

*Mathew Oommen, President, Reliance Jio Infocomm*

*Six slots of 5MHz are already available in the 700MHz 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, 700MHz, sub-700MHz and unlicensed bands such as 2.5GHz and 5.2GHz 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, millimetre-wave (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,[6] which translates to only 1.4dB of attenuation over a 200m cell size. Rain would therefore only have a minimal effect on the propagation of mmWave from 28GHz to 38GHz. In contrast, building materials such as tinted glass result in high penetration losses of 40dB. This makes outdoor-to-indoor

4 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

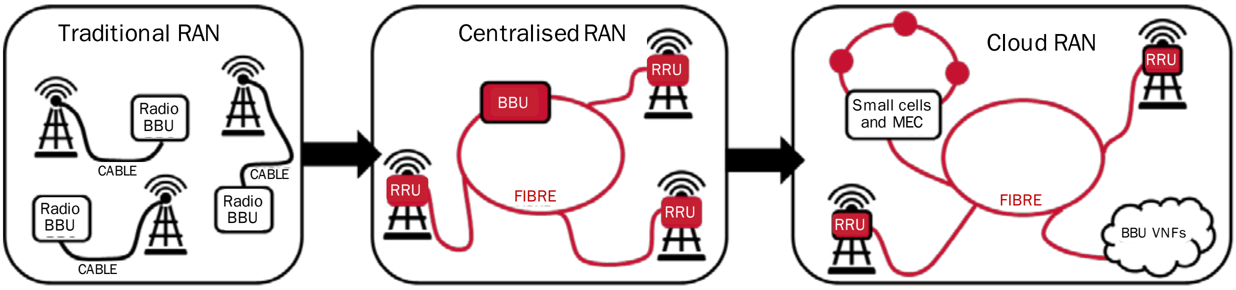
5 See the opinion of Industry bodies and operators at http://indiatoday.intoday.in/story/coai-for-spectrum-auction-only-in-late-2018-early-2019/1/937801.html and https://economictimes.indiatimes.com/news/economy/policy/no-case-for-holding-spectrum-auctions-now-big-telcos-to-trai/articleshow/61582394.cms

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

penetration of mmWave difficult, providing relatively better quality outdoors than indoors, giving operators 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 an 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, which 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 acts as a precursor to 5G network slicing.

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




## Progress on 5G to date

The timing of the launch and the eventual success of 5G relies on adoption of common global standards. On 26 February 2017, a group of 22 mobile telecoms companies announced their collective support for acceleration of the 5G new radio (5G-NR) standardisation schedule to enable large-scale trials and deployments as early as 2019. AT&T, BT, DT, Ericsson, Etisalat, Huawei, Intel, KDDI, Korea Telecom, LG Electronics, LG Uplus, NTT DoCoMo, Qualcomm Technologies, SK Telecom, Swisscom, Telia Company, Sprint, Telia Company, Telstra, Vivo, Vodafone, ZTE indicated that they would support a corresponding work plan proposal for the first phase of 5G-NR specification at the next 3GPP RAN Plenary Meeting on 6–9 March 2018 in Dubrovnik, Croatia. Their proposal is for work on Non-Standalone 5G-NR to be completed by December end-2017/early-2018 and for Standalone 5G-NR to be completed by June 2018.[7]

[7] 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 various parts of the world. Figure 6 summarises the key trials that have taken place during 2017, while Figure 7 provides an overview of ongoing and upcoming trials.

*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 |
| **Hong Kong** | 15GHz | 6Gbit/s | 4×4 MIMO antenna technology, by SmarTone and Ericsson |
| **USA** | 5.1–5.8GHz | 450Mbit/s | Fixed wireless broadband network activated in selected areas of 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 travelling at 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 an 8K video via on-board CPE and uploading of a 4K video filmed on a camera mounted on the train, by Samsung and KDDI |

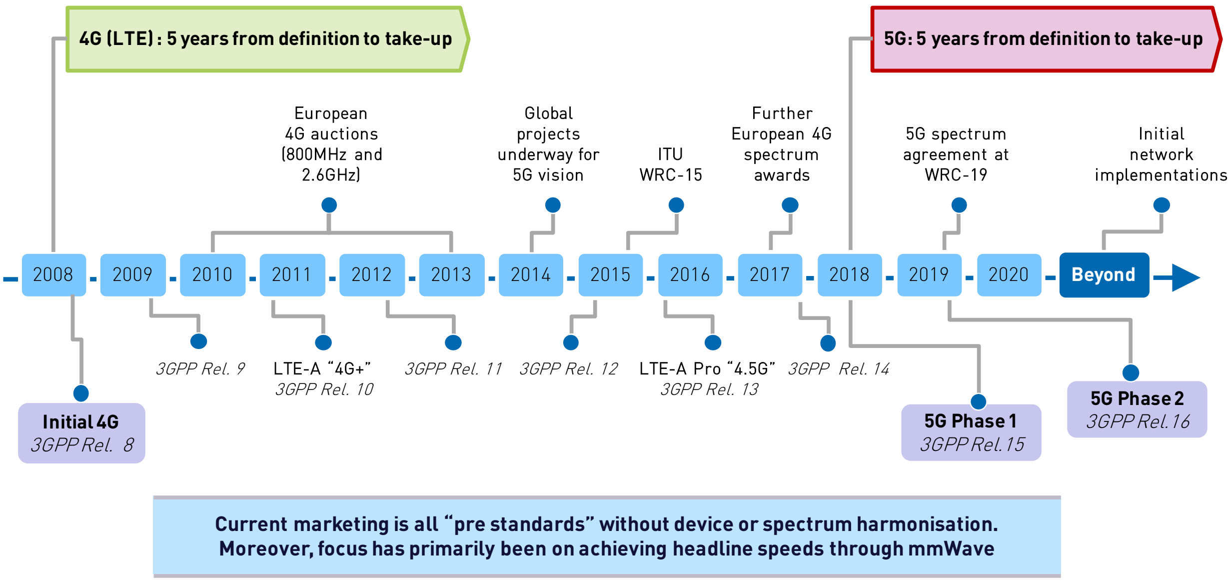
*Figure 7: Ongoing and upcoming 5G trials [Source: Analysys Mason, 2017]*

| Country | Timeline and type of trial | Other details |
|---|---|---|
| **Europe** | 2019, pre-commercial | Field trials by EE, with first commercial services expected to go live the following year |
| **China** | 2019, pre-commercial | Field trials in six Chinese cities in 2019 by China Telecom |
| **USA** | 2017 | Fixed wireless customer pilots by Verizon and Ericsson, with goal of launching NGN by end of the decade |
| **Japan** | 2020, commercial | Plan to provide 5G coverage in Tokyo at time of 2020 Olympics |
| **Korea** | 2018 Winter Olympics, 2020, commercial | Intel and KT plan to showcase a 5G preview during the 2018 Winter Olympics, with a goal of commercial launch by 2019–20 |

# Commercial launch

Although 5G commercial trials are planned for the coming years, the fact that 5G spectrum standards and protocols are not yet fully standardised means that concrete commercial roll-out plans have yet to be finalized 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, which would enable network deployment to begin in Europe from 2020 onwards, with the real impact of 5G coming after 2025. Figure 8 summarises the 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 prove challenging, given that 4G adoption remains in its infancy and LTE network roll-out is still underway. Commercial launch of 5G in India will require the evolution of both demand- and supply-side drivers. Relevant consumer segments and specific use cases relevant to the Indian context still need to be identified and developed. Meanwhile, operators have made heavy investments in 4G and are only now starting to generate returns. Thus, it may still be a while before we see operators with the commitment and resources to "take the plunge" with deployment and launch of 5G.

On a brighter note, however, industry enthusiasm regarding early 5G deployment is already visible in India. Operators are already using some 5G technologies (such as Massive MIMO) and incorporating them into 4G. Given the current rate of progress in the industry, India is likely to be ready for commercial launch of 5G by 2022, which is within two years of expected launch in developed markets and represents good progress compared to 4G roll-out (where India lagged behind developed markets by at least four to five years).

*At Airtel, we have pioneered the roll-out 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 others on our website, **http://results.analysysmason.com/search?w=5G&af=kc:true**) are available free of charge (samples only for the reports):

- *A spectrum roadmap towards 5G*:
  **http://www.analysysmason.com/About-Us/News/Insight/a-spectrum-roadmap-towards-5g/#16%20March%202017**
- *5G fixed–wireless: the investment case for operators*:
  **http://www.analysysmason.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.analysysmason.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.analysysmason.com/Research/Content/Comments/5G-fixed-case-Aug2016-RDTW0-RDCS0/#19%20August%202016**

# About the authors

**Rohan Dhamija**, *Partner, Head – India (South Asia) & Middle East*

Rohan has over 15 years' experience of advising telecoms and media operators and investors across five continents on board-level strategy issues. He has directed over 100 engagements related to business planning, spectrum strategy, pricing and go-to-market strategy, M&A support and operational improvement.

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

Janette has over 15 years' experience as a strategy consultant on 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 Practic*e

Vishal has over nine years' 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.

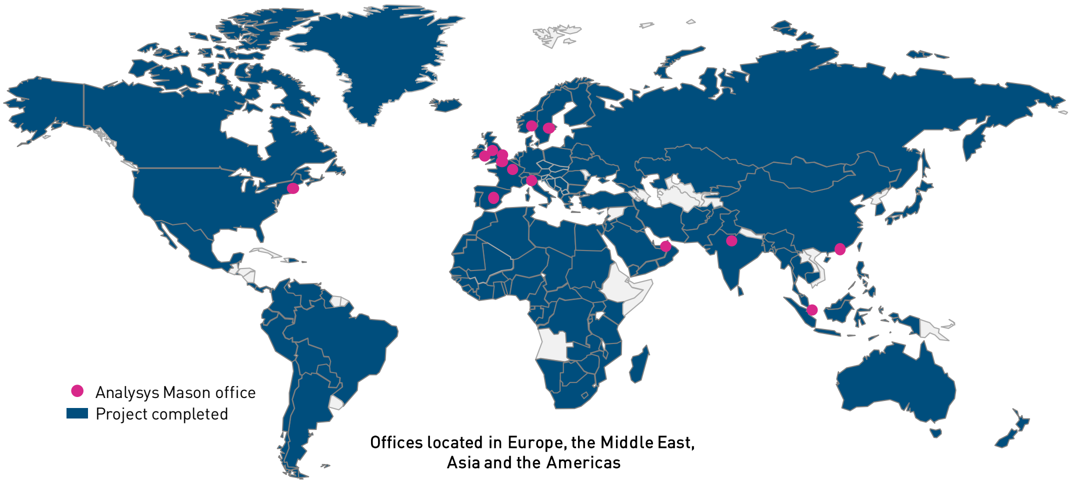
**Shreyas Sharma**, *Associate Consultant, India Practice*

Shreyas has experience of advising leading telecoms operators, internet players and private-equity investors in the Asia–Pacific region.

# About Analysys Mason

**Analysys Mason** is a global specialist adviser on telecoms, media and technology. Through our worldwide presence, we have delivered strategy advice, operations support and market intelligence to leading commercial and public-sector organisations in over 110 countries.

We have successfully completed around 775 strategy and operations advisory engagements for TMT clients in over 60 countries in the last 3 years alone.




For more than 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.

We are respected worldwide for the exceptional quality of our work, our independence and the flexibility of our teams in responding to client needs. We are passionate about what we do and are committed to delivering excellence to our clients. The company has around 235 staff worldwide, with headquarters in London and offices in Boston, Cambridge, Dubai, Dublin, Hong Kong, Madrid, Manchester, Milan, New Delhi, Oslo, Paris, Singapore and Stockholm.

Published by Analysys Mason Limited • 1st Floor, Tower 'C', Building No. 10, DLF Cyber City, Phase II, Gurugram, Haryana 122002

Tel: +91 124 450 1860 • Email: consulting@analysysmason.com • **www.analysysmason.com/services/Consulting/**

Registered in England No. 5177472

## About ETTelecom

**ETTelecom.com**, a part of India's top business daily, The Economic Times, is a telecom intelligence media vertical focused on delivering news, information and data-driven tools to professionals in the industry to help them make smart decisions about the sector. Launched in October 2013, ETTelecom has grown into a one-stop destination for telecom professionals with its deepest and widest sectoral coverage spanning across countries. With a daily newsletter subscriber base of 2.5 lakh, it has 3 million monthly unique page views.

You can stay connected with ETTelecom by following it on Twitter **@ETTelecom**

# Contacts

**Rohan Dhamija**
Partner, Head – India (South Asia) & Middle East

rohan.dhamija@analysysmason.com
+91 85 275 93560

**Boston**
Tel: +1 202 331 3080
boston@analysysmason.com

**Cambridge**
Tel: +44 (0)1223 460600
cambridge@analysysmason.com

**Dubai**
Tel: +971 (0)4 446 7473
dubai@analysysmason.com

**Dublin**
Tel: +353 (0)1 602 4755
dublin@analysysmason.com

**Hong Kong**
Tel: +852 3669 7090
hongkong@analysysmason.com

**London**
Tel: +44 (0)20 7395 9000
london@analysysmason.com

**Madrid**
Tel: +34 91 399 5016
madrid@analysysmason.com

**Manchester**
Tel: +44 (0)161 877 7808
manchester@analysysmason.com

**Milan**
Tel: +39 02 76 31 88 34
milan@analysysmason.com

**New Delhi**
Tel: +91 124 4501860
newdelhi@analysysmason.com

**Oslo**
Tel: +47 920 49 000
oslo@analysysmason.com

**Paris**
Tel: +33 (0)1 72 71 96 96
paris@analysysmason.com

**Singapore**
Tel: +65 6493 6038
singapore@analysysmason.com

**Stockholm**
Tel: +46 709 211 719
stockholm@analysysmason.com

## Stay Connected

You can stay connected by following Analysys Mason on twitter, LinkedIn, YouTube or sign up to our RSS feed.

@AnalysysMason

linkedin.com/company/analysys-mason

youtube.com/AnalysysMason

analysysmason.com/RSS/