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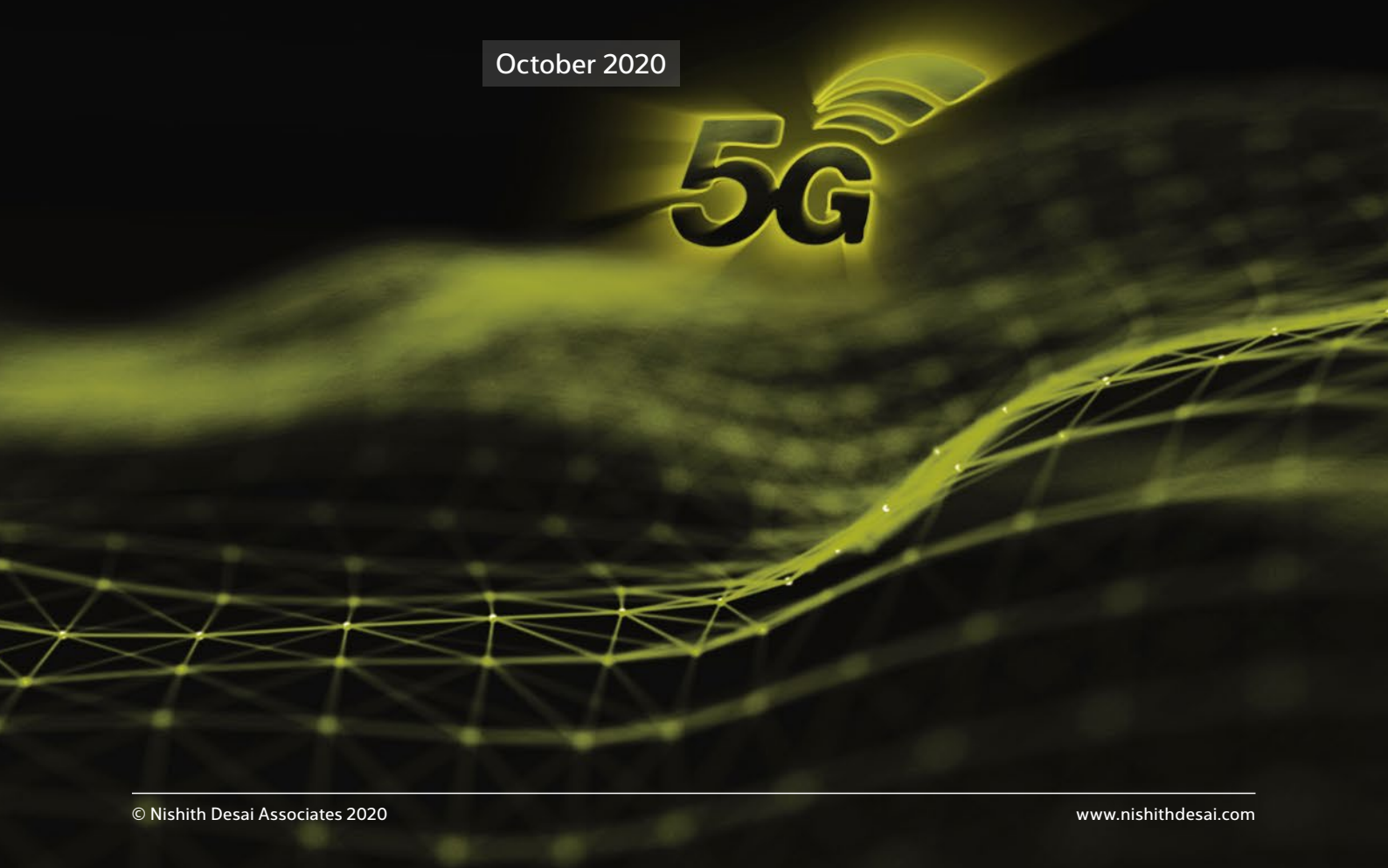
Research

5G Technology in India

Strategic, Legal and Regulatory Considerations

October 2020



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Contents

Summary

5G technology will usher in a much greater revolution than itself. At the base level, it will significantly increase the capacity and reach of existing mobile networks through greater data throughput and ultralow latency. But in a larger sense, 5G will become the backbone of many fourth industrial revolution (IR4) technologies like Artificial intelligence, augmented reality/virtual reality, drones, internet of things, telemedicine, and autonomous vehicles. Many kinds of devices, billions in number, will be connected to each other through 5G and offer the kind of capabilities and user experience never seen before. Our businesses and lives will change forever. And India is not staying behind in this revolution. In this paper, we provide a primer on 5G technology in non-technical terms, overview of extended 5G applications for various sectors, the regulatory landscape for 5G in India, and finally outline various important strategic, policy, regulatory, technical and behavioral considerations.

* Prepared by the 5G Practice Core Team of Nishith Desai Associates

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1. Introduction

The number of mobile users worldwide and their data needs have increased exponentially over the last two decades. In the same time period, we have seen tremendous improvements in mobile technologies. However, the existing mobile technologies are reaching their peaks. As more people and devices continue to join the network, the service quality and efficiency will drop drastically unless we move on to the new 5G technology.

With the promises of high data speed, ultralow latency, and billions of connections, 5G technology for mobile networks is gaining attention worldwide. The first 5G mobile networks are available to consumers in Australia, China, Ireland, Monaco, New Zealand, Norway, Philippines, Romania, and South Korea. Other countries such as Finland, Germany and Pakistan have already held auctions for 5G spectrum and are expected to build and deploy networks soon. More than 40 telecom operators worldwide have already launched 5G.[1]

5G is a highly scalable technology with high data throughput. Different types of 5G cells can support different types of deployment environments, such as homes, coffee shops, small office, aircrafts, shopping centers, airport terminals, transportation hubs, and large open areas. When deployed in its full form, it is expected to replace two discontinuous technologies, cellular mobile network and Wi-Fi, with one continuous technology for seamless user experience on all types of mobile and Internet of Things (**"IoT"**) devices. This convergence of cellular network with Wi-Fi will also provide a significant reduction in power usage, technology complexity and cost.

In India, the mobile telecommunications market has recently undergone a tectonic shift. The market has become highly competitive with the introduction of new players offering cheaper and better voice and data plans to consumers with better coverage. This has led to a price war affecting all mobile operators. Their profits have gone down and debts have gone up. This shift has also brought consolidation among the mobile service providers to align synergies and achieve economies of scale to better compete in the market.[2] In addition, in October 2019, the Supreme Court ruled against the incumbent mobile operators and asked them to reimburse US$13.9 billion in license fees, penalties and interest payments (Bharti Airtel about US$3 billion; Vodafone Idea about US$3.9 billion and Reliance Jio about US$1.8 billion) to government.[3] Recently, the Supreme Court has provided 10 years period to pay the pending licensee fee in equal yearly instalments.[4] These developments seem to be clouding the rollout of 5G in India.

However, the size of the telecom equipment sector is expected to grow to US$26.38 billion by 2020, bolstered in part by the growth of internet subscribers in the country to 829 million by 2021. The overall internet traffic could grow four-fold by 2021, at a 30% CAGR. The Mobile Value-Added Services (MVAS) industry is

1. Kapoor, Sanjay; Banerjee, Ayon (2020). "How 5G technology is critical to India's digital dream" *The Economic Times.* February 20, 2020. https://economictimes.indiatimes.com/tech/internet/how-5g-technology-is-critical-to-indias-digital-dream/articleshow/74232323.cms. Last Accessed: October 14, 2020.

2. Sengupta, Devina (2020). "DoT okays merger of Tata Tele consumer mobility business with Airtel." The Economic Times. February 7, 2020. https://economictimes.indiatimes.com/industry/telecom/telecom-news/dot-oks-merger-of-tata-tele-consumer-mobility-business-with-airtel/articleshow/73991445.cms. Last Accessed: October 14, 2020. and https://economictimes.indiatimes.com/industry/telecom/telecom-news/vodafone-idea-to-merge-aditya-birla-telecom/articleshow/65847075.cms?from=mdr

3. Sarkar, Soumeet; Chaturvedi, Arpan (2019). "Supreme Court Rules Against Telecom Operators in Rs 92,000-Crore AGR Dispute" *Bloomberg|Quint* October 24, 2019. https://www.bloombergquint.com/business/supreme-court-asks-telecom-operators-to-pay-rs-92000-crore-dues. Last Accessed: October 14, 2020.

4. Rajagopal, Krishnadas (2020). "Supreme Court directs telcos to pay AGR dues in 10 years" *The Hindu, September 1, 2020.* https://www.thehindu.com/news/national/supreme-court-directs-telcos-to-pay-agr-dues-in-10-years/article32493787.ece. Last accessed: October 14, 2020.

projected to grow to US$23.8 Billion by the end of 2020 at a CAGR of 18.3%.[5] In addition, the National Digital Communications Policy, 2018 envisages attracting investments worth US$100 billion in the telecommunications sector by 2022.[6] Such exponential growth potential entices mobile operators to jockey for a leadership position in the future 5G market in India.

5. Indian Brand Equity Foundation (2020). Sector Report – Telecommunications, February 2020. https://www.ibef.org/download/Telecommunications-February-2020.pdf. Last accessed: October 14, 2020.

6. National Digital Communications Policy, 2018. The Department of Telecommunications, India. https://dot.gov.in/sites/default/files/EnglishPolicy-NDCP.pdf. Last accessed: October 14, 2020.

2. 5G Technology

I. Evolution of Wireless Standards

The first generation of wireless communication technology were in introduced in 1979 and are referred to as 1G, until they were replaced by 2G technology later in 1991. 2G was digital, allowed for encrypted conversations, and introduced data services for mobile phones. In the interim, 2.5G was also introduced, which denoted networks that implemented packet-switched network capabilities in addition to circuit-switched capabilities.

The third generation of mobile network standards, known as 3G, was introduced in 1998. The 3G family of standards introduced much higher bandwidths for transfer of information and allowed for mobile broadband access to smartphones and laptops. 3G made several modern mobile phone features possible, such as faster internet browsing, video calling, mobile television. The current prevalent standard, 4G, was introduced in 2008 and allowed for much higher broadband speeds, internet protocol telephony, gaming, high-definition video and audio, video conferencing and cloud computing.[7] See Figure 1 for the evolution of wireless standards.

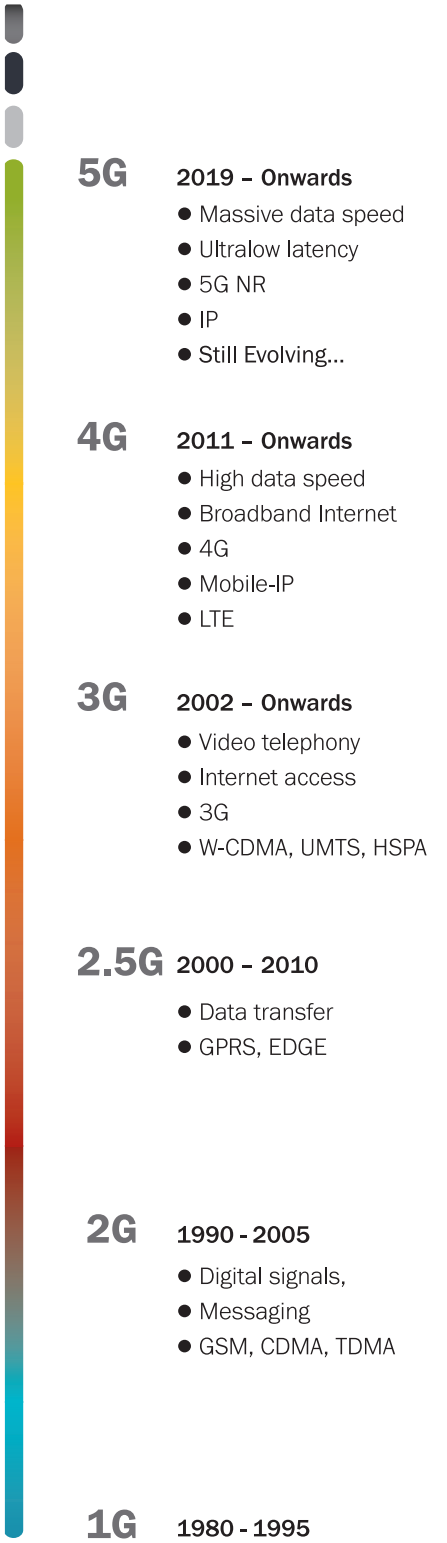

Figure 1: Evolution of wireless standards

7. Meraj ud in Mir, Mohammad; Sumar, Sumit (2015). "Evolution of Mobile Wireless Technology from 0G to 5G" *International Journal of Computer Science and Information Technologies*, 6(3) , 2015, 2545-2551. https://ijcsit.com/docs/Volume%206/vol6issue03/ijcsit20150603123.pdf. Last Accessed: October 14, 2020.

The current standard of mobile network technologies in the process of wide-scale deployment is 5G. With this latest iteration of standards, mobile internet speeds are expected to reach up to 10 Gbps along with significantly reduced latency, much higher capacity to support a huge number of devices, and increased bandwidth to transfer much larger amounts of data. As discussed further below, 5G is also expected make several novel and innovative applications possible, such as internet of things, drones, and autonomous vehicles to name a few.

II. 5G Frequency Spectrum

One of the significant differences between 5G and older generations of wireless networks is the frequency of electromagnetic spectrum utilized by the latest standard of wireless technologies. Data throughput in a mobile network is limited by the channel bandwidth (the difference between highest and lowest signal frequencies) available for the technology to use. On the frequency spectrum, narrower channel bandwidths are available at lower frequencies, whereas at higher frequencies, wider channel bandwidths are available. While digitization, multiplexing techniques and software-based data compression algorithms allow us to cram more data in the same channel bandwidth, at one point the laws of physics constrain any further improvements.

In order to provide a greater channel bandwidth, 5G is planned to operate in three different frequency ranges: Low-band, Mid-band, and Millimeter Wave (mmWave). Low-band 5G uses the same frequency range as 4G, which is typically below 3GHz. It offers slightly better data speed than 4G at up to 250 Mbit per second (**"Mbps"**). Mid-band 5G uses a frequency range up to 6 GHz, typically used by Wi-Fi, to provide a downlink speed of up to 1 Gbit per second (**"Gbps"**). Millimeter wave 5G uses a much higher frequency range between 24GHz and 300 GHz to provide high-speed data at a downlink speed of 2 Gbps, which can even go up to 20 Gbps.[8]

The 3GPP, an umbrella group of leading telecommunications standards development organization, has proposed 5G NR (New Radio) as a new global standard for air interface of 5G Networks. Under 5G NR, there are two frequency groups: FR1 (Frequency range <6 GHz), in the range of 3.3-4.2 GHz with maximum channel bandwidth of 100 MHz; and FR 2 (Frequency range > 24 GHz) in the range of 24 GHz to 300 GHz with minimum channel bandwidth of 50 MHz and maximum of 400 MHz. See Figure 2 for 5G Frequency Spectrum with respect to visible light and human audio range.

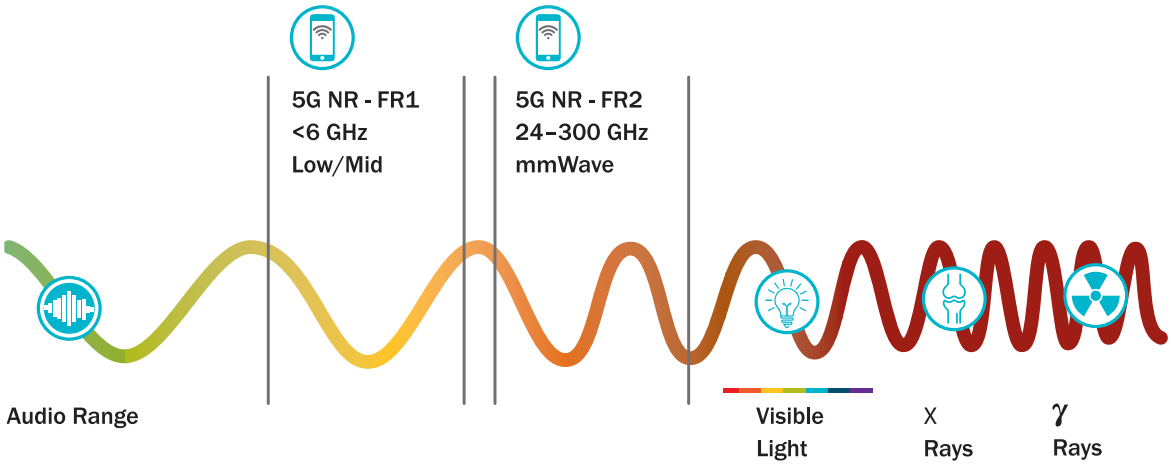

Figure 2: 5G Frequency Spectrum

8. Nordrum, Amy; Clark, Kristen (2017). "5G Bytes: Millimeter Waves Explained" *IEEE Spectrum*. https://spectrum.ieee.org/video/telecom/wireless/5g-bytes-millimeter-waves-explained. Last Accessed: October 14, 2020.

Since the low-band 5G can be built on the existing 4G infrastructure and mid-band and mmWave require new spectrum auctions, low-band 5G is expected to be rolled out few years earlier than 5G in the other two bands. However, the true potential of 5G will be realized when mmWave 5G is deployed. Many countries have reserved or started to free up millimeter wave spectrum for 5G. It would take several years before mmWave 5G would be deployed.

As mmWave 5G uses higher frequency, the signal travels to shorter distances. Since the coverage area is limited, many more cell towers will be required to build a seamless 5G network. However, cell tower antenna size will be much smaller, so less visible. Given the huge throughput capabilities, each cell will be able to support up to 10 times more connections (e.g. mobile phones, tablets and IoT devices) in the same areas compared to 4G. So, this 5G technology will be very useful in densely populated urban areas.

III. Open Radio Access Network

A Radio Access Network (**"RAN"**) connects wireless devices to other parts of the network through radio waves. A RAN comprises of a base station and antenna, which assists in providing radio access and in co-ordination of network resources across wireless devices.[9] When a device is wirelessly connected to the core telecom network, the RAN transmits its signal to various wireless endpoints, and the signal travels with another networks' traffic.

A base station may consist of a radio, an operating system, microprocessor, digital signal processor and host of utilities and application code. However, in case of 5G these parts don't need to exist inside a single base station unit and can be distributed across group of base stations including cloud.[10] Further, the traditional RAN requires significant upgrades to keep up with increasing demand for data.[11] Hence, creating an Open Radio Access Network also known as Open-RAN will lead in leveraging the cloud infrastructure by enabling service providers to adopt new solutions such as multi-vendor RAN solution to meet the increasing network demand due to adoption of 5G network.

The Telecom Infra Project (**"TIP"**) which was formed by Facebook in 2016[12] to support the development of disaggregated and interoperable 2G/3G/4G/5G RAN solutions[13] defines Open-RAN as: *"an initiative to define and build 2G, 3G, 4G and 5G RAN [Radio Access Network] solutions based on a general-purpose vendor-neutral hardware, open interface and software-defined technology."*[14]

9. SDxCentral Staff (2018). "What Is the Radio Access Network?", *SDXCENTRAL*, January 18, 2018, available here: https://www.sdxcentral.com/5g/definitions/radio-access-network/, Last Accessed: October 13, 2020.

10. Bennett, Richard (2020). "Opening up the 5G Radio Access Network", *HighTech Forum*, July 16, 2020 available here: https://hightechforum.org/opening-up-the-5g-radio-access-network/, Last Accessed: October 13, 2020.

11. Accenture Strategy (2019), "Open-RAM: The Next generation of Radio Access Networks", *Accenture*, 2019, available here: https://cdn.brandfolder.io/D8DI15S7/as/qcr9sa-6ckfrk-j253y/OpenRAN-The_Next_Generation_of_Radio_Access_Networks_-_Report.pdf, Last Accessed: October 13, 2020.

12. Parallel Wireless (2020), "Understanding the Different Open RAN Groups in the Telecom Industry", *Parallel Wireless*, August 3, 2020, available here: https://www.parallelwireless.com/understanding-the-different-open-ran-groups-in-the-telecoms-industry/, Last Accessed: October 13, 2020.

13. TIP, "OpenRAN", available here: https://telecominfraproject.com/openran/, Last Accessed: October 13, 2020.

14. *Ibid.*

Table 1:Traditional Ran And Open-Ran

Particulars	Traditional RAN	Open-RAN
Network Upgrade	Physical replacement of infrastructure required.	Network can be upgraded through simple update of the software.
Disaggregation of hardware and software	Hardware and software cannot be separated.	Open-RAN puts software at the center of the network and allows disaggregation of hardware and software. Thus, allowing separation of software from the underlying hardware.
Cost	RAN accounts for approximately 80% of total network costs.[15]	Open-RAN is expected to lower the cost associated with deployment and maintenance of networks since the entire network is virtualized over cloud.
Interoperability	Traditional RAN interface does not support interoperability between different vendors.	Open-RAN supports interoperability and can feature technologies from multiple vendors.

IV. Benefits Over Traditional RAN

Traditionally, telecommunication companies followed a hardware-driven approach of adding a layer to the network whenever a new technology emerged. This approach required substantial investment by the TSPs to upgrade their networks whenever any new technology emerged. Hence, it was not only financially burdensome for the TSPs to adopt new technologies, it also required TSPs to rely on exclusive vendors for its network infrastructure and equipment with less scope for adopting new, innovative and cheaper ways of deploying and managing networks.

Realising the restrictions of this approach, Open-RAN has emerged as a preferred technology amongst telecom operators. Unlike traditional RAN, Open-RAN decouples hardware and software; and it is quicker to deploy open networks as compared to traditional ones. This provides operators more flexibility to deploy and upgrade their specification. Further, the Open-RAN technology is cost efficient because it reduces operators' reliance on exclusive vendors and reduces the expenditure incurred on infrastructure.

Other benefits of adoption of Open-RAN is that in the event any new technology emerged, the telecom operators do not have to replace their infrastructure but undertake an easy software upgrade.[16]

Open-RAN will provide open interfaces which will enable multiple vendor deployment, allowing small vendors and operators to introduce their own services or to customize the network as per their own unique requirements. An open interface will also create less latency in the network, will provide higher availability qualities to support IoT services. In order for 5G to support an open, multi-vendor network with an enlarged supply chain, more innovation and greater competition, adoption of Open-RAN by the network providers should be encouraged.

V. O-RAN Alliance

The O-RAN ALLIANCE is a worldwide community of over 200 mobile operators, vendors, and research and academic institutions operating in the RAN industry. It was founded in February 2018 by AT&T, China Mobile, Deutsche Telekom, NTT DOCOMO and

15. Baburajan K (2020), "5G mobile operator strategies to cut their huge power cost", *Telecomlead*, April 3, 2020, available here: https://www.telecomlead.com/5g/5g-mobile-operator-strategies-to-cut-their-huge-power-cost-94645, Last Accessed: October 13, 2020.

16. Tele.Net (2020), "ORAN Promise: Industry explores the potential to build flexible networks", *Tele.Net*, July 2020, available here: https://tele.net.in/oran-promise-industry-explores-the-potential-to-build-flexible-networks/ , Last Accessed: October 13, 2020.

Orange.[17] O-RAN ALLIANCE seeks to: (i) re-shape the RAN industry by promoting open, virtualized, and fully interoperable mobile networks, and (ii) clearly define requirements for O-RAN. It also publishes new specifications, open software for the RAN and supports its members in integration and testing. O-RAN ALLIANCE specifications are based on 3GPP specifications.[18]

Apart from the founding members and various telecom operators such as SK Telecom, Telus Communications Inc., KDDI, Singtel, Vodafone, Verizon, Airtel, O-RAN ALLIANCE also include contributors such as Nokia, HCL, IBM, Qualcomm, Intel, Softbank, Samsung, Toshiba Verizon, Facebook, Ericsson, amongst others.[19] In December 2018, India's Reliance Jio also joined the O-RAN ALLIANCE board.[20]

VI. Telecom Infra Project ("TIP")

TIP has over 500 members including telecom operators, vendors, developers, service providers, start-ups[21] and seeks to promote strong partnership among the industry towards building next generation RAN,

Besides this, over 30 companies formed the Open RAN Policy Coalition to pressurize governments to establish measures for adoption of Open-RAN technology.[22] These members have also started forming partnerships among themselves to accelerate the adoption of Open-RAN. For example, TIP has collaborated with the O-RAN ALLIANCE to jointly develop interoperable 5G open RAN solutions[23]; the GSMA collaborated with the O-RAN ALLIANCE on opening up 5G networks.[24]

In October 2019, Rakuten successfully implemented the world's first open, virtualised and distributed Open-RAN in Japan.[25] In UK, Vodafone also started trials for the deployment of open RAN.[26] In India too, Vodafone Idea Limited has deployed Mavenir's Open RAN solutions for 4G.[27] Another Indian operator, Bharti Airtel recently deployed Altiostar's Open vRAN solution for 4G networks across multiple cities in India. This Open vRAN solution also has 5G ready software and would provide seamless upgradation to 5G network using the same architecture.[28]

17. O-RAN ALLIANCE, (2020) "Transforming Radio Access Networks Towards Open, Intelligent, Virtualised And Fully Interoperable Ran", *O-RAN ALLIANCE*, available here: https://www.o-ran.org/, Last Accessed: October 13, 2020.
18. Shenbagaraman, Ganesh (2020), "Who disaggregated my RAN", *RCR Wireless News*, June 1, 2020, available here: https://www.rcrwireless.com/20200601/open_ran/who-disaggregated-my-ran, Last Accessed: October 13, 2020.
19. O-RAN ALLIANCE, (2020) "Membership", *O-RAN ALLIANCE*, available here: https://www.o-ran.org/membership, Last Accessed: October 13, 2020.
20. Khan, Danish (2018), "Reliance Jio Joins O-RAN Alliance Board", *The Economic Times*, December 12, 2018, available here: https://telecom.economictimes.indiatimes.com/news/reliance-jio-joins-o-ran-alliance-board/67053871 , Last Accessed: October 13, 2020.
21. TIP, "Our Members", available here: https://telecominfraproject.com/members/ , Last Accessed: October 13, 2020.
22. Dyer, Keith (2020), "Lobby group formed to push Governments to drive Open RAN adoption", *The Mobile Network*, May 5, 2020, available here: https://the-mobile-network.com/2020/05/lobby-group-formed-to-push-governments-to-drive-open-ran-adoption/ , Last Accessed: October 13, 2020.
23. Sharma, Ray (2020), "O-RAN Alliance, TIP Team Up to Develop Interoperable Open RAN Solutions", *The Fast Mode*, March 2020, available here: https://www.thefastmode.com/technology-solutions/16523-o-ran-alliance-tip-team-up-to-develop-interoperable-open-ran-solutions , Last Accessed: October 13, 2020.
24. O-RAN ALLIANCE (2020), "GSMA and O-RAN ALLIANCE Collaborate on Opening up 5G Networks", *O-RAN ALLIANCE*, May 29, 2020, available here: https://www.o-ran.org/in-the-news/2020/5/29/gsma-and-o-ran-alliance-collaborate-on-opening-up-5g-networks , Last Accessed: October 13, 2020.
25. Business Wire (2020), "Rakuten Mobile and NEC Begin Production of Open RAN 5G Radio Equipment", *Business Wire*, March 23, 2020, available here: https://www.businesswire.com/news/home/20200323005749/en/Rakuten-Mobile-and-NEC-Begin-Production-of-Open-RAN-5G-Radio-Equipment , Last Accessed: October 13, 2020.
26. Fletcher, Bevin (2019), "Vodafone initiates first open RAN trials in the U.K., challenging traditional vendors", *Fierce Wireless*, October 7, 2019, available here: https://www.fiercewireless.com/tech/vodafone-initiates-first-open-ran-trials-uk-challenging-traditional-vendors , Last Accessed: October 13, 2020.
27. Business Wire (2020), "Vodafone Idea Deploys Mavenir OpenRAN Solution", *Business Wire*, April 23, 2020, available here: https://www.businesswire.com/news/home/20200423005364/en/Vodafone-Idea-Deploys-Mavenir-OpenRAN-Solution , Last Accessed: October 13, 2020.
28. Sharma, Ray (2020), "India's Bharti Airtel Deploys Altiostar's Open vRAN Solution", *The Fast Mode*, May, 2020, available here: https://www.thefastmode.com/technology-solutions/17014-indias-bharti-airtel-deploys-altiostars-open-vran-solution , Last Accessed: October 13, 2020.

VII. Associated Technologies

Despite the significant advantages offered by the frequency spectrum utilized by 5G, millimeter wave frequencies are affected by weather conditions and the geographic layout. They are absorbed by water vapor in the air, snow, rain and vegetation. They are also difficult to pass through walls, so it gives limited coverage inside buildings. To overcome these problems, new associated technologies are introduced. Beamforming is a technology that enables multiple bitstreams of data to use multiple antennas as phased arrays to reach each connected device optimally. Edge computing will enable basic computing of data closer to the user to reduce congestion in data traffic and latency. Small cells, which are low-powered radio access nodes, can be independently set up with a coverage area of up to several hundreds of meters to augment 5G networks. Multiple-input and multiple-output (**"MIMO"**) antennas have been used to multiply capacity of a mobile connection through multipath propagation. Massive MIMO antennas used in 5G will help focus energy on a connected device through multiple links and bring greater throughput and efficiency.[29]

In addition to mobile operator networks using 5G for public networks, 5G will also be deployed by many organizations for private networks for internal use. Under the 5G NR FR2, various types of cells can be used to support various types of deployments:[30] High power Metrocell can be used to cover urban areas to provide additional capacity to the regular 5G network coverage in the range of hundreds of meters. Medium power Microcell can be used fill the gaps in regular coverage. Low power Picocell can be used in public areas like airports, transport hubs, and shopping centers. Lowest power Femtocell can be used in confined spaces, like homes, coffee shops and small offices, to cover up to 32 users with a range of tens of meters.

VIII. Pros and Cons

Like any other technologies, 5G also has several pros and cons, see Figure 3.

29. Qualcomm (2019). "How 5G massive MIMO transforms your mobile experiences" Qualcomm Technologies OnQ Blog. June 20, 2019. https://www.qualcomm.com/news/onq/2019/06/20/how-5g-massive-mimo-transforms-your-mobile-experiences. Last Accessed: October 14, 2020.

30. "5G speed vs 5G range-What is the value of 5G speed,5G range". rfwireless-world.com. https://www.rfwireless-world.com/Terminology/5G-Speed-Vs-5G-Range.html. Last accessed October 14, 2020.

Figure 3: Pros and Cons of 5G

IX. 5G and Health Risks

Radiation from electromagnetic waves has the potential to affect human bodies at the cellular level. When significant in quantity, they could pose serious health risks. For over a century, we have been using electromagnetic waves for radio transmission. However, its use has been increasing every decade by many folds. We currently live in a world in which we are continuously surrounded by invisible electromagnetic radiation generated by human activities such as the use of Wi-Fi, radio, satellite television, etc.

Like all other wireless technologies, 5G also uses electromagnetic waves for transmission of data. It uses higher frequency waves in the millimeter wave range than those used by most widespread applications, such as citizen band (CB) radio, FM radio, on-air UHF and VHF television, microwave ovens, 4G mobile networks and Wi-Fi. Additionally, because of shorter signal reach, 5G antennas are also positioned at a shorter height from ground levels and much closer to people. So, it is natural for us to be concerned about health risks in 5G. Many cities have banned, canceled or delayed installation of 5G networks.[31]

Despite operating at a higher frequency, 5G fits into the non-ionizing radiation zone, unlike ultraviolet rays, x-rays and gamma rays, which fall in the ionizing radiation zone. The highest allocated frequency of 5G is 300 GHz, which is millions of magnitudes lower than ionizing radiation zone frequencies at higher than 3 PHz. 5G frequencies are even significantly lower than visible light. Among many other applications, including satellite transmissions, full body

31. Mims, Christopher (2019). "Cities Are Saying No to 5G, Citing Health, Aesthetics—and FCC Bullying" *The Wall Street Journal*. August 24, 2019. https://www.wsj.com/articles/cities-are-saying-no-to-5g-citing-health-aestheticsand-fcc-bullying-11566619391. Last Accessed: October 14, 2020.

scanners used at airports also operate in this frequency range of millimeter wave.

The International Commission on Non-Ionizing Radiation Protection has issued guidelines for devices operating in non-ionizing zones, including the Radiofrequency Electromagnetic Fields (**"RF EMF"**)[32] of 100kHz to 300 GHz, where 5G operates. Based on several decades of research, the Commission has concluded that *"RF EMF exposure below the thermal threshold is unlikely to be associated with adverse health effects."*[33]

An *IEEE Spectrum* article suggests that non-ionizing radiation is *"not the kind of radiation that could damage DNA and possibly cause cancer."* It further points out that since millimeter waves don't penetrate the body and *"reflect off the skin's surface,"* they are less likely to damage the skin.[34] IEEE Standards Association has also issued standards for the safety levels with respect to human exposure to radiation at up to 300 GHz frequency.[35] *IEEE Future Network* has also published guidelines for radiofrequency exposure limits for 5G.[36]

The World Health Organization (**"WHO"**) has also delved into possible health risks associated with 5G.[37] Previously in 2014, WHO had said that *"To date, no adverse health effects have been established as being caused by mobile phone use."*[38] It has put mobile at par with substances like coffee and pickles for possible carcinogenic impact. However, WHO continues to monitor health risks with evolving mobile technologies.

In the US, two laws directly deal with health risks posed by equipment using electromagnetic waves or having electromagnetic radiation: The Radiation Control for Health and Safety Act of 1968[39] and the Occupational Safety and Health Act of 1970.[40] In India, the Telecom Regulatory Authority of India (**"TRAI"**) released a paper on electromagnetic radiation from mobile towers reviewing various studies on its effect on human health and concluded that there seems to be no causality between electromagnetic radiation due to mobile phone towers and disease in human beings.[41] The Department of Telecommunications (**"DoT"**) also requires Telecom Service Providers (**"TSPs"**) to conduct a periodic audit as per procedure established by the Telecommunication Engineering Centre to ensure that emissions from mobile phone base stations for general public exposure conform to the set standards.[42]

32. ICNIRP (2020). "ICNIRP Guidelines for Limiting Exposure to Electromagnetic Fields (100 KHz to 300 GHz). *HEALTH PHYS* 118(5): 483–524; 2020. https://www.icnirp.org/cms/upload/publications/ICNIRPrfgdl2020.pdf. Last Accessed: October 14, 2020.

33. ICNIRP (2020). "RF EMFS" International Commission on Non-Ionizing Radiation Protection Website. https://www.icnirp.org/en/frequencies/radiofrequency/index.html. Last Accessed: October 14, 2020.

34. Pretz, Kathy (2019). "Will 5G Be Bad for Our Health?" *IEEE Spectrum.* November 12, 2019. https://spectrum.ieee.org/news-from-around-ieee/the-institute/ieee-member-news/will-5g-be-bad-for-our-health. Last Accessed: October 14, 2020.

35. IEEE SA (2019). "C95.1-2019 - IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz" IEEE Standards Association. October 4, 2019. https://standards.ieee.org/standard/C95_1-2019.html. Last Accessed: October 14, 2020.

36. Foster, Kenneth R.; Kodera, Sachiko; Hirata, Akimasa (2019). "5G Communications Systems and Radiofrequency Exposure Limits" *IEEE Future Networks Tech Focus*, Volume 3, Issue 2, September 2019. https://futurenetworks.ieee.org/tech-focus/september-2019/5g-communications-systems-and-radiofrequency-exposure-limits. Last Accessed: October 14, 2020.

37. The World Health Organization (2020). "5G mobile networks and health" WHO Newsroom Q&A. February 27, 2020. https://www.who.int/news-room/q-a-detail/5g-mobile-networks-and-health. Last Accessed: October 14, 2020.

38. The World Health Organization (2014). "Electromagnetic fields and public health: mobile phones" The WHO Newsroom Fact Sheet. October 8, 2014. https://www.who.int/news-room/fact-sheets/detail/electromagnetic-fields-and-public-health-mobile-phones. Last Accessed: October 14, 2020.

39. The Radiation Control for Health and Safety Act of 1968. Public Law 90-062. 82 Stat. 1173. https://www.govinfo.gov/content/pkg/STATUTE-82/pdf/STATUTE-82-Pg1173.pdf. Last Accessed: October 14, 2020.

40. The Occupational Safety and Health Act of 1970. Public Law 91-596. 84 Stat. 1590. http://www.gpo.gov/fdsys/pkg/STATUTE-84/pdf/STATUTE-84-Pg1590.pdf. Last Accessed. October 14, 2020.

41. Information Paper on Effects of Electromagnetic Field Radiation from Mobile Towers and Handsets, Telecom Regulatory Authority of India, July 30, 2014. https://www.trai.gov.in/sites/default/files/EMF_Information_Paper_30.07.2014.pdf. Last accessed: October 14, 2020.

42. License Agreement for Unified License, Chapter IV – Technical Conditions, Condition 24.1.

X. Standards-setting Agencies

A. Global

- International Telecommunications Union (**"ITU"**):
  - ITU Radiocommunication Sector (**"ITU-R"**): Coordinates standards related to the usage of radio-frequency spectrum internationally and satellite orbit resources.
  - ITU Telecommunications Standardization Sector (**"ITU-T"**): Coordinates standards for telecommunications and information communication
  - ITU Development (**"ITU-D"**): Coordinates equitable, sustainable and affordable access to information and communications technologies (**"ICT"**). Provides training programs on policy and regulation formation, and financial strategies for ICT deployment to developing countries.
- **3GPP** – Industry Standard Group: Unites seven telecom standards development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, and TTC).
  - **ARIB** – The Association of Radio Industries and Businesses, Japan
  - **ATIS** – The Alliance for Telecommunications Industry Solutions, USA
  - **CCSA** – China Communications Standards Association
  - **ETSI** – The European Telecommunications Standards Institute
  - **TSDSI** – Telecommunications Standards Development Society, India
  - **TTA** – Telecommunications Technology Association, Korea
  - **TTC** – Telecommunication Technology Committee, Japan

B. India

- Telecommunications Standards Development Society, India (**"TSDSI"** – https://tsdsi.in/): An autonomous, member-based standard development organization (SDO) supported by the DoT and Ministry of Electronics and Information Technology (MeitY) of the Government of India.
- Telecommunication Engineering Center (**"TEC"** - http://www.tec.gov.in/): The TEC is a body under the aegis of the DoT that is responsible for specifying common standards with regards to telecom network equipment, services and interoperability; issuing interface approvals and service approvals; formulating standards and fundamental technical plans; and providing technical support and advice to the DoT and TRAI.

3. Applications

The ITU-R has defined three key usages of 5G wireless network technology: Enhanced Mobile Broadband, Ultra Reliable Low Latency Communications, and Massive Machine Type Communications. In addition, as discussed further below, 5G also has sector-specific applications that enable the next generation of emerging technologies.

I. Enhanced Mobile Broadband ("EMBB")

eMBB extends the current 4G LTE mobile broadband services to the next level of higher bandwidth capacity. It also enhances connectivity and provides higher user mobility. Here, the data rate supported for downlink is up to 20 Gbit per second and uplink is up to 10 Gbit per second and latency is 4 ms.

II. Ultra Reliable Low Latency Communications ("URLLC")

With strict requirements for latency performance (1 ms) and reliability of the connections, it provides robust, uninterrupted data connections for mission critical applications in industry and governments, such as aircraft navigation system, nuclear reactor safety system, power grid operations, intelligent transport system, telemedicine, automated factories and warehouses, etc.

III. Massive Machine Type Communications ("MMTC")

mMTC supports a very large number of different types of devices, such as IoT devices and sensors, in a small area. The connection density can be 10 million devices per square kilometer.

IV. Sector-Specific Applications

The incredible speed and bandwidth afforded by 5G networks have a huge potential to enable several applications of upcoming technologies. A few of them are discussed in this section:

V. Internet of Things ("IoT")

IoT refers to a network that connects devices, instead of people. It has several applications – such as for farming, industrial automation, smart retail, supply chain management, construction management, and disaster management. 5G is uniquely positioned to address the challenges posed by IoT by providing higher bandwidth and faster speeds over wireless networks to allow a larger number of devices to coordinate and communicate at faster speeds.

VI. Artificial Intelligence ("AI")

5G technology will enable faster access to huge data pools, data collection sensors and computing powers to rapidly build AI models. Once initial AI models are built, they can be further refined through continuous usage and feedback loop. 5G will enable wider deployment of AI models and the feedback loop. It will also provide access to real-time contextual information, such as macro-economic, weather, socio-political events, etc., from various sources to further improve the models. AI models are also, in return in a different way, going to increase efficiency and improve management of 5G networks.

VII. Media and Entertainment

The media & entertainment market has witnessed a boom over the last few years. Internet streaming platforms have only grown in terms of number of subscribers and amount of content available for consumption as more

and more people cut the cord on their televisions. In addition, the quality of content available for consumption has also increased as consumers slowly move from high-definition media to ultra-high-definition media such as 4K resolutions. 5G networks will enable delivering such high bandwidth content to a growing number of mobile and home devices at greater speeds.

VIII. Telemedicine

Telemedicine is a fast-emerging area in healthcare. Telemedicine uses various technologies to remotely provide traditional healthcare services. It is a broad concept involving services such as tele-radiology, tele-consultation, tele-nursing, tele-ICU and tele-surgery. Huge data throughput combined with ultralow latency of 5G network will increase use of telemedicine and provide access to quality healthcare to people living in far away from expert healthcare service providers.

IX. Communications

Long distance communication started with telegraph in the 19th century and has since evolved into video calling as technology and capabilities have evolved over time. 4G was the first generation of networks that first made video calling truly possible. As more and more consumers adopt video calling as a preferred mode of communication, higher amounts of bandwidth intensive video will have to be delivered over networks to mobile devices. Businesses that allow remote work, which is becoming increasingly common, will also require better network capabilities to enable video conferencing services to allow employees to connect remotely. 5G networks are expected to make these applications smoother and easier to handle.

X. Gaming

Online multiplayer gaming requires high bandwidth and extremely low latency, which is made possible by 5G networks. Video games is a booming industry and is expected to grow in India as well, owing to the growing young population increasingly adopting the internet and smartphones. The newest technological trend in gaming involves processing the game data over the cloud and delivering the result to the users' device. In order to enable real-time delivery of the game data, higher speeds and lower latency is a prerequisite, which is made possible by 5G networks.

XI. Autonomous Vehicles

Autonomous vehicles generate and process a huge amount of data, owing to the multiple sensors that enable it. They also require a lot of bandwidth and lower latency in order to communicate and make quick decisions, that may be life saving for its passengers. 5G networks are best equipped to provide the sort of connectivity that is required to make autonomous vehicles a safe possibility.

XII. Smart Cities

Infrastructure needed for smart cities, like traffic sensors, disaster monitors, early warning systems, autonomous vehicles, delivery robots, drones, network sensors, public transport, public utility monitors, security systems, etc. also require dedicated connectivity to enable generating, carrying and analyzing the vast amounts of data generated by each of these. The distinct advantages offered by 5G are highly suitable for smart city applications.

4. Evolution of Telecommunications Policy in India

I. History

Telecommunications in India originated in the mid-19th Century with the introduction of the telegraph by the British. It was not until much later that a law governing telegraph communications was put in place – the Indian Telegraph Act, 1885. This was followed by the introduction of the Indian Wireless Telegraphy Act, 1933, which is intended to regulate the possession of the wireless telegraphy apparatus. These Acts provide an exclusive authority to the Central Government for establishing, maintaining, and working telegraphs, and wireless telegraphy equipment, and to grant licenses for such activities. Initially, telecom services were provided by the Indian Post & Telecommunication Department. Much later, in 1985, the Indian government separated DoT from Indian Post and Telecommunication Department and set up two public undertakings – the Mahanagar Telephone Nigam Limited (**"MTNL"**) to run the telecom services of metro cities, and Overseas Communication Services (OCS) was converted into Videsh Sanchar Nigam Limited (**"VSNL"**) or international long-distance operations. Until the early 1990s, the Government had completely monopoly in the telecom sector.

In 1994, the National Telecom Policy[43] (**"NTP 1994"**) was adopted with a view to achieving telecom growth and encouraging private investment to bridge the resource gap that the government could not provide for. NTP 1994 was the first step towards deregulation, liberalization and private sector participation in the telecom service sector.

Another crucial development made way for the growth of the telecom industry in India – the landmark judgment of the Supreme Court in *Ministry of Information and Broadcasting, Government of India v. Cricket Association of Bengal.*[44] Through this judgment, the Supreme Court ruled that electromagnetic spectrum is public property and accordingly, *"they have to be used in the best interest of the society and this can be done either by a central authority by establishing its own broadcasting network or regulating the grant of licenses to other agencies, including the private agencies."* This judgement opened a way for the privatization of telecom services and allowed private companies to offer telecom services in competition to government-owned public sector units. To regulate the activities of the private sector, an independent regulatory agency was required. In 1997, an autonomous statutory body – the TRAI – was set up under the Telecom Regulatory Authority of India Act, 1997 to act as an independent regulator of the telecom industry in India.

This landmark Supreme Court judgment and the setting up of TRAI was followed by the New Telecom Policy, 1999[45] (**"NTP 1999"**), which focused on creating an environment to attract investment in the telecommunications sector, making available affordable communication to everyone, and creating a modern and efficient telecommunications infrastructure. Later, a revised National Telecom Policy[46] was introduced in 2012 (**"NTP 2012"**) with the intention of developing robust telecom infrastructure to provide seamless coverage to rural and remote areas of India, proliferating high quality broadband, attracting foreign and domestic investment, and repositioning the mobile device as an instrument of socio-economic empowerment.

43. National Telecom Policy (1994). The Department of Telecommunications, India. https://dot.gov.in/national-telecom-policy-1994. Last accessed: October 14, 2020.

44. (1995) 2 SCC 251. https://mib.gov.in/document/supreme-court-judgement-airwaves. Last accessed: October 14, 2020.

45. New Telecom Policy (1999). The Department of Telecommunications, India. https://dot.gov.in/new-telecom-policy-1999. Last accessed: October 14, 2020.

46. National Telecom Policy (2012). The Department of Telecommunications, India. https://dot.gov.in/sites/default/files/NTP-06.06.2012-final_0.pdf. Last accessed: October 14, 2020.

II. National Digital Communications Policy, 2018

In 2018, a revised policy was released – the National Digital Communications Policy, 2018. The revised title of the policy itself signals a change in the government's approach towards thinking about communications. The objectives of the latest policy include identifying and making available new spectrum bands for timely deployment of 5G networks, creating a roadmap for emerging technologies and their use in communications, and enabling high-speed internet and internet of things by rolling out 5G networks.[47]

47. National Digital Communications Policy, 2018. The Department of Telecommunications, India. https://dot.gov.in/sites/default/files/EnglishPolicy-NDCP.pdf. Last accessed: October 14, 2020.

5. Regulatory Landscape

I. Key Regulations

A. Indian Telegraph Act, 1885

The Indian Telegraph Act, 1885 is one of the oldest legislations governing telecommunications still in effect in India. This law: a) empowers the Government of India to take control of the existing telegraph lines and lay down the necessary infrastructure for further expansion of telecommunications in India; b) authorizes the Government of India to grant telecom licenses to establish, maintain, work a telegraph within any part of India; and c) authorizes the Government of India to take possession of licensed telegraphs and to order interception of messages on the occurrence of any public emergency or in the interest of public safety.

B. The Indian Wireless Telegraphy Act, 1933

This Act was enacted to regulate the possession of wireless telegraphy apparatus. According to this Act, the possession of wireless telegraphy apparatus by any person can only be allowed in accordance with a license issued by the telecom authority. Further, the Act also levies penalties if any wireless telegraphy apparatus is held without a valid license.

C. Telecom Regulatory Authority Of India Act, 1997

The Telecom Regulatory Authority of India Act, 1997 (**"TRAI Act"**) enabled the establishment of the TRAI which is a co-regulator of the telecom sector in India. Initially, the TRAI Act empowered the TRAI with quasi-judicial authority to adjudicate upon and settle telecom disputes. Later this Act was amended by the Telecom Regulatory Authority of India (Amendment) Act, 2000 to bring in better clarity and distinction between the regulatory and recommendatory functions of TRAI. TRAI also issues a number of tariff and quality of service regulations applicable to provision of telecom services.

D. Unified License

In 2013, the DoT introduced the Unified License. The Unified License paved the way for the implementation of DoT's One Nation - One License plan by consolidating license terms for different telecom services under the ambit of one license, i.e. the Unified License. The Unified License replaces the old regime of a telecom operator applying for separate licenses for separate services proposed to be offered by bringing all the major telecom services under one license. The Unified License agreement provides for several conditions that the service provider must comply with, including general conditions applicable to the licensee, commercial conditions relating to tariff, license fees payable, and technical, operating and security conditions applicable to provision of telecom services.

E. Information Technology Act, 2000

The Information Technology Act, 2000 is applicable to information and communication technologies. While the law was not enacted to directly apply to the telecom industry, the information technology industry and telecom industry are closely linked and therefore in 2008, the Act was amended to include TSPs/Internet Service Providers (**"ISPs"**) and 'communication devices.' TSPs and ISPs are considered intermediaries under the law because they receive, store or transmit data 'on behalf of another person'.[48] In addition, security rules for protection of sensitive personal data or information also apply to TSPs and ISPs.[49]

48. Section 2(w), Information Technology Act, 2000.

49. Information Technology (Reasonable security practices and procedures and sensitive personal data or information) Rules, 2011

II. Regulatory Agencies

A. The Department of Telecommunications

As per the Allocation of Business Rules, 1961, the DoT exercises the powers of the licensing and regulatory authority for telecom in India.[50] Some of its important functions are: a) licensing and regulation; b) international cooperation in matters connected with telecommunications (such as International Telecommunication Union (ITU), International Telecommunication Satellite Organization (INTELSAT), etc; c) promotion of private investment in the Indian telecommunications sector; d) promotion of standardization, research and development in telecommunications.

B. The Telecom Regulatory Authority of India

TRAI acts as an independent regulator of the telecommunications industry in the country established under the TRAI Act. One of the main objectives of TRAI is to provide a fair and transparent policy environment to promote a level playing field and facilitate fair competition amongst various telecom players. TRAI's powers are recommendatory, mandatory, regulatory and judicial. The important recommendatory powers of TRAI include: a) the need and timing for introduction of new service providers; b) grant of telecom licenses including their terms and conditions; c) revocation of license for non-compliance of terms and conditions of license. The recommendatory powers of TRAI must be viewed in light of the policy making powers of DoT. While the DoT is the sole authority for licensing of all telecommunications services in India, it is mandatory for the DoT to seek TRAI's recommendations before making decisions with respect to the matters over which TRAI has recommendatory jurisdiction. Once it has received TRAI's recommendations, the DoT may either accept or reject the recommendations.[51] TRAI is also the sole authority to a) fix tariffs for telecommunication services; b) setting out terms of interconnection between telecom providers and standards of quality of service for TSPs. It has been proposed that TRAI's name will be changed to Digital Communications Regulatory Authority of India but the same has not been implemented yet.[52]

C. Ministry of Electronics & Information Technology ("MEITY")

MEITY is responsible for "policy matters relating to information technology; Electronics; and Internet (all matters other than licensing of Internet Service Provider)", "administration of the Information Technology Act, 2000 and other IT related laws", and the "Unique Identification Authority of India".[53] Some matters, including privacy, relating to applications over the internet fall within the bounds of MEITY's jurisdiction. On the other hand, DoT imposes privacy obligations on TSPs through the Unified License.

III. Spectrum Allocation

Spectrum is allocated in India based on the National Frequency Allocation Plan,[54] which itself is based on the international frequency table issued by the International Telecommunications Union. A wing of the DoT, the Standing Advisory Committee on Frequency Allocation (**"SACFA"**), gives approval for radio frequency (spectrum) used by TSPs. In addition to obtaining a telecom

50. Government of India (Allocation of Business) Rules, 1961. As Amended up to 31st January 2017. https://cabsec.gov.in/writereaddata/allocationbusinessrule/completeaobrules/english/1_Upload_1187.pdf, Last Accessed: October 14, 2020.

51. This stipulation was brought about by an amendment to the TRAI Act in 2000.

52. Available here https://telecom.economictimes.indiatimes.com/news/trai-to-be-renamed-as-digital-communications-regulatory-authority-of-india-manoj-sinha/65971515. Last Accessed: October 14, 2020.

53. Government of India (Allocation of Business) Rules, 1961.

54. NFAP (2018). "National Frequency Allocation Plan – 2018." *The Department of Telecommunications, The Government of India.* https://dot.gov.in/sites/default/files/NFAP%202018.pdf. Last Accessed: October 14, 2020.

license, a no objection certification from SACFA is required to begin rolling out services. The certificate is granted on the basis of a detailed technical evaluation including field studies to determine possible aviation hazards and interference (Electro Magnetic Interference (**"EMI"**)/Electro Magnetic Compatibility (**"EMC"**)) to existing and proposed networks.

The government is bound to ensure that its spectrum licensing decisions are rational, transparent, and free from arbitrariness. The courts have time and again upheld this principle of transparency. In the case of *Delhi Science Forum v. Union of India*[55], the Supreme Court held that the privatization policy adopted by the government is a necessary consequence of liberalization and that the procedures adopted for such grant should be "reasonable, rational and in conformity with the conditions which have been announced."

The *Supreme Court of India in the case of Centre for Public Interest Litigation and Ors. Vs. Union of India*[56] held that electromagnetic spectrum is a natural resource that belongs to the public at large. The government's first-come-first-served policy of allocating spectrum was heavily criticized by the Court, which held that a public auction is the best way of licensing public property. Consequently, the Supreme Court delivered an order against thirteen respondents holding that such respondents had been favored by the government and had been illegally granted telecom licenses. The Supreme Court ordered the cancellation of 122 telecom licenses granted in various service areas for the 2G spectrum and imposed financial penalties ranging from INR 5 Million (approximately US$65,000) to INR 50 Million (approximately US$650,000) on the grounds that the TSPs had benefited at the cost of the public exchequer because of a wholly arbitrary and unconstitutional decision taken by the DoT for grant of licenses and spectrum. Going forward, spectrum could only be allocated through a public auction.[57]

In order to ensure optimal deployment of 5G, adequate spectrum availability is imperative. The DoT had constituted a High Level Forum (**"HLF"**) in 2017 to make recommendations to steer India towards deployment of 5G networks.[58] The HLF recognized two crucial issues with spectrum allocation in India: (a) the limited licensed mobile spectrum available in India, i.e. 220 Mhz, compared to other countries; and (b) the cost of spectrum, relative to per capita GDP, which is much higher than other countries.[59] The HLF recommended that 5G spectrum be released in three tiers:

1. 8-803 MHz, 3300-3600 MHz, 24.25-27.5 GHz, and 27.5 – 29.5 GHz) are recommended to be declared as available for 5G networks in order to provide certainty to the ecosystem
2. Identify Tier – certain bands (617-698 MHz, 1427-1518 MHz, 29.5 to 31.3 GHz and 37.0 to 43.5 GHz) are recommended to be designated for potential 5G use, which may be announced after consultation with other domestic users.
3. Study Tier – certain bands (3600-3700 MHz) are recommended to be designated for exploratory studies for 5G use.

In India, 5G spectrum allocation is tentatively scheduled for in mid-2020. According to reports, 8,293.95 Mhz of 4G and 5G spectrum is due for auction, which may cost telecom companies approximately INR 5860 billion (about US$78 billion) if all the spectrum is sold at base price.[60]

55. 1996 AIR 1356.
56. (2012) 3 SCC 1
57. (2012) 3 SCC 1
58. (7)Constitution of High Level Forum for 5G India 2020, Department of Telecommunications, No. 6-33/2017 – IC. https://dot.gov.in/sites/default/files/Details%20of%20HLF%20for%205G%20India%202020_1.pdf. Last Accessed: October 14, 2020.
59. (8)Report of the High Level Forum on 5G, p. 27, https://dot.gov.in/sites/default/files/5G%20Steering%20Committee%20report%20v%2026_0.pdf. Last Accessed: October 14, 2020.
60. Next Spectrum Auction Likely in April-June 2020, Economic Times, December 4, 2019. https://economictimes.indiatimes.com/industry/telecom/telecom-news/next-spectrum-auction-likely-in-april-june-2020/articleshow/72357947.cms. Last accessed: October 14, 2020.

IV. Plans For 5G

A. Trai White Paper – 'Enabling 5G in India'

In February 2019, TRAI released a report[61] outlining the necessities and challenges for deploying 5G and where India currently stands on each of them, respectively. The report touched upon the architecture of 5G networks and tracked the spectrum and backhaul requirements for 5G, regulatory challenges and issues relevant to successful deployment of 5G networks, and scope for investment in 5G networks and its applications.

B. 5G High Level Forum Report – "Making India 5G Ready"

In 2017, the Central Government set up a HLF to recommend policy initiatives and action plans towards the ends of rolling out early, efficient and pervasive 5G networks; expanding the manufacturing base for semiconductor assembly and testing plants; and promoting industry and research into 5G technologies. The Forum published their report with suggestions for spectrum policy, regulatory policy, 'applications and use cases labs', developing application layer standards, and evaluating any applicable international standards.[62]

C. 5G Hackathon

The Government of India is also trying to provide a boost to research and development of technologies leveraging 5G networks. Most recently, the DoT organized a 5G Hackathon *"to identify & scale ideas, relevant to India, in the 5G realm, that will be developed into workable products and services"*.[63] The competition has identified a number of crucial categories to demonstrate the use of 5G technology, such as: a) healthcare, education and governance; b) environment, public safety and disaster management; c) smart cities and infrastructure; d) logistics and transportation; e) cyber security; f) multimedia and broadcast; g) AgriTech and livestock.[64]

C. TSDSI's 5g Radio Interface Technology

ITU-R has set certain international standard and specifications for 5G networks known as International Mobile Telecommunications - 2020 (**"IMT 2020"**). These standards are set to be finalized in 2020. Some of the key features of IMT 2020 are[65]:

- compatibility of services within IMT and with fixed networks;
- capability of interworking with other radio access systems;
- high quality mobile services;
- user equipment suitable for worldwide use;
- enhanced peak data rates to support advanced services and applications:
- Initially peak data rates of 100 Mb/s for high and 1 Gb/s for low mobility
- Downlink peak data rate of 20 Gb/s;
- Uplink peak data rate of 10 Gb/s;
- Target downlink "user experienced data rate" of 100 Mb/s;
- Target uplink "user experienced data rate" of 50 Mb/s

In 2017, India's TSDSI had proposed adoption of Low Mobility Large Cell (**"LMLC"**) as mandatory 5G requirement, which was also adopted by ITU-R IMT 2020 Technical

61. Enabling 5G in India, Telecom Regulatory Authority of India, February 2019, https://trai.gov.in/sites/default/files/White_Paper_22022019_0.pdf. Last accessed: October 14, 2020.
62. 5G High Level Forum (2019). "Making India 5G Ready" Report of the 5G High Level Forum. https://dot.gov.in/sites/default/files/5G%20Steering%20Committee%20report%20v%2026_0.pdf. Last Accessed: October 14, 2020.
63. 5G Hackathon Objectives. https://www.5ghackathon.in/. Last accessed: October 14, 2020.
64. 5G Hackathon Categories. https://www.5ghackathon.in/. Last accessed: October 14, 2020.
65. ITU (2020). ITU-R FAQ on International Mobile Telecommunications (IMT). Updated 27 April 2020. https://www.itu.int/en/ITU-R/Documents/ITU-R-FAQ-IMT.pdf. Last accessed: October 14, 2020.

Performance Requirements as a mandatory test configuration under the Rural eMBB test environment.[66] LMLC fulfills the requirements of affordable connectivity in rural, remote and sparsely populated areas.

In 2019, at the ITU-R working party meeting i.e. ITU-R WP 5D, TSDSI had also submitted its specifications and standards "IMT-2020 Radio Interface Technology (**"RIT"**)". TDSI's RIT incorporates India-specific technology enhancements that can enable larger coverage for meeting the LMLC requirements.[67]

Currently, RIT has completed the 7th step of the 8-step process of ITU-R WP5D. Further, the specification of the TSDSI technology has been added in the draft IMT-2020 specification document, which is being undertaken and is expected to be finished in the meetings of ITU-R WP5D to be convened in October and November 2020.[68]

TSDSI RTI is an adaptable radio interface wherein all the technical requisites of IMT 2020 are fulfilled over the varied test environments. The main focus of this is to connect next generation devices and provide services across various sectors. The key focus of TSDSI's RIT is on following:-

- Enhanced spectral efficiency and broadband access;
- Low latency communication;
- Support millions of IOT devices;
- Power efficiency;
- High speed connectivity;
- Large Coverage (in particular for Rural areas);
- Support multiple frequency bands including mmWave spectrum[69]

However, as per news report,[70] the TSPs in India are likely to approach the DoT to seek its intervention on adoption of India specific 5G standards. As per the TSPs, India should align its standards and adopt the global 5G network standard approved by the ITU. In case global standards are not adopted, it may lead to interoperability issues between network and devices.

However, the TSDSI Chairman Prof. Bhaskar Ramamurthi has contended that both the Indian and ITU standards have similar costs and have the ability to interoperate in networks across the world. He further slammed the rural connectivity contention of the telcos and argued that while ITU compliance would render 60% rural coverage, the proposed Indian standards would cover 95% rural areas.[71]

The adoption of global standards is more in line with the interest of TSPs and consumers both as it would lead to leveraging the global 5G expanse. It would also provide convenience to overseas Indian users and foreigners. Further, adopting the Indian standards would be strenuous and financially cumbersome for the TSPs.

66. Weissberger, Alan (2019), India's TSDSI candidate IMT 2020 RIT with Low Mobility Large Cell (LMLC) for rural coverage of 5G services. 5 July 2019. https://techblog.comsoc.org/2019/07/05/indias-tsdsi-candidate-imt-2020-rit-with-low-mobility-large-cell-lmlc-for-rural-coverage-of-5g-services/. Last accessed: October 14, 2020.
67. Weissberger, Alan (200), TSDSI's 5G Radio Interface spec advances to final step of IMT-2020. SPECS standard. 28 July 2020. https://techblog.comsoc.org/2020/07/28/tsdsis-5g-radio-interface-spec-advances-to-final-step-of-imt-2020-specs-standard/. Last accessed: October 14, 2020.
68. TSDSI (2020). TSDSI's 5th Generation Radio Interface technology reaches final step to be notified as an IMT2020 standard by ITU, 23 July 2020. https://tsdsi.in/tsdsis-5th-generation-radio-interface-technology-reaches-final-step-to-be-notified-as-an-imt2020-standard-by-itu/. Last accessed: October 14, 2020.
69. Weissberger, Alan (200), TSDSI's 5G Radio Interface spec advances to final step of IMT-2020.SPECS standard. 28 July 2020. https://techblog.comsoc.org/2020/07/28/tsdsis-5g-radio-interface-spec-advances-to-final-step-of-imt-2020-specs-standard/. Last accessed: October 14, 2020.
70. Parbat, Kalyan (2020). Telcos to move DoT to stop adoption of India-specific 5G standards, else costs will jump. 16 September 2020. https://telecom.economictimes.indiatimes.com/news/telcos-to-move-dot-to-stop-adoption-of-india-specific-5g-standards-else-costs-will-jump/78126187. Last accessed: October 14, 2020.
71. MoneyControl (2020). Telcos to approach DoT against India-specific 5G standards citing cost concerns: Report. 16 September 2020. https://www.moneycontrol.com/news/business/companies/telcos-to-approach-dot-against-india-specific-5g-standards-citing-cost-concerns-report-5845651.html. Last accessed: October 14, 2020.

6. Key Considerations

5G is going to revolutionize not just the mobile telecommunications sector but also how we use technology in our businesses and lives. The implications are far reaching. In this section, we will review some key strategic, policy, regulatory, technical and behavioral issues (Figure 4) that need to be considered as we move to implement 5G.

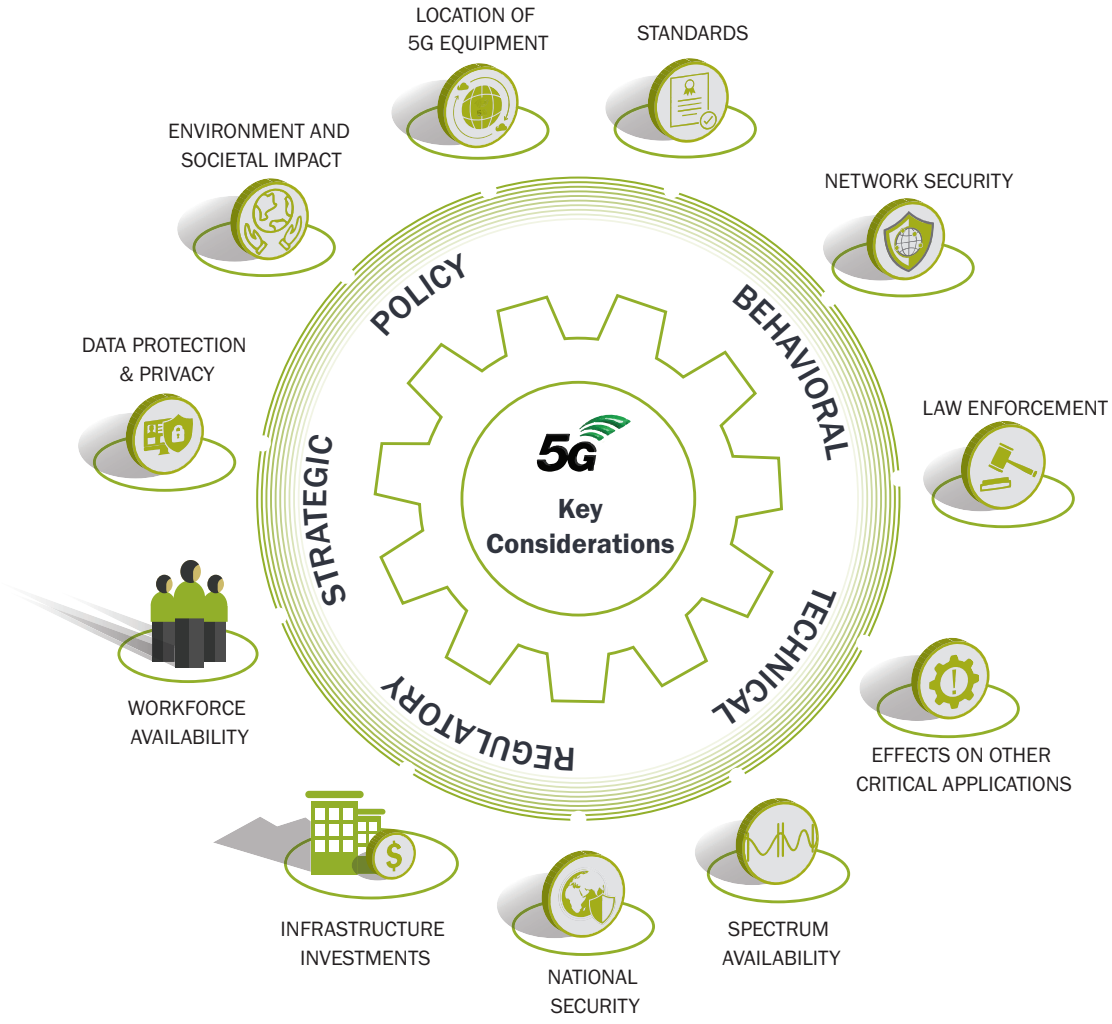

Figure 4: Key Considerations

I. Standards

5G technology is not based on one set of standards. Various views exist on 5G standards in different countries and with different equipment makers.[72] Traditional mobile infrastructure technology providers, such as Ericsson, Nokia, Samsung and Qualcomm, each have their own sets of standards. Newer providers, such as Huawei and ZTE, offer entirely new integrated, end-to-end systems with different sets of standards. In a contrast to these hardware switch-based standards, Japanese company Rakuten has developed a new virtualized, cloud-native mobile network.[73]

The legacy mobile networks in most countries are based on technology and equipment provided by the US and European companies, such as Ericsson, Nokia, and Qualcomm. Their 5G technology is likely to be built on standards providing incremental upgrade from 4G. This will reduce the costs but also delay achieving the full potential of 5G networks.

Some countries where the mobile infrastructure is still growing are more likely to leapfrog to 5G technologies. The company that is first to rollout 5G installations in various countries will be able to control the *de facto* standards and create lasting dominance.[74]

II. Spectrum Availability

With the explosive growth of frequency usage in various wireless applications have put huge pressure on spectrum availability. Frequency spectrum being a constrained resource, telecom authorities worldwide are continuously trying to maximally utilize allocated frequency bands and repurpose under-used or inefficient frequency bands used by older technologies to emerging technologies.

The DoT has specified a range of 300 MHz in the mid-band of 3.3-3.6 GHz for 5G.[75] This will enable a start of 5G network. However, to receive the real benefits of 5G technology, the government has to free up frequency in millimeter wave range of greater than 24 GHz.

In most countries with private mobile operators, telecom authorities undertake the auction process to license the use of a specific band of frequency within the allocated frequency to a mobile operator to build its network. These auctions fetch millions of dollars. For example, a base price of one MHz fetches US$26 million in Italy, US$18 million in South Korea, US$10 million in the US and US$5 million in Australia.[76] Also, given the huge capital cost requirement for being a mobile operator most countries have only few mobile operators capable of participating in the auction process. This increases the risk of collusion and reduction in the income from the action.

In India, the DoT conducts such auctions. The TRAI has recommended a base price of Rs.492 Crore (about US$66 million) per MHz. A band of 100 MHz required to operate 5G network would cost US$6.6 billion in just licensing the frequency. Some leading mobile operators have protested the pricing and asking the government to delay the auction by three to four years to recover from the recent competitive war.[77] This can delay or slow down the rollout of 5G in India.

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72. 5GPPP (2019). "View on 5G Architecture" 5G PPP Architecture Working Group Report. European Union. June 2019. https://5g-ppp.eu/wp-content/uploads/2019/07/5G-PPP-5G-Architecture-White-Paper_v3.0_PublicConsultation.pdf. Last Accessed: October 14, 2020.
73. Hardesty, Linda (2019). "Rakuten builds a greenfield wireless network in Japan" *FierceWireless*. February 14, 2019. https://www.fiercewireless.com/wireless/rakuten-builds-a-green-field-wireless-network-japan. Last Accessed: October 14, 2020.
74. Duesterberg, Thomas (2019). "Problems and Prospects for 5G Deployment in the United States." *Forbes*. April 30, 2019. https://www.forbes.com/sites/thomasduesterberg/2019/04/30/problems-and-prospects-for-5g-deployment-in-the-united-states/#589bd75d312e. Last Accessed: October 14, 2020.
75. Kapoor, Sanjay; Banerjee, Ayon (2020). "How 5G technology is critical to India's digital dream" *The Economic Times*. February 20, 2020. https://economictimes.indiatimes.com/tech/internet/how-5g-technology-is-critical-to-indias-digital-dream/article-show/74232323.cms. Last Accessed: October 14, 2020.
76. Kaushik, Manu (2019). "Why telecom ministry rejected demand to cut 5G spectrum prices." Business Today. November 27, 2019. https://www.businesstoday.in/sectors/telecom/why-telecom-ministry-rejected-demand-to-cut-5g-spectrum-prices/story/391156.html. Last Accessed: October 14, 2020.
77. Kumar, Rohit (2020). "Indian telecom players protest push for pricey 5G spectrum auction" *Nikkei Asian Review*. February 20, 2020. https://asia.nikkei.com/Spotlight/5G-networks/Indian-telecom-players-protest-push-for-pricey-5G-spectrum-auction. Last Accessed: October 14, 2020.

While there is growing commercial demands for spectrum allocation for mobile wireless networks, spectrum allocation also needs to be effectively managed to protect other usages, including those by defense organizations, government services, first responders, local police force, and scientific community.

III. Infrastructure Investments

Transitioning from 4G to 5G will involve two major costs: 1) purchasing license for new frequencies, 2) building new 5G infrastructure. The overall costs are expected to be in trillions of dollars worldwide.[78] Given the huge up-front costs, governments and mobile operators together have to develop various investment strategies and identify various funding sources for long-term investments, including private equity, sovereign funds, and infrastructure investment funds.

Fortunately, 5G enables much greater device density or significantly more connections within a coverage area. As indicated by Randall Stephenson, the CEO of AT&T, at CEO Speaker Series of Council on Foreign Relations, "*4G networks, in a square mile you can connect thousands of devices. 5G, millions of devices per square mile, much lower power, much lower compute requirement.*"[79] So, these costs will be divided among much greater number of users and devices.

In India, like in most large economies, with the exception of China, the mobile network is built and operated by private companies. According to UBS, the cost for mobile operators to rollout 5G in India would be as high as US$30.5 billion.[80]

Another issue for India is that a large population of India lives in rural areas. Also, the population in rural India is dispersed across family farms. Because of the shorter reach of high frequency 5G signals, mobile operators would have to do many more installations for the same population coverage compared that in urban areas. Given that the affordability of rural India is significantly lower, the operators would be less inclined to rollout 5G in rural areas, unless the government provides incentives, such as grants or lower-rate loans. One alternative for the government is to allocate a portion of income generated from spectrum auctions to fund installations in rural, lower density areas.

IV. Workforce Availability

Successful and speedy rollout of 5G will depend on the availability of qualified workforce to install new access points and build up the 5G network. Previous generations of mobile network used large towers which provided coverage for many kilometers around a tower. 5G is based on technology with much smaller coverage, requiring setting up smaller bases. Millions of small cells will be required to be set up.[81] In some cases, even retrofitting streetlights and traffic signals. They will require skills in small cell antenna installation, 5G equipment specifications, 5G construction best practices, 5G infrastructure design, distributed antenna systems, fiber optic backhaul installations, etc.[82]

Several mobile industry leaders have suggested that the Indian workforce is not ready for

78. Kharif, Olga and Moritz, Scott (2017) "Upgrade to 5G Costs US$200 Billion a Year, May Not Be Worth It" *Bloomberg*. December 18, 2017. https://www.bloomberg.com/news/articles/2017-12-18/upgrade-to-5g-costs-200-billion-a-year-and-may-not-be-worth-it. Last Accessed: October 14, 2020. And. Gopalaiah, Satish (2020). "Why 5G is seen as a game-changer for India." *Business Today*. January 29, 2020. https://www.businesstoday.in/opinion/columns/why-5g-is-seen-as-a-game-changer-for-india/story/394896.html. Last Accessed: October 14, 2020.

79. Council on Foreign Relations (2019). "CEO Speaker Series with Randall Stephenson." September 18, 2019. https://www.cfr.org/event/ceo-speaker-series-randall-stephenson. Last Accessed: October 14, 2020.

80. BusinessLine (2019). " 5G in India will need investment of US$30 bn from telcos: UBS

81. Dano, Mike (2019). "Technicians to Actually Install 5G in Short Supply." *Light Reading*. May 28, 2019. https://www.lightreading.com/employment/technicians-to-actually-install-5g-in-short-supply/d/d-id/751711. Last Accessed: October 14, 2020.

82. Maurer, Roy (2020). "The 5G Workforce Needs a Big Boost" *SHRM*. January 28, 2020. https://www.shrm.org/resourcesandtools/hr-topics/talent-acquisition/pages/5g-workforce-labor-shortage.aspx. Last Accessed: October 14, 2020.

5G.[83] 5G technology has many new, radically designed technologies. Indian workforce will need to be trained for the new architectural and installation requirements for 5G. While India has a large IT workforce, the workforce is not sufficiently trained for security sensitivities in network infrastructure.

The industry, academic institutions and governments will have to come together to develop a large workforce in a short time. They will have to prepare specific curriculum to develop practical skills, bring industry experts and master operators to train people, create awareness about career opportunities in 5G to attract people, offer financial aids to support training, and provide attractive compensation to retain skilled workers.

V. Location of 5G Equipment

5G technology, specifically millimeter Wave technology, uses high frequency in the range of 24 GHz to 300 GHz. At this frequency, 5G requires a greater number of access point installations due to shorter coverage reach than those required by the previous 4G technology to cover the same area. This not only increases the installation costs but also involves approvals from local authorities requiring varying timeline for the deployment.[84]

In the US, the *STREAMLINE Small Cell Deployment Act (S. 1699)* was introduced in June 2019 to streamline the process required for the approval for small cell deployment. It aims to amend Section 332(c) of the Communications Act of 1934[85] to curtail the involvement of local zoning authority and speed up 5G installation process. National League of the Cities and National Association of Counties have opposed this bill, arguing that it: complicates existing efforts to deploy small cell infrastructure; transfers public property to private companies with no public obligation; imposes unfair and inappropriate timelines on local governments, restricts fees the local authorities can charge to process installation requests, and creates a new unfounded mandate on local governments.[86]

In India, this issue is going to be even more critical given many more new towers will be required for small cell operations. Telecom companies in India have to install mobile towers, especially in cities, on private properties in densely populated areas. In 3G and 4G installations, they had found it difficult to install towers near schools, residential areas and hospitals due to opposition by local residents. While state governments have issued guidelines for the installations, local municipal bodies do not issue or significantly delay permissions.[87] The DoT at the Central Government level has been creating awareness regarding the key fear factor of EMF radiation through online portal, articles, and seminars to reduce opposition.[88]

VI. National Security

National security has come on the forefront in the deployment of 5G infrastructure. 5G is expected to provide the backbone to most government,

83. ET Telecom (2019). "ETTelecom 5G Congress 2019: 5G-ready infrastructure, low cost devices, advanced apps, robust workforce critical for 5G adoption" *The Economic Times Telecom.* August 2, 2019. https://telecom.economictimes.indiatimes.com/news/5g-congress-5g-ready-infrastructure-low-cost-devices-advanced-apps-robust-workforce-critical-for-5g-adoption/70481706. Last Accessed: October 14, 2020. And Ashwin, Anusha (2018). "5G will require upskilling and reskilling of existing workforce: Sriram T.V., Juniper Networks" *Voice & Data.* December 10, 2018. https://www.voicendata.com/job-opportunities-5g-will-require-upskilling-reskilling-existing-workforce-sriram-t-v-juniper-networks/. Last Accessed: October 14, 2020.

84. Fisher, Tim (2020). "5G Challenges: Why It Isn't Rolling Out Faster." *Lifewire.* https://www.lifewire.com/5g-challenges-4580354. Last Accessed: October 14, 2020.

85. 47 U.S.C. 332(c).

86. National League of Cities. https://nlc.quorum.us/campaign/22944/ and https://www.cacities.org/CMSPages/GetFile.aspx?nodeguid=a78c750e-2bad-4c0b-9b30-521296c01cc7&lang=en-US. Last Accessed: April 25, 2020. National Association of Counties. https://www.naco.org/articles/senators-why-rush-5g-while-rural-areas-ignored. Last accessed: October 14, 2020.

87. Shrinivasa, M (2018). "Citizens don't want telecom towers in residential areas." *The Economic Times.* April 16, 2018. http://timesofindia.indiatimes.com/articleshow/63778224.cms. Last Accessed: October 14, 2020.

88. PTI (2018). "Telecom Minister blames people obstructing mobile tower installation for call drops." *The Economic Times,* September 27, 2018. https://economictimes.indiatimes.com/industry/telecom/telecom-news/telecom-minister-blames-people-obstructing-mobile-tower-installation-for-call-drops/articleshow/65984269.cms. Last Accessed: October 14, 2020.

military, infrastructure and critical commercial applications. For most countries, many of the equipment and underlying hardware and software technologies used in 5G are not locally produced. This dependence on other countries to help develop and sustain this vital infrastructure brings with it new vulnerabilities and risks. Many countries fear espionage by foreign governments once 5G becomes an integral part of national informational infrastructure.[89]

In the United States, the government passed a law *Secure 5G and Beyond Act of 2020 (S. 893)* to require the President to develop and implement a strategy to secure next generation wireless communications systems and infrastructure.[90] In March 2020, the President issued a special policy guideline—National Strategy to Secure 5G.[91] It outlines the lines of effort involved in facilitating the rollout of 5G in the US, assessing risks and identifying core security principles, addressing risks to economic and national securities, and promoting responsible global development and deploying 5G.

Congressional Research Service which assists the US Congress in legislative process has also issued a report outlining national security issues in 5G technology.[92] The report argues that poor business practices of foreign technology companies combined with local laws requiring these companies to cooperate for national intelligence work would significantly increase national security risk for other countries.

India is facing the same national security concerns as other nations. On one hand, it does not want to be left behind in this highly impactful technology. On the other hand, it does not want to compromise national security. India recently revised its foreign direct investment policy to restrict investments by individuals and companies from neighboring countries.[93]

In this interconnected, globalized world, it would be difficult to isolate and develop the entire range of mobile technology indigenously. Countries have to carefully look into the level of risks involved in key parts of the 5G technology and develop a strategy to manage and monitor those risks, when those technologies are imported.

VII. Law Enforcement

Huge amount of data will be flowing through a 5G network. Encryption of data is an important tool to ensure that the data, whether at rest at servers or in motion in networks, is secure. Encryption becomes even more critical in 5G networks as almost all mission critical applications in government and corporate sectors will be running on it.

However, encryption has been at the center stage of the security debate for a while now. Stronger encryption allows greater protection of data, but it reduces the ability of law enforcement to timely monitor and detect fraudulent and terror activities. Law enforcement and security agencies tend to look unfavorably upon encryption. They logically argue that it makes investigation and collecting evidence tougher while allowing suspects and perpetrators to hide behind strong encryption. Law enforcement in the US and UK have even asked for a "backdoor" access capability for encrypted communication. These arguments have received a pushback from the tech industry arguing that encryption is essential for security and consumers demand strong privacy protection.

89. National Cyber Security Center, UK (2019). "Annual Report: Huawei Cyber Security Evolution Centre Oversite. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/790270/HCSEC_Oversight-BoardReport-2019.pdf. Last Accessed: October 14, 2020.
Also, Bryan-Low, Packham, et. al (2019). " Hobbling Huawei: Inside the U.S. war on China's tech giant" *Reuters*. May 21, 2019. https://www.reuters.com/investigates/special-report/huawei-usa-campaign/. Last Accessed: October 14, 2020.

90. S.893 - Secure 5G and Beyond Act of 2020. https://www.congress.gov/bill/116th-congress/senate-bill/893. Last Accessed: October 14, 2020.

91. The White House (2020). "National Strategy to Secure 5G of the United States of America" March 2020. https://www.whitehouse.gov/wp-content/uploads/2020/03/National-Strategy-5G-Final.pdf. Last Accessed: October 14, 2020.

92. Hoehn, John R., Sayler, Kelley M. (2020). "National Security Implications of 5G Mobile Technologies" Congressional Research Service. March 25, 2020. https://crsreports.congress.gov/product/pdf/IF/IF11251. Last Accessed: October 14, 2020.

93. NDA Hotline (2020). "FDI Policy Revised: Neighbouring Countries Restricted From Opportunistic Investments" *Nishith Desai Associates Regulatory Hotline*. April 20, 2020. http://www.nishithdesai.com/information/research-and-articles/nda-hotline/nda-hotline-single-view/article/fdi-policy-revised-neighbouring-countries-restricted-from-opportunistic-investments.html. Last Accessed: October 14, 2020.

In India, Section 69 of the Information Technology Act allows certain government agencies to order decryption of communication. However, this is limited only to cases where any such entity has the capability to decrypt in the first place. Accordingly, it may be difficult to enforce this power in the case of end-to-end encryption.

The Unified License issued to TSPs has a provision that prohibits them for employing bulk encryption on their network. At the same time, the license also imposes an obligation on the service provider to preserve the privacy of users' communication. With 5G, it may be possible to ensure some level of security and privacy by encrypting only the edges of the network rather than the entire network itself.

Additionally, 5G allows data to be transferred through multiple types of networks and devices. This makes it difficult for law enforcement agencies to undertake digital audit or track suspects complicating digital evidence gathering and surveillance.[94] Europol, a pan-European law enforcement agency, has warned that 5G will affect the ability of law enforcement in crime prevention as criminals will be difficult to track over 5G networks.[95] On the other hand, significantly accurate device location will improve relocating missing person or get more accurate starting point to trail a missing person as well as identifying the buildings or locations of interests in illicit drug and other fraudulent activities.[96]

VIII. Network Security

5G technology is based on virtualized network architectures that use "flat" packets, which is more likely to be exposed to cyberattacks.[97] Billions of devices are expected to join the network, including IoT devices. This significantly increase the surface area of cybersecurity attacks.[98] Additionally, these devices will have varied degrees of security features built into them. Such diversity in security features will also make some nodes more susceptible to attacks.

Denial-of-service and distributed denial-of-service attacks have been around for over two decades. Under these attacks, the attacker does not enter into the network, but overwhelms it from outside by continuously sending a torrent of data packets to various devices and servers within the network. 5G is likely to be vulnerable to these types of attacks given the huge number of connected devices. The factors that will fuel these attacks, include: 1) The gap between developing and adopting a new technology and property securing it; 2) availability of cheap bots to do such attacks; 3) hyper connectivity; 4) insufficient resources to monitor and tackle these attacks.[99]

More than 70% of breaches in a network begin at the endpoint.[100] The transition to edge computing in 5G technology will bring computing capabilities closer to the users at endpoints to reduce bandwidth usage.[101] However, it adds new challenges to network security. It has to be managed at every aggregation point of the edge

94. Watson, Ariel (2019). "How 5G Challenges and Benefits Law Enforcement." *Cellebrite*. February 28, 2019. https://www.cellebrite.com/en/blog/how-5g-challenges-and-benefits-law-enforcement/. Last Accessed: October 14, 2020.

95. BBC (2019). "Police will 'struggle' to track criminals via 5G." *BBC.Com*. July 19, 2019. https://www.bbc.com/news/technology-49043822. Last Accessed: October 14, 2020.

96. Roke (2020). "5G & Law Enforcement – How It Could Impact Investigation & Crime Prevention" *Roke.com*. February 21, 2020. Last Accessed: October 14, 2020.

97. Maddison, John (2019). "Addressing New Security Challenges with 5G" *CSO Online*. February 19, 2019. https://www.csoonline.com/article/3341381/addressing-new-security-challenges-with-5g.html. Last Accessed: October 14, 2020.

98. Netscout (2018). "Netscout Predicts 5G Trends in 2019" December 27, 2018. https://www.netscout.com/blog/5G-trends-predictions-2019. Last Accessed: October 14, 2020.

99. Sirbu, Maria (2019). "Security concerns in a 5G era" SC Magazine. May 30, 2019. https://www.scmagazineuk.com/security-concerns-5g-era-networks-ready-massive-ddos-attacks/article/1584554. Las Accessed: October 14, 2020.

100. Absolute (2019). "2019 Endpoint Security Trends Report" Absolute Software Corporation Study. https://www.absolute.com/go/study/2019-endpoint-security-trends/. Last Accessed: October 14, 2020.

101. Hardesty, Linda (2019). "Rakuten builds a greenfield wireless network in Japan" *FierceWireless*. February 14, 2019. https://www.fiercewireless.com/wireless/rakuten-builds-a-greenfield-wireless-network-japan. Last Accessed: October 14, 2020.

computing nodes as supposed to at the central level. Security features and functions will have to be embedded directly on the edge compared to "bolted on" in a traditional network.[102]

5G uses Authentication and Key Agreement (**"AKA"**) protocol to establish a secure connection between a network and a device. The same protocol is also used in 3G and 4G networks. While 5G AKA proposed by 3GPP is has closed several gaps in the previous version of the protocol. However, several gaps may still exist in the new protocol.[103]

In addition, 5G will have to exists in parallel to older cellular technologies, such as 4G and 3G, especially in rural areas where dispersed population density will not make economic sense to upgrade existing cellular infrastructure. When a downgrade attack happens on a device, where the device is tricked into operating in an older protocol or lack of 5G availability will the security risk will increase in many folds.[104]

IX. Data Protection & Privacy

An important concern that 5G is also expected to address is privacy and security. Current networks, where cellular network is separate from computer wi-fi/ethernet network, require data to be transferred to a centralized server for processing after data collection. This puts personal data at risk not only because the data is pooled collectively in a common centralized server, but also during transmission over multiple networks in order to reach its destination. Edge computing will allow to filter certain sensitive data and store it closer to the users rather than at servers. This will improve privacy protections as the sensitive data would be accessible only to the nodes connected to the edge server. Distributing personal data of users across the network will make it harder for malicious hackers to gain access to a large pool of data with minimal effort.[105]

On the other hand, some argue that data protection and privacy are more likely to be compromised, as 5G is expected to bring "billions of cameras, sensors and other 'smart' devices' online.[106] Sheer increase in the collected data and greater ability to cross-reference the data points from textual, graphical, audio and visual formats will create huge risks for user privacy.

Additionally, the short range 5G data cells will allow more accurately pinpoint the user's location. With 4G technology, we are able to geographically locate a device within meters with much less precision. Whereas, 5G enables location within a couple of centimeters.[107] In some cases, specifically financial payment transactions, this will increase security, but in many other cases, this may also lead to increased privacy abuse and security risks.

Always connected devices along with the user's inability to use a device (including 5G-based appliances) without agreeing to certain licensing conditions may also lead to indiscriminate data collection and potential abuse of privacy. Privacy International has offered recommendations for regulatory agencies and corporations for self-regulation.[108]

102. Maddison, John (2019). "Addressing New Security Challenges with 5G" CSO Online. February 19, 2019. https://www.csoonline.com/article/3341381/addressing-new-security-challenges-with-5g.html. Last Accessed: October 14, 2020.

103. Basin, David; Dreier, Jannik; Hirschi, Lucca, et al (2018). "A Formal Analysis of 5G Authentication." CCS '18: Proceedings of the 2018 ACM SIGSAC Conference on Computer and Communications Security, January 2018 Pages 1383–1396 https://doi.org/10.1145/3243734.3243846. Last Accessed: October 14, 2020.

104. Privacy International (2019). "Welcome to 5G: Privacy and security in a hyperconnected world (or not?)" July 23, 2019. https://privacyinternational.org/long-read/3100/welcome-5g-privacy-and-security-hyperconnected-world-or-not. Last Accessed: October 14, 2020.

105. Cherrayil , K. Naushad (2019). "Advantages and disadvantages of edge computing and cloud computing" *TechradarPro.* December 11, 2019. https://www.techradar.com/news/advantages-and-disadvantages-of-edge-computing-and-cloud-computing. Last Accessed: October 14, 2020.

106. FitzGerald, Drew (2019). "5G Race Could Leave Personal Privacy in the Dust" *The Wall Street Journal.* November 11, 2019. https://www.wsj.com/articles/5g-race-could-leave-personal-privacy-in-the-dust-11573527600. Last Accessed: October 14, 2020.

107. Council on Foreign Relations (2019). "CEO Speaker Series with Randall Stephenson." September 18, 2019. https://www.cfr.org/event/ceo-speaker-series-randall-stephenson. Last Accessed: October 14, 2020.

108. Privacy International (2019). "Welcome to 5G: Privacy and security in a hyperconnected world (or not?)" July 23, 2019. https://privacyinternational.org/long-read/3100/welcome-5g-privacy-and-security-hyperconnected-world-or-not. Last Accessed: October 14, 2020.

X. Effects on Other Critical Applications

5G technology uses frequencies nearby to those used by weather and Earth observation satellites. Any interference from 5G to the operations of these satellites can affect the speed and accuracy of weather forecast.[109] The FCC had auctioned the 24 GHz spectrum band in March 2019 over the objections of NOAA and NASA, receiving nearly US$2 billion in bids.[110] On May 16, 2019, Neil Jocobs, Acting Under Secretary at National Oceanic and Atmospheric Administration (NOAA), testified[111] to the US Congress that there could be as much as 30 percent reduction in the accuracy causing two- to three-day delay in hurricane preparations. This is also expected to affect operations of NASA. The Ranking Members of the Senate Committees on Finance and Commerce, Science and Transportation wrote to the FCC to not allow "wireless companies to operate in a 24 GHz band until vital weather forecasting operations are protected."[112] In November 2019, the World Radiocommunications Conference organized by the Interlamination Telecommunications Union decided to create new international standards that would include 24 GHz band and may interfere with other critical applications operating in this frequency range.[113]

XI. Environmental and Societal Impact

Many countries have specific laws related to the environmental impact of any new construction. US The National Environmental Policy Act in the US specifies that efforts must be taken to "prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man."[114] While countries are speeding up the rollout 5G in order to not left behind, the environmental and other societal impact of this new technology are often not fully assessed.

On August 9, 2019 in the US, the US Court of Appeals for the D.C. Circuit ruled that it was not in the public interest for the FCC to remove regulatory requirements related to environmental and other societal impact in order to expedite the rollout of 5G service.[115] The Court specifically noted that, while such impact of microcell technology used by the current cellular network has been understood, such impact of the newer small cell technology used in 5G need to be assessed before their deployment.

This type of rulings in other jurisdictions, including in India, will affect new constructions of 5G small cells, specifically delay the new installations and increase costs of the rollout of 5G.

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7. Conclusion

Arguably, the story of human progress over thousands of years is the story of evolution of technology over time. With each iteration, humans improve the tools at our disposal to enable a better quality of life. 5G standards are the next step in network evolution that will provide a much-needed impetus to emerging technologies that are awaiting deployment.

As discussed, there are considerable challenges to overcome in deploying next-gen networks but they are by no means unsurmountable. The Indian government is making consistent efforts to make sure that the country does not fall behind and keeps pace with the rest of the world. This clearly indicates that the government is cognizant of the numerous advantages that 5G networking technology can provide.

Even though telecom service providers may have faced some setbacks in the Indian market, the industry is poised for enormous growth. Building on the initiatives that it has already taken, the government should streamline its telecom policy measures and consider more innovative revenue models to incentivize deployment of 5G networks. To ensure that the benefits of 5G networks also flow down to rural areas, the government should consider various forms of incentives to allow telecom companies to expand 5G coverage while ensuring steady revenue growth. Commercial 5G networks could easily complement the government's existing efforts to provide broadband connectivity, such as BharatNet.

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