5G IN INDIA

Demystifying Reality from Myth

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Abbreviations

3GPP	3rd Generation Partnership Project
4G	4th Generation
5G	5th Generation
AGR	Adjusted Gross Revenue
AR	Augmented Reality
DoT	Department of Telecommunications
EDGE	Enhanced Data GSM Evolution
eMBB	enhanced Mobile BroadBand
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
GPKS	General Pack Radio Service
GPS	Global Positioning System
ICT	Information and Communication Technology
IoT	Internet of Things
ITU	International Telecommunications Union
LMLC	Low Mobility Large Cell
LTE	Long Term Evolution
MGI	McKinsey Global Institute
mMTC	massive Machine-Type Communications
NR	New Radio
N-SA	Non-Standalone
SA	Standalone
TDSAT	Telecom Disputes Settlement and Appellate Tribunal
TRAI	Telecom Regulatory Authority of India
TSDSI	Telecommunications Standards Development Society, India
uRLLC	ultra-Reliable and Low-Latency Communications
VoLTE	Enabled Voce over LTE Network
VR	Virtual Reality

Acknowledgement

Foreword

The widespread availability of mobile wireless networks in the past two decades has transformed India. Our network evolved from 2G in the early 2000s, to 3G in the late 2000s and 4G in the past five years.

5G is the next generation of cellular communications technology with both evolutionary and revolutionary services that can be even more valuable to India. 5G promises more than High-Speed phone connectivity adding new Machine Type and High Reliability and Low Latency communications technology. These technologies can become a Virtual infrastructure to strengthen India's physical infrastructure in transportation, agriculture, health, and manufacturing sectors.

5G can unleash new economic opportunities and societal benefits giving it the potential for being a transformational technology. It can help India leapfrog the traditional barriers to development adding US$1tn economic impact by 2035.

Currently, only the high-speed connectivity component of 5G technology is ready and has started rolling out globally since mid-2019. Deployment is still in its infancy with 80 million subscribers. 5G services, for now, are deployed in the non-standalone mode and depending on the 4G network to function. Even when 5G becomes fully independent, most operators will support 4G, 3G, and 2G connectivity to cater to coverage holes and phones that are not 5G capable. The Machine Type and High Reliability and Low Latency Communications technology segments of 5G will take another two years to be deployment-ready.

The Government of India formed a High-Level Forum to recommend policy initiatives for 5G. The Forum submitted a report in August 2018 with several key policy recommendations covering spectrum allocation, regulatory reforms, educational initiatives, and technology development. The Forum recognised that 5G deployment faces special challenges because of the need to serve a range of non-phone type applications where the user community will be new to wireless technology.

Also, due to the use of higher frequency bands, 5G will need a higher network density increasing network investments. 5G deployment will also need special policy measures to ensure it reaches the economically weaker and the rural segments of our society. It is noteworthy that India's current 4G deployments also need significant enhancements.

This Report has summarised public perceptions of 5G deployment and use cases, as well as offering parallel perspectives from industry experts in the field. There is a wide gap between the

two, highlighting the need to vigorously engage the public to increase the awareness of the opportunities and the challenges of this new technology. A well-informed public will help influence both public policy on 5G deployment and promote India's 5G technology eco-system. We are indeed grateful to Udai S Mehta and Sidharth Narayan of CUTS International for bringing out this valuable study.

Arogyaswami J Paulraj
Professor Emeritus, Stanford University and
Chair of the Task Force of the
High Level Government Forum for 5G 2020

Executive Summary

Introduction

Globally telecom players, policymakers, think tanks, etc. are actively discussing the 5G opportunity. However, much of the discussion in the public domain has been driven with a business, and not from a consumer's perspective. Furthermore, anecdotal evidence suggests that there is a lack of awareness and misconceptions amongst consumers across the world about what 5G is expected to deliver and when. This sparks possibilities of misconceptions and myths in the minds of consumers.

This report aims to separate myths from reality within the context of 5G delivery in India, from a consumer perspective, through a survey of 500 consumers of 4G services through smartphones, in New Delhi, which was conducted in late 2019.

Myth 1: 5G is all about Enhanced Speed

The technological evolution from 3G to 4G was marked noticeably by enhanced speed and reduced latency, thereby improving the internet experience of consumers. The same impression continues to shape consumer's imagination as to what benefits 5G is likely to bring, i.e. most respondents perceive 5G as either mere hype or just a faster 4G. Few were informed enough to choose alternatives such as "enabling new use cases" or "device-to-device communication-oriented services" (IoT).

Reality

While 4G led the way in transitioning from voice led to data-driven communication, 5G is set to bolster the same, while also enabling various new use-cases for consumers and businesses. The technical superiority of 5G offers three chief characteristics, mentioned below:

- Enhanced mobile broadband (eMBB) speed: It enables 5G to theoretically offer lightning speeds up to 100x faster than 4G, and supports new applications requiring greater bandwidth. Expected consumer-facing use cases enabled by it include ultra-high-definition video streaming, data-intensive use cases like untethered, real-time Augmented Reality (AR) and Virtual Reality (VR), cloud gaming, etc.

- Ultra-reliability and low latency communication (uRLLC): It reduces latency in 5G, up to a factor of 10, down to single-digit milliseconds. Expected consumer-facing use cases enabled by it include autonomous vehicles, health monitoring system/telehealth, smart grids etc, among various other industrial use cases.

- Massive machine-type communications (mMTC): It enhances 5G's capabilities to support a high density of devices (up to millions per km²), i.e. it will enable the creation of a strong web of interconnected devices that will be able to communicate amongst each other. Expected consumer-facing use cases enabled by it include expansion of Internet of Things (IoT) use cases to smart consumer wearables, smart homes, smart cities, etc.

Myth 2: 5G is around the Corner

It has been widely believed that 5G enabled services is around the corner, and may become available soon in India. Exciting announcements have been made by companies, such as OnePlus, Samsung, Huawei, etc., pertaining to launching smartphone processors supporting 5G connectivity. Realme, the Chinese smartphone manufacturer, has recently launched India's first 5G enabled phone named X50Pro. This has further echoed the buzz of 5G being launched in India.

Reality

Although it is correct to say that India is narrowing the delay in adopting a telecom technology as against its track record of long delays, the current status of 5G deployment in India is nowhere near commercial deployment. India's upgrade from 4G to 5G does not seem likely this year. Select reasons have been given below:
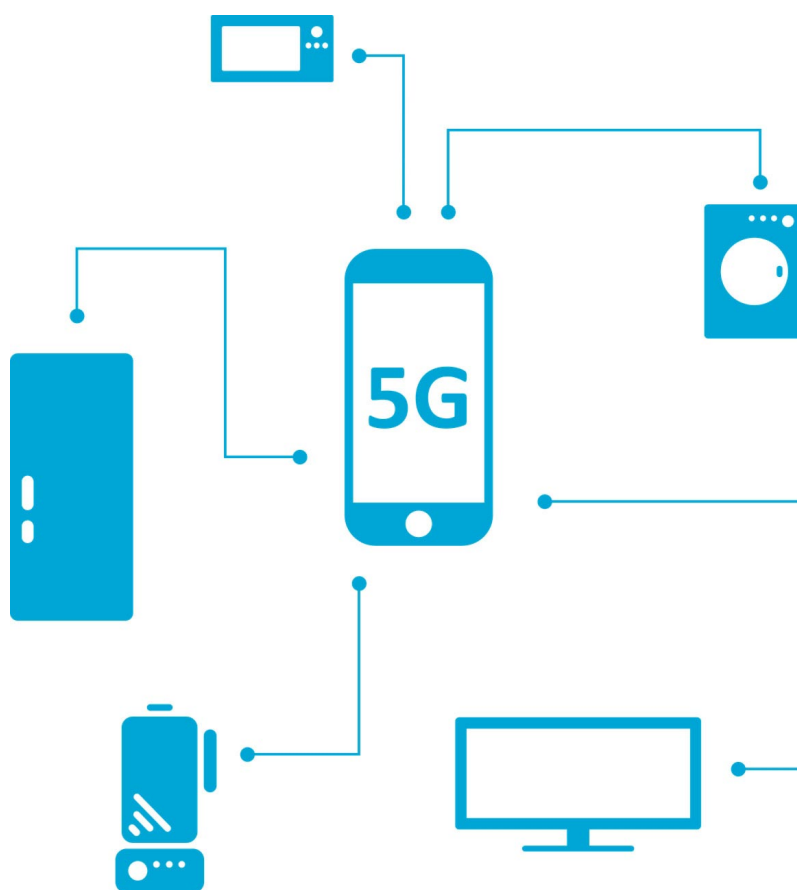
- Weak financial position of India's telecom sector: Jio's aggressive pricing strategy while entering the telecom sector in late 2016 led to financial constraints for the incumbent players in the market, which also resulted in consolidation. Adding to the financial woes the issue of Adjusted Gross Revenue (AGR), poses an estimated debt burden of ₹92,000 crores on the telecom sector. Therefore, the current financial strength of the sector does not seem to be ready to make investments in buying 5G spectrums, which may delay the availability of 5G networks for consumers.

- 4G itself at a nascent stage: Parts of India are still reliant on 2G and 3G connectivity, and the country does not have a robust 4G ecosystem. Also, India has been ranked 109 out of 124 countries on the parameter of mobile internet speeds to 4G. More so, Telecom Regulatory Authority of India (TRAI) is still considering to initiate industry dialogue on broadband speed and reliability.[1] Therefore, before a pan India spread of reliable 4G is achieved, a countrywide release of 5G may prove to be premature and a daunting task for the government and other relevant stakeholders, shortly.

- Late roll out of 5G beneficial for India: Industry experts believe that country-specific use cases are yet to be developed for India, which may take time. Furthermore, experts also stress that India largely being a price-sensitive market, may wait for economies of scale for cheaper 5G supported devices, which may take up to 2022.

- Hiccups in collaborative standard setting for 5G: Telecommunications Standards Development Society, India (TSDSI) has developed a home-grown use case of 5G called Low-Mobility-Large-Cell (LMLC). In December 2019, LMLC was accepted as a candidate for evaluation as a 5G standard but is facing strong opposition from the telecom vendors as they would need to tweak their technologies for making it compatible for India. Incompatible technologies can hinder the growth and expansion of 5G, and running away from standardisation may have its own very high costs.

For the aforementioned reasons, 5G is unlikely to enter the Indian market any time soon. Notably, India lags behind other Asian countries, such as South Korea, Japan and China in deploying 5G in 2020.

Myth 3: 5G will Replace 4G Altogether and Fast

It remains to be checked whether once deployed, can 5G be expected to replace 4G LTE altogether, and fast. This issue gets more pertinent, considering many consumers have shown willingness to change their mobile device, operating system and even their service provider, in case 5G is made first available to them.

Reality

4G and 5G are set to coexist for a long time, not only in India, but elsewhere as well. This may be based on the following:

- Interworking 4G and 5G: Building a dense network for 5G is expensive and can only partially be secured in the first few years of deployment. Therefore, interworking 5G with 4G is inevitable. As a feature, 4G-5G interworking means that when 5G is being deployed, it will leverage the existing 4G deployments, making the transition process from 4G to 5G smooth over a period of time. So, even if 5G is launched soon, it will work in conjunction with 4G networks in the early stages and not replace 4G altogether.

- India is still expanding its smartphone user base: Indian mobile phone market has largely been dominated by feature phones, many of which are still relying on 2G mobile technology. Industry experts
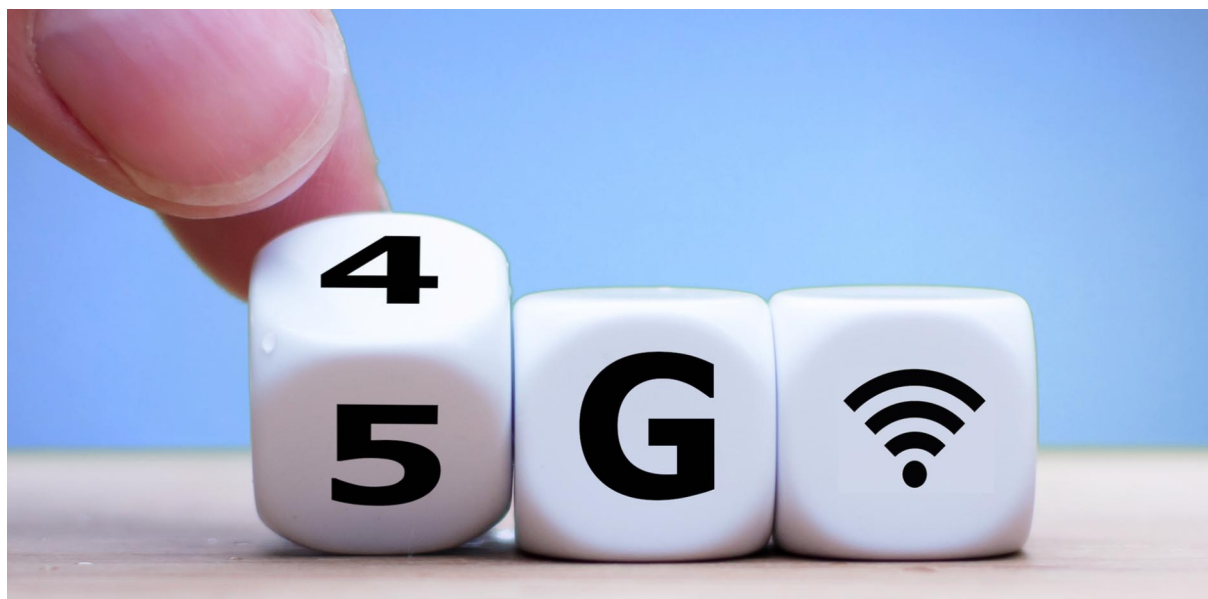
also subscribe to the view of 2G feature phones staying in the Indian market, due to their inexpensiveness.

- Setting-up of 5G antennas and towers may take time: In order to facilitate reasonable coverage, 5G service providers would have to build 5G antennas and towers extensively. The entire process is not only time-consuming, but expensive as well, making its reach unevenly spread across geographies. Due to such barriers, even after the initial launch of 5G in the country, consumers are expected to mostly be availing the coexisting 4G services, even on a 5G enabled handset, in a 5G enabled city.

Conclusion

The survey findings suggest that consumers are eager to avail 5G services. While buying a new smartphone, they prioritise it to be 5G-enabled, apart from having various other upgrades.

While 5G is already becoming available in some countries in limited pockets, India is striving to beat its past of delays in the adoption of telecom technology. Predictions abound, as to India's future capability to act as a major market for 5G in the years to come, however, realising that vision is still a way to go.

Going forward, a major issue that the government should be focussing on is the financial health of the telecom sector which has been highlighted as a challenge in this report.

Expediting the process of 5G trials, spectrum auctions and subsequent deployment is another area to look upon. The Department of Telecommunications (DoT) has given several timelines for spectrum allocation in 2019, the last one of which was for auction in the fiscal year 2019-20. However, trials are not expected sooner than the last quarter of 2020. While consumers look forward to 5G, the absence of 5G-enabled devices along with useful use cases of 5G technology can be seen as significant hurdles, which must be overcome.

1 / Evolution of Mobile Communications

Several countries have started trialling the 5th Generation (5G), the latest iteration of mobile telephony. It promises to deliver several features that will unlock a host of new use cases.

About the Report

While voice communications by radio have a long history, mobile phone service as we know it is only about four decades old. The mobile phone network has kept pace with these technological improvements – from making calls secure from eavesdropping, increasing the number of concurrent calls on the network, sending text and data on the network, and significantly reducing call costs – all these have helped proliferate the use of mobile phones.

Newer technology has been developed and rolled out in a series of waves or generations, currently at 4th Generation (or 4G). Figure 1 describes the features/improvements delivered in each iteration:

Several countries have started trialling the 5th Generation (5G), the latest iteration of mobile telephony. It promises to deliver several features that will unlock a host of new use cases. In a recent report, McKinsey Global Institute (MGI) has estimated an increase in global gross domestic product (GDP) by about US$2tn through the use of 5G in key sectors such as healthcare, retail, mobility, and manufacturing.[2]

Globally telecom players, policymakers, think tanks, etc. are actively discussing the 5G opportunity. However, much of the discussion in the public

Figure 1: Enhanced Utility for Consumers with Each Generation Upgrade

1G & 2G
- 1G brought first taste of mobile calling
- 2G enabled roaming, and added texting and basic internet utility to mobile voice telephony

3G
- It enabled internet surfing, 3D games
- No 3G means no Global Positioning System (GPS), no web browsing, and no apps

4G
- It enhanced internet speeds while allowing interconections of limited devices
- No 4G means no seemless video calling and video streaming

5G
- It will facilitate massive person to machine, and machine to machine communication
- This will enable novel consumer and industrial use cases

There is a lack of awareness and misconceptions amongst consumers across the world about what 5G is expected to deliver and when.

domain has been driven by confused opinions and myths such as that 5G will be all about businesses and not consumers,[3] and that there are no real use cases that would be relevant for the consumer market. Furthermore, anecdotal evidence suggests that there is a lack of awareness and misconceptions amongst consumers across the world about what 5G is expected to deliver and when.

Therefore, there is a need to dispel the myths and reinstate realties. Thus, this report aims to separate fact from fiction within the context of 5G delivery in India.

Survey Methodology

A survey of 500[4] consumers of 4G services using a smartphone was conducted in New Delhi in late 2019. The sample spread ensured gender balance, and comprised users from different age groups and varying educational background. The survey was aimed at capturing consumer perspectives on the utility derived from existing telecom services and their expectations from 5G. It also asked questions to determine their level of satisfaction with existing services, their expectations from 5G, and barriers to adoption. The survey comprised a mix of multiple-choice and open-ended questions.

In broad terms, the survey attempted to answer the following questions within the Indian context:

a. Consumer's awareness and eagerness about new use cases to be unlocked by 5G, and expected time for their availability.
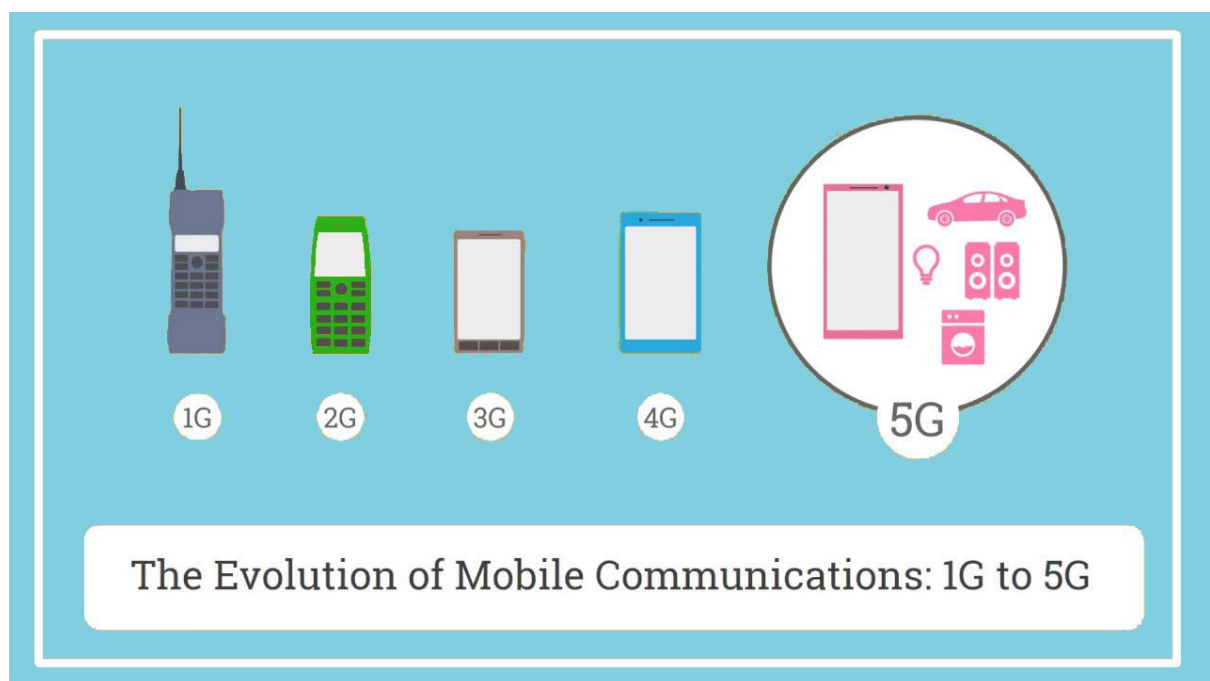
The Evolution of Mobile Communications: 1G to 5G

> The improvements heralded by 5G can be considered seismic; it is expected to offer 7 times more bandwidth and 10 times higher connection density over 4G.

b. Consumers awareness about 5G's deployment status, and eagerness to avail the same.

c. When will 5G be available in India for commercial use? What are the hurdles to its deployment and adoption in India?

Relevance of this Report

While we have described the generational technological improvements as "iterations", the improvements delivered in each iteration were explosive. For example, 2G made mobile telephony secure and introduced asynchronous text messaging service. 3G made mobile phones mainstream with a significant drop in usage costs. With fast internet, 4G made information accessible at fingertips and truly turned the world into a global village with low-cost international costs.

3G and 4G connected individuals with mobile devices. About 88 percent of households in India have mobile phones. To put this in perspective, 77 percent of the bottom quintile has a mobile phone, but only 18 percent of them have access to tap water.[5] 31 percent of mobile phone users use a smartphone.[6]

The improvements heralded by 5G can be considered seismic; it is expected to offer 7 times more bandwidth and 10 times higher connection density over 4G. It is expected to be the enabler for smart homes, offices, and cities. Imagine a city that reacts to the world around it, taking information from the people within it, crunching data from sensors on roads, vehicles, buildings, and much more to improve the quality of life for all.[7]

Figure 2: 4G and 5G: A Comparative View

Latency
- 4G - 10ms
- 5G - 1ms

Data Traffic
- 4G - 7.2 Exabytes/Month
- 5G - 50 Exabytes/Month

Connection Density
- 4G -1,00,000 Connections/Km
- 5G -10,00,000 Connections/Km

Peak Data Rates
- 4G - 1 Gb/s
- 5G - 20 Gb/s
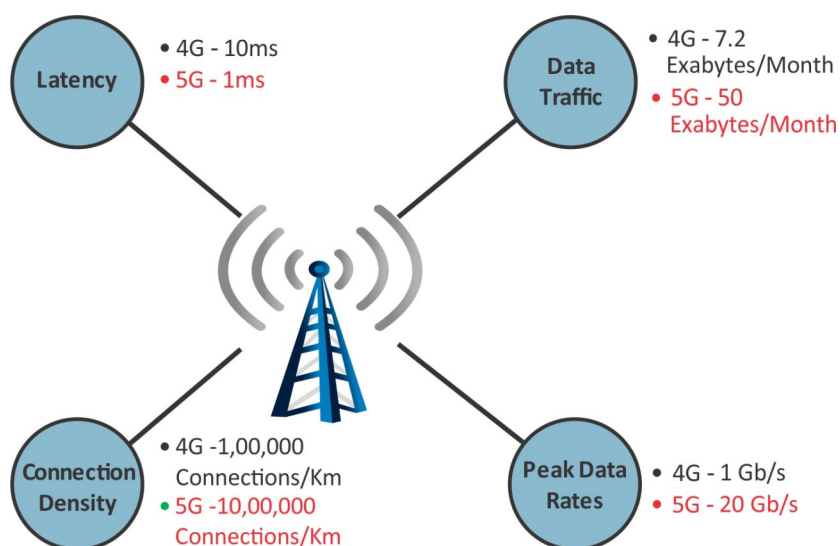
Source: Policy Forum at AT&T[8]

2 / Use Cases of 5G

The COVID-19 pandemic has transformed the way we work and live forever. Given that social distancing is the new way of living, dependence on telecom and internet services have become a necessity.

Thus, it is an opportune time for policymakers, regulators and service providers to lead the massive deployment of 5G. Thus, it is time to dispel the myths about 5G.

Myth: 5G is all about Enhanced Speed

The technological superiority of 5G promises lightning-fast internet speed with reduced latency,[9] acting as an enabler for some use cases of 5G. Viewed from a consumer's perspective, the technological evolution from 3G to 4G was marked noticeably by enhanced speed and consequently improved the internet experience of consumers. 4G managed to improve the speed and latency over 3G and thereby amplified the quality of services that 3G had already begun facilitating such as video calling and streaming.

The new use cases that 4G supported were limited in scope and utility. Possibly, a similar nature of shift in experience is

The importance and role of 5G in bridging the prevailing digital divide in India needs to be underlined. This becomes more pressing in light of the COVID-19 pandemic, which has increased reliance on digital technology-driven services.

Dr Arvind Mayaram
Economic Advisor to the Chief Minister of Rajasthan and Chairman, CUTS Institute for Regulation & Competition

Graph 1: Consumers Perception of 5G[10]

- Mere Hype — 21%
- Just Faster 4G — 41%
- Faster 4G + Enable New Applications + IoT — 27%
- 11%
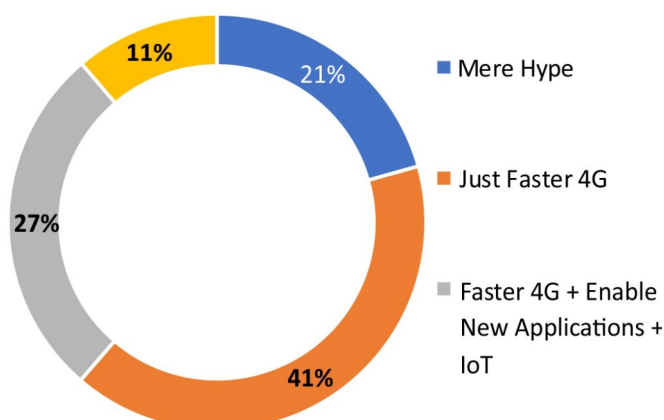
being expected from 5G, *i.e.* an improved speed and better experience in the older applications. The survey checked whether the same impression continues to shape consumer's imagination as to what benefits 5G is likely to bring.

Most consumers perceive 5G as either mere hype or just a faster 4G. Few were informed enough to choose alternatives such as 'enabling new use cases' or 'device-to-device communication-oriented services'.

Most respondents' perception of 5G has seen overwhelmingly resounding responses where consumers have associated 5G just with speed. Select quotes of consumers have been given below.[11]

Female, aged between 26-40 years

- 5G is useful for better speed, and superior voice quality

Male, aged between 18-25 years

- 5G is just faster than 4G
- 5G means superfast internet speed

Female, aged over 41 years

- Faster internet with better coverage

Presenting the Reality: 5G will Unlock Many Novel Cases

While 4G led the way in transitioning from voice led to data-driven communication, 5G is set to bolster the same, while also enabling various new use-cases for consumers and businesses. With automation brought forth by 5G, a consumer will be empowered to manage more things in lesser time with enhanced efficiency through use cases like smart homes, smart wearables, interconnected entertainment devices, etc., with the help of significantly higher speed, bandwidth, and lower latency.

The technical superiority of 5G makes such upgrades possible. These are based on three chief characteristics, as recognised by the International Telecommunications Union (ITU).[12] As mentioned below:

- Enhanced mobile broadband (eMBB) speed: It enables 5G to theoretically offer lightning speeds up to 100x faster than 4G, and supports new applications requiring greater bandwidth. Expected consumer-facing use cases enabled by it include

> 5G's enhanced capabilities will unlock many consumers facing industrial use cases, by enabling Machine to Machine, and Person to Machine communication.
>
> ***Arogyaswami Paulraj***
> *Professor Emeritus, Stanford University and Chair of the Task Force of the High Level Government Forum for 5G 2020*

ultra-high-definition video streaming, data-intensive use cases like untethered, real-time Augmented Reality (AR) and Virtual Reality (VR), cloud gaming, etc.

- Ultra-reliability and low latency communication (uRLLC): It reduces latency in 5G, up to a factor of 10, down to single-digit milliseconds. Expected consumer-facing use cases enabled by it include autonomous vehicles, health monitoring system/ telehealth, smart grids, etc, among various other industrial use cases.

- Massive machine-type communications (mMTC): It enhances 5G's capabilities to support a high density of devices (up to millions per km²), i.e. it will enable the creation of a strong web of interconnected devices that will be able to communicate amongst each other. Expected consumer-facing use cases enabled by it include expansion of the IoT use cases to smart consumer wearables, smart homes, smart cities, etc.

Considering such use-cases, the 5G revolution is being seen as more than just a telecommunication service for consumers, but instead as an advanced technology acting as the backbone for enabling several other technologies.

Notably, the survey results show that consumers depict different levels of eagerness to avail such advanced use cases. This has been represented in Graph 2.

Graph 2: Consumers Eagerness to Avail Select 5G Enabled Use-Cases[13]

Bar chart — Number of respondents by Service/Service Attribute:
- 10x Internet Speed: 434
- Paired Devices: 430
- Instant Cloud Access: 424
- Smart Meters: 422
- Live UHD Video Streaming: 419
- Interactive Cloud Gaming: 403
- Mobile AR/VR Services: 399

■ Consumers Eager to use such service (attribute)
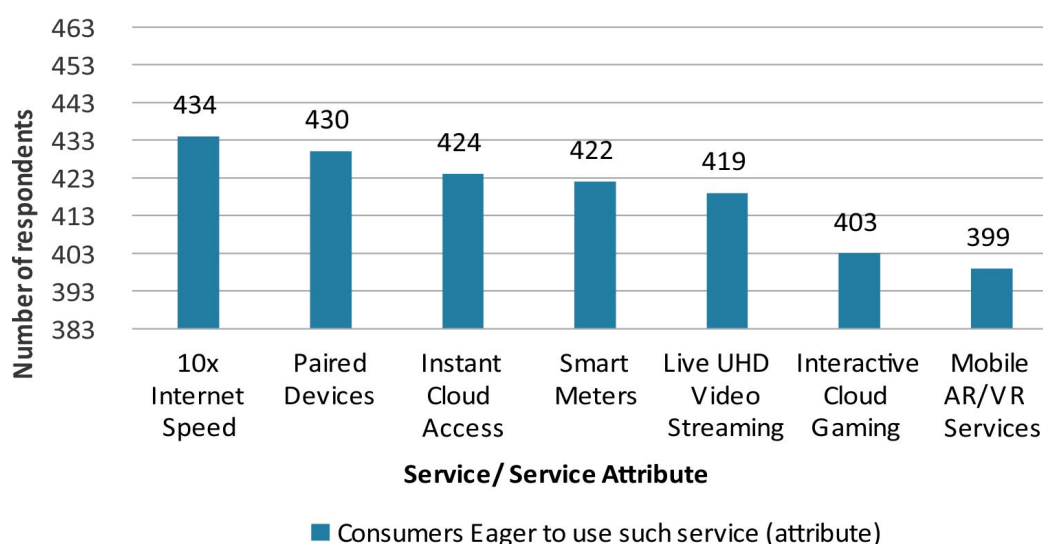
Seeing this in the light of consumers' perception that 5G is only about speed highlights an important fact, that although the consumers lack awareness about the various use cases that 5G might facilitate, they are eagerly looking forward to such use cases when informed of the possibilities of 5G. However, special attention needs to be given to consumers uptake and perception towards the IoT.

The ITU defines IoT as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies (ICT).[14] In the phrase IoT, the term "things" refers to both physical objects as well as the objects of the information world (virtual world) which can be identified and integrated into communication networks.[15]

Graph 3: Consumers Uptake of IoT Devices[17]
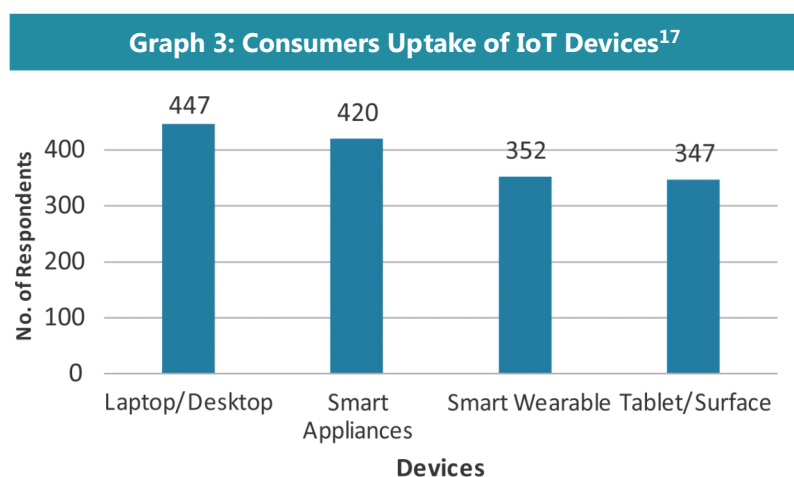
When this associated information is integrated with the means of ICTs, it generates a system of inter-related devices called the IoT which can assimilate and process more information in one unit and produce better outputs than the other units individually.[16]

While IoT has entered mainstream usage already (commonly in the wearables and entertainment devices), the scope of its applications is very large. If IoT can be used to connect a cell phone with a watch, it can also be used to link all the electronic devices in a building or on the street, for instance. This is where the role of 5G comes in.

5G promises to offer highly enhanced speed, data capacity, efficiency, lower latency, security, and reliability.[18] Due to these, 5G is expected to fulfil the potential of IoT as being envisioned to connect tens of billions of devices.[19] From a consumer perspective, there are various IoT devices available. The survey mapped the uptake of such devices, findings for which are given in the adjoining graph.

Select quotes of the reasons for using IoT enabled devices have been given below.

Female, aged between 26-40 years

- Enhancing the experience of digital entertainment

- User friendly technology for enhancing convenience

Male, aged between 18-25 years

- Enthusiastic about technology and keeping up with its latest trend

Female, aged over 41 years

- To get immediate notifications related to health and fitness

Graph 4: Reasons for not Using IoT Devices[20]

- High cost of Device — 50%
- No/Limited Utility — 30%
- Unaware about the Device — 17%
- Other Reasons — 3%
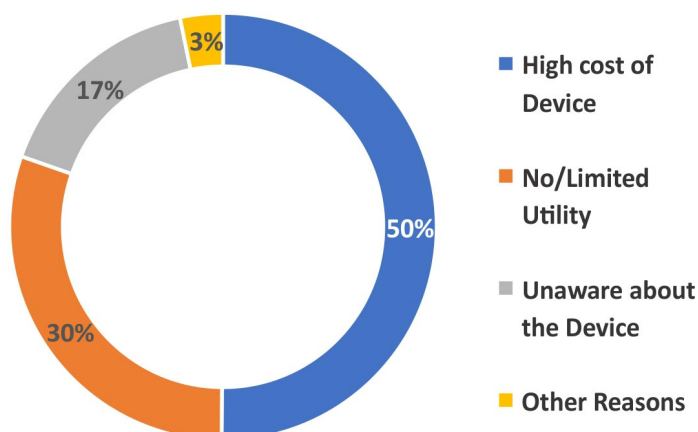
Reasons for not using the devices mentioned above were also covered in the survey.

These primarily related to the initial high cost of devices, coupled with perceived limited or no utility of the functions/features of presently available devices for their needs.

A breakup of the reasons for not using IoT devices has been provided in Graph 4.

3 / When will 5G Come to India?

Myth: 5G Coming to India Soon

It has been widely believed that 5G enabled services are around the corner, and may become available soon in India. Headlines claiming 5G being rolled out in select cities have already made the news.[21] Exciting announcements have been made by companies such as OnePlus, Samsung, Huawei, etc., pertaining to launching processors for smartphones with support for 5G connectivity.[22] Realme, the Chinese smartphone manufacturer, has recently launched India's first 5G enabled phone named X50Pro.[23] This has further echoed the buzz of 5G being launched in India.

As is visible from Graph 5, consumers are positive for the rollout of 5G soon. More than 50 percent of respondents expected 5G to be available before the end of 2020. Respondents also noted to be hopeful of many of 5G's consumer facing use cases being made available in the not so distant future. Their perceived timelines have been captured in graph 6.

The analysis of data from the survey suggests that a large number of consumers associate several challenges with the deployment of 5G. Most significant of those issues is infrastructural inadequacy in the telecom sector which 66 percent of the consumers think would be the main barrier in road to 5G deployment.

About 41 percent of the consumers also see the absence of 5G enabled devices as a challenge. Notably, consumers also depict different levels of awareness with respect to 5G's deployment globally. Graph 8 showcases the same.

Graph 5: Consumers Perception on 5G Availability in Delhi[24]

- Already Deployed
- Within 3 Months
- 2020
- 2021
- 2022 & Beyond

6%
16%
21%
21%
36%
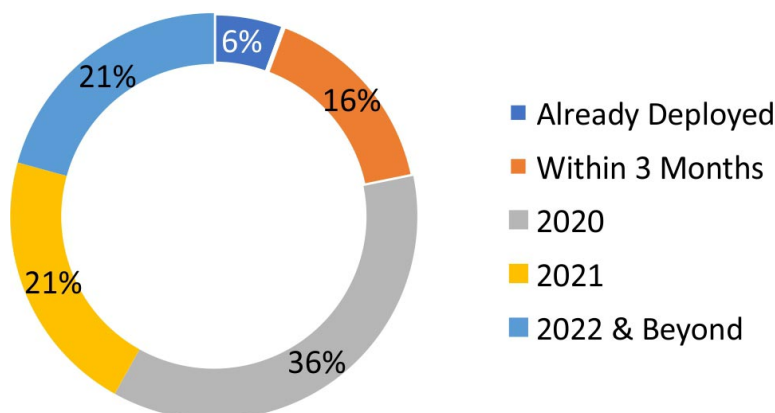
Graph 6: Consumers Expectation on Availability of Use Cases of 5G[25]

Expected time of availability (y-axis: 0, 50, 100, 150, 200, 250, 300)

Service/Service Attribute	Within 3 Months	Within 3 Years	Beyond 3 Years
10x Internet Speed	138	257	68
Paired Devices	153	253	57
Instant Cloud Access	159	239	65
Smart Meters	133	237	93
Live UHD Video Streaming	149	230	84
Interactive Cloud Gaming	136	243	84
Mobile AR/VR Services	151	237	75

Service/ Service Attribute

■ Within 3 Months ■ Within 3 Years ■ Beyond 3 Years

Graph 7: Consumers Perceived Challenges in 5G's Deployment[26]

No. of respondents (y-axis: 0, 50, 100, 150, 200, 250, 300, 350)

Perceived challenges	No. of respondents
Telecom Infrastructure Inadequacy	250
Absence of 5G enabled Devices	157
Absence of Useful Use Cases in India	141

Perceived challenges
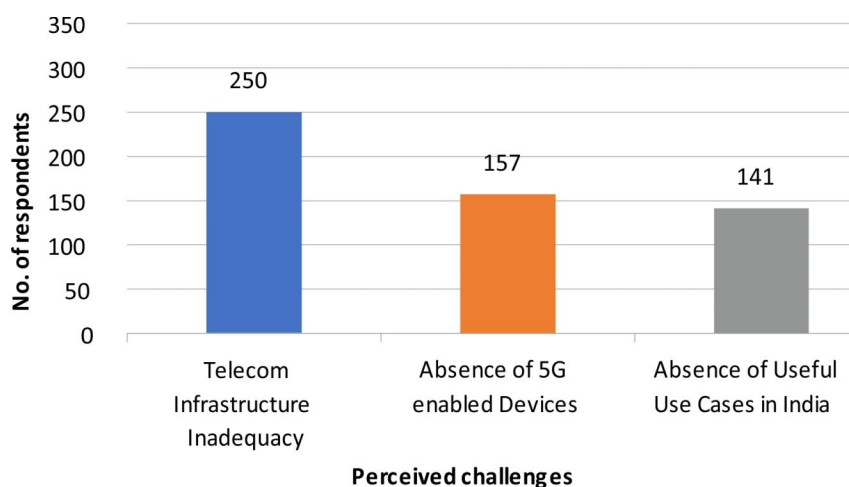
Graph 8: Consumers Perception of 5G's Global Deployment Status[27]
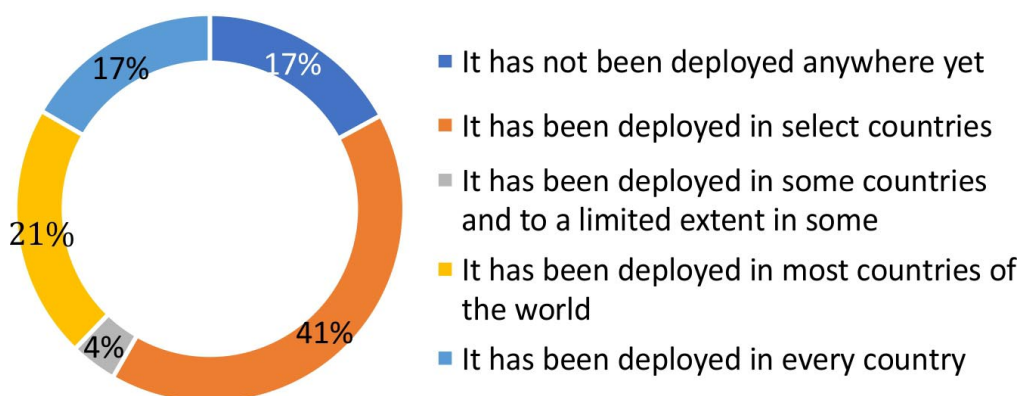
- 17% ■ It has not been deployed anywhere yet
- 41% ■ It has been deployed in select countries
- 4% ■ It has been deployed in some countries and to a limited extent in some
- 21% ■ It has been deployed in most countries of the world
- 17% ■ It has been deployed in every country

Presenting the Reality: Complete Commercial Deployment of 5G will take time

Although it is correct to say that India is narrowing the delay in adopting a telecom technology as against its track record of decadal delays, the current status of 5G deployment in India is nowhere near commercial deployment. India is expected to make an upgrade from 4G to 5G shortly but does not seem likely this year, i.e. 2020.[28] Various reasons have been recorded for the same, most important of which have been discussed below.

> India is expected to make an upgrade from 4G to 5G shortly but does not seem likely this year, i.e. 2020.

Weak Financial Position of India's Telecom Sector

Jio's aggressive pricing strategy while entering the telecom sector in late 2016, resulted in consolidation, due to financial constraints for the incumbent players in the market. Struggling revenues forced Telenor to sell their operations to Airtel,[29] and also triggered a merger of Vodafone and Idea.[30] The public sector players – BSNL and MTNL – are looking at the government to be bailed out of their financial woes.

Another worry for telecom sector is the issue of AGR, following the Supreme Court dated October 2019, which overturned the Telecom Disputes Settlement and Appellate Tribunal (TDSAT) order and revised the definition of AGR, resulting in at an estimated debt burden of ₹92,000 crores on the telecom sector.[31]
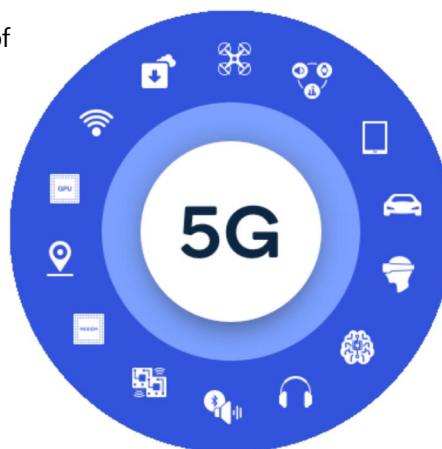
It is believed that Vodafone's Idea is being seen to be on the verge of bankruptcy, while the financial condition of Airtel is also worrying post the judgement.[32] The DoT has moved the SC to allow staggered payment of such dues for 20 years, to provide relief to the ailing telecom sector.[33]

Still, the current financial strength of the sector does not seem to be ready to make investments in buying 5G spectrums, which is expected to delay the availability of 5G networks for consumers.

> The government needs to lower the price of spectrum, since they are much higher than global averages, especially considering the purchasing power of telecoms in India.
>
> ***TV Ramachandran***
> *President, Broadband India Forum and Member of the High Level Government Forum for 5G 2020*

The weak financial position of the sector is also visible through the graphs, which show that despite continuous year on year increase in the total number of telecom subscribers in the past few years, the revenue of the sector sloped down in the corresponding period.

Graph 9: Year-on-Year Revenues and Subscribers for Telcos

YEAR ON YEAR TOTAL SUBSCRIBERS

Total Telecom Subscribers

- 996.49 — FY 2015
- 1058.86 — FY 2016
- 1194.58 — FY 2017
- 1206.22 — FY 2018

SUBSCRIBERS IN MILLIONS

FINANCIAL YEARS 2015 - 2018

YEAR ON YEAR REVENUES

Total Telecom Sector Revenues

- 41.69 — FY 2015
- 40.29 — FY 2016
- 40.93 — FY 2017
- 39.49 — FY 2018

REVENUE IN BILLION US$

FINANCIAL YEARS 2015 - 2018

Source: https://www.ibef.org/download/telecommunications-feb-2019.pdf, accessed on 26.04.2019

> Higher spectrum prices are more detrimental to the weaker and lower income sections of society as their adoption of the benefits of technology is significantly delayed. This reinforces the need for the government to lower the price of spectrum.
>
> ***TV Ramachandran***
>
> *President, Broadband India Forum and Member of the High Level Government Forum for 5G 2020*

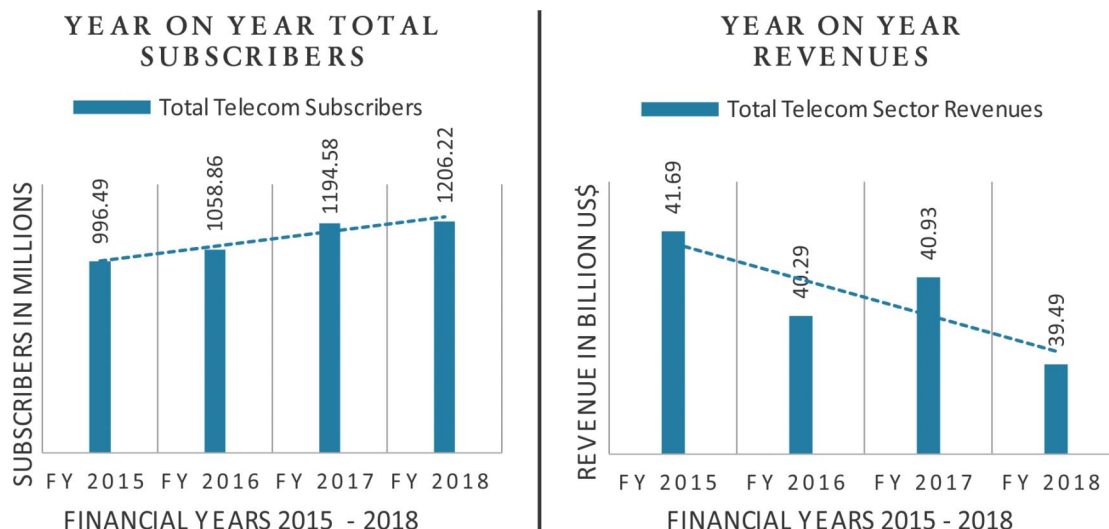### 4G itself at a Nascent Stage

It has been argued that many parts of the country are still reliant on 2G and 3G connectivity.[34] As is the case at present, India does not have a robust 4G ecosystem in the country and a substantially large number of users still belong to 2G and 3G.[35] Also, by 2025, the user base of 4G is expected to be nearly four times the number of 5G users, globally, with 59 percent of the global user base expected to be on 4G speeds by 2025.[36] An ITU report states that until the case for 5G is made, policymakers should focus on enhancing the availability and quality of 4G networks.[37]

Added to this, India has been ranked 109 out of 124 countries on the parameter of mobile internet speeds. A major reason for the same is that 4G download speeds in the country (9.12 Mbps) are much lower than the global average (23.54 Mbps).[38] Accordingly, a countrywide release of 5G may prove to be a daunting task for the government and other relevant stakeholders, soon.

Late Roll Out of 5G Beneficial for India

Industry experts believe that country-specific use cases are yet to be developed for India, which may take time. It is also said that 5G would only make sense once India-centric commercially viable use cases are developed, since 4G is more than adequate to cater for most Indian consumers, as well as for the existing IoT, soon.[39]

Furthermore, experts also stress that India largely being a price-sensitive market, may wait for economies of scale for cheaper 5G supported handsets, before rolling out 5G.[40] Similar skepticism was also acknowledged by the report of the 5G High-Level Forum titled 'Making India 5G Ready', as prepared by the steering committee constituted by the DoT, which also added that *5G deployment strategy faces conflicting considerations. If we go for early adoption, the equipment is likely to be more expensive, and being early, it will also be glitchy needing costly maturing. On the other hand, early adoption will fast track the country's embrace of 5G's benefits and increase opportunities to develop innovative use cases that support Indian needs. Balancing these conflicts needs to study.*[41]

Hiccups in Collaborative Standard Setting for 5G

The TSDSI has developed an indigenous Radio Interface Technology (RIT), as an India specific technology enhancement, which increases the mobile signal coverage area of the Low-Mobility-Large-Cell (LMLC) technology. The technology has been sent to the ITU for evaluation, to be adopted as a standard.[42] Together, TSDSI-RIT and LMLC are believed to hold the potential to enable rapid and affordable deployment of 5G in rural, remote, and sparsely populated areas.[43]

Although the efforts of TSDSI are laudable, experts and telecom companies allege a lack of harmonisation between India's proposed standards, with the ones which are being finalised by global Standard Setting Organisations (SSOs), i.e. the 3rd Generation Partnership Project (3GPP), of which TSDSI is also a member. Any deviation from a harmonised standard development process can lead to various adverse impacts on relevant stakeholders.

The world is gazing at a time of massive connectivity, especially with the advent of 5G. In such times, different and incompatible

> The world is gazing at a time of massive connectivity, especially with the advent of 5G. In such times, different and incompatible technologies can hinder the growth and expansion of technology.

The many benefits of adopting a collaborative/harmonised standard-setting approach, while ensuring interoperability have been well documented in the CUTS report titled 'Standards Development and the 5G Opportunity'.

technologies can hinder the growth and expansion of technology. Running away from standardisation may have its own very high costs.

The many benefits of adopting a collaborative/harmonised standard-setting approach, while ensuring interoperability have been well documented in the CUTS report titled 'Standards Development and the 5G Opportunity'.[44] It calls for being wary of unilateral standard-setting approaches which may have adverse impacts on follow-on innovation, interoperability, consumer choice, etc.

For the aforementioned reasons, 5G is unlikely to enter the Indian market any time soon. The deployment will be gradual and the existing circumstances sufficiently justify the delay. The erstwhile Telecom Secretary Aruna Sundararajan also expected a complete roll-out of 5G by 2022. Notably, India lags behind other Asian countries like South Korea, Japan, and China in deploying 5G in 2020.

4 / Future of 4G

India must leverage its strength in software development, and focus on developing data driven use cases of 5G in the Indian context.

Vikram Tiwathia
*Deputy Director General*
Cellular Operators
Association of India

Myth: 5G will Replace 4G Altogether and Fast

Considering the enhanced capabilities of 5G, it remains to be checked whether once deployed, can 5G be expected to replace 4G LTE altogether, and fast. This gets the issue more pertinent, considering many consumers have shown willingness to change their mobile device, operating system, and even their service provider, in case 5G is made first available on them. This same has been shown in Graph 10, which shows their eagerness to adopt 5G, once made available.

Presenting the Reality: 4G to Stay for Now, and Co-Exist with 5G

Contrary to such expectations, 4G and 5G are set to coexist for a long time, not only in India but elsewhere as well. No wireless network has ever wholly replaced its predecessor, if only because there are so many areas of the world such as India where 3G and even 2G service is still the norm.[46] Furthermore, this may be based on the following:

Graph 10: Consumers Willingness to Change Handsets, Operating Systems or Service Providers to Avail 5G Sooner[45]
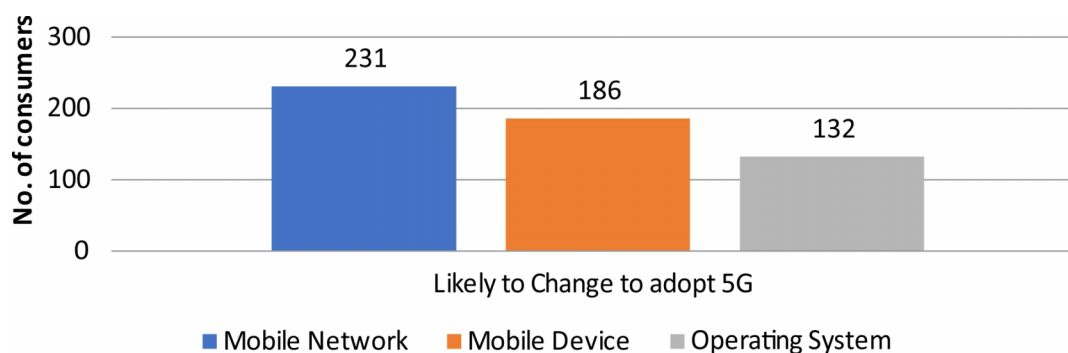
Standalone vs. Non-Standalone Technology

As per 3GPP Release 15,[47] 5G will be deployed with the help of two distinct technologies, i.e. Standalone (SA) and Non-standalone (NSA) 5G networks.

Simply put, *SA 5G features full user and control plane capability using a next-gen core network architecture, i.e. it will reconfigure infrastructure for cloud data behind the scenes, as well as how data is parcelled up and sent over a network.*

SA 5G is not backward compatible. Whereas, NSA 5G still makes use of existing 4G Long-Term Evolution (LTE) radio and backend technologies, and combines them with the New Radio technologies of 5G to provide faster connections to users.[48]NSA 5G is backward compatible.

India needs enhanced download/upload capability through proliferation of public WiFi hotspots, and undertake adequate field trials of 5G use cases.

TV Ramachandran

President, Broadband India Forum and Member of the High Level Government Forum for 5G 2020

Notably, technical specifications of NSA were defined in December 2017, whereas those for SA were defined in June 2018.[49] Apart from the early standardisation of NSA, this mode of 5G deployment is considered to be a faster way than SA, since it makes use of existing LTE networks. It is also set to be cost-saving initially, since the added investments required for setting-up the 5G core network would be avoided.

Furthermore, most of the initial use cases of 5G would not require SA or end-to-end 5G coverage, and the NSA mode will be sufficient to cater to them.[50] Therefore, it may be safe to assume, that the first round of 5G enabled products and networks will make use of the currently available LTE technology, or 4G in other words. To back it up, most of the world (except China) is moving ahead with NSA, primarily to deriving value from existing and costly network investments.[51]

Interworking 4G and 5G

Building a dense network for 5G is expensive and can only partially be secured in the first few years of deployment. Therefore, interworking 5G with 4G is inevitable. As a feature, 4G-5G interworking means that when 5G is being deployed on a higher frequency, it will leverage the existing 4G deployments. To fill the coverage gaps in 5G in the initial phase, it will combine the low with high-frequency access. It is also referred to as LTE-NR interworking.

LTE-NR interworking is considered valuable as it will make the transition process from 4G to 5G smooth over a while. So, even if 5G is launched soon, it will work in conjunction with 4G networks in the early stages and not replace 4G altogether. The interworking

> In view of the extremely low penetration of fixed broadband in India, to ensure reasonable mobile broadband quality (speed), it is critical to have, as in other comparable nations, ubiquitous availability of Public WiFi Hotspots to reduce the pressure on the limited mobile spectrum.
>
> ***TV Ramachandran***
> *President, Broadband India Forum and Member of the High Level Government Forum for 5G 2020*

technology is not only suggested by telecom associations across the world but also by several major cellular operators.[52]

India is Still Expanding its Smartphone User Base

The Indian mobile phone market has largely been dominated by feature phones.[53] It was only in end 2018 that India's smartphone[54] market equalled that of feature phones.[55] Notably, feature phones are still relying on 2G mobile technology. Industry experts also subscribe to the view of 2G feature phones staying in the Indian market, due to their inexpensiveness.[56] Safe to say, that 5G replacing any previous technology, seems a tall order from the near future.

Setting-up of 5G Antennas and Towers May Take Time

To facilitate reasonable coverage, 5G service providers would have to build 5G antennas and towers extensively. Also, 5G technology demands that these be very close to users, as opposed to its predecessor technologies. The entire process is not only time-consuming but expensive as well, making its reach unevenly spread across geographies.

Due to such barriers, even after the initial launch of 5G in the country, consumers are expected to mostly be availing of the coexisting 4G services, even on a 5G enabled handset, in a 5G enabled city.[57]
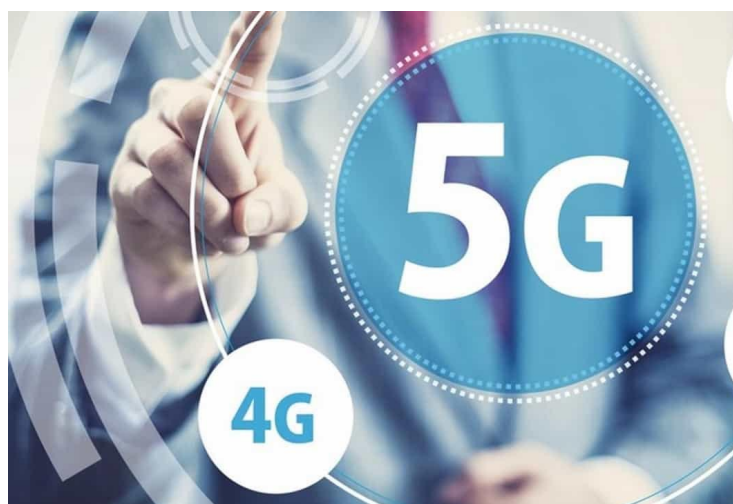
To sum up, expecting 5G to wipe out 4G completely and fast may not be a sound economic idea. Since LTE was not a backward-compatible technology, a lot of investment has had to be made and is still being made for setting up the 4G infrastructure. This investment would be justified only if the telecom companies can reap the benefits of the infrastructure. 5G NR is expected to coexist with LTE. The coexistence of LTE and NR was also a 3GPP Release 15 work item.[58] For this, several coexistence techniques have been proposed and are under consideration.[59] 4G base station sites are expected to support 5G NR in managing the coverage issues.

5 / Conclusion

> The government's initial efforts towards the Digital India programme, and the National Digital Communication Policy are appreciable. However, the momentum with respect to 5G has waned since the announcement of this Policy. This needs to be re-energised for India to leverage Digital Transformation.
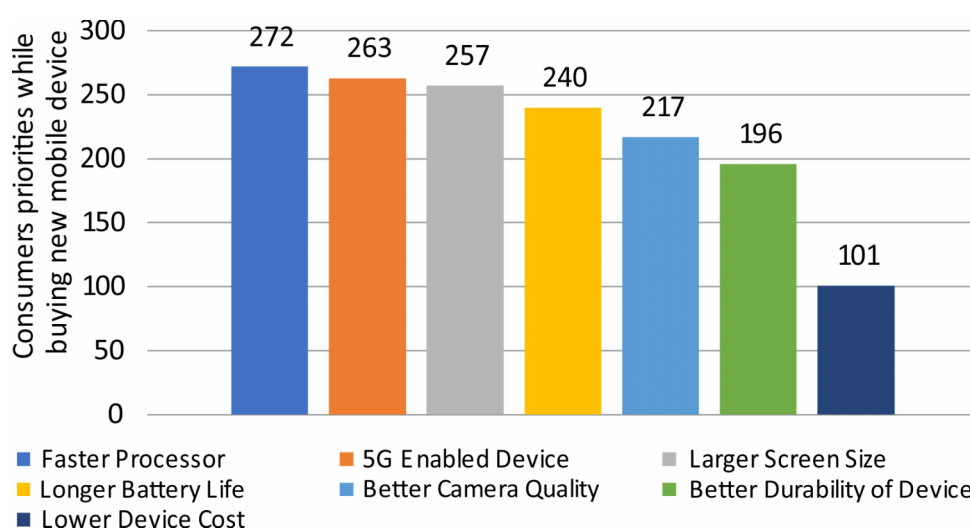>
> ***Vikram Tiwathia***
> *Deputy Director General*
> *Cellular Operators*
> *Association of India*

5G, the new telecom Generation, has created a lot of buzzes even before it hit the markets. It may be fair to say that the buzz is well deserved as 5G promises speeds, latency, and several network factors that are unprecedented. These factors make 5G the valuable commodity that it is being made out to be. While a lot of the buzz is well-placed, there has been significant misinformation in various reports that seem to have created some myths in the minds of the consumers, which have been busted in this report.

Irrespective of the above, the survey findings suggest that consumers are eager to avail of 5G services. While buying a new smartphone, they prioritise it to be 5G enabled, apart from having various other upgrades. These have been given in Graph 11.

5G is already beginning to be available in some countries in limited pockets, with 61 operators in 34 countries as per recent figures.[61] India is striving to beat its past of delay in the adoption of a telecom technology of nearly a decade. Predictions abound, as to

Graph 11: Consumers Priorities While Buying a New Smartphone[60]

Legend:
- Faster Processor
- 5G Enabled Device
- Larger Screen Size
- Longer Battery Life
- Better Camera Quality
- Better Durability of Device
- Lower Device Cost

Values: 272, 263, 257, 240, 217, 196, 101

> 5G deployment faces several challenges beyond those in 2, 3 and 4G networks. 5G may need new business models, improved infrastructure sharing, greater security controls and interworking with applications/sectors that have not so far used wireless connectivity. All this requires urgent government action, some of which were outlined in the August 2018 5G High Level Forum Report.
>
> ***Arogyaswami Paulraj***
> *Professor Emeritus, Stanford University and Chair of the Task Force of the High Level Government Forum for 5G 2020*

India's future capability to act as a major market for 5G in the years to come, however, realising that vision is still a way to go.[62]

Going forward, a major issue that the government should be focussing on is the financial health of the telecom sector which has been highlighted as a challenge in this report. Quarter after quarter, the telcos are reporting record losses which are the case for all telcos, whether state-run or not. While it could indicate poor business strategies, but at the same time, one cannot rule out the existence of some structural, governance and policy issues in the telecom sector which could be ailing the health of the sector. In that light, the first step by the government should be to consult the relevant stakeholders for devising ways to strengthen the telecom sector, for fulfilling the country's ever-growing telecom needs.

This may also impact the timelines of spectrum auction, 5G trials, and subsequent deployment. The DoT has already given several timelines within last year for spectrum allocation, the last one of which was for auction in the last quarter of the fiscal year 2019-20. However, trails are not expected sooner than the last quarter of this year.

While consumers look forward to 5G, the absence of 5G enabled devices along with useful use cases of 5G technology were seen as significant challenges for consumers to avail 5G in India, which must be overcome.

Annexure

Table 1: Technological Progress from 1G to 4G	
Strengths	**Limitations**
1G	
• Mode of service: voice only	• Poor voice quality due to interference • Made use of Frequency Modulation[63] (FM) technology, which compromised security, since calls could be decoded using an FM demodulator • Relied upon Frequency Division Multiple Access[64] (FDMA), due to which only a limited number of users could avail the service, and network coverage was poor • Roaming was not possible between similar systems
2G	
• Roaming is possible • Enhanced security through encrypted voice transmission • First internet at the lower data rate • General Packet Radio Service[65] (GPRS) was introduced and successfully deployed, which was capable of data rate up to 171.2Kbps (maximum) • Enhanced Data GSM Evolution[66] (EDGE) also developed to improve data rate for GSM networks, which was capable to support up to 473.6Kbps (maximum) • Multimedia message support	• Limited hardware capability • Low internet speed • Unable to facilitate content-rich services, such as videos

Strengths	Limitations
3G	
• Faster internet speed • Decreased latency[67] and lag • Enhanced security, a greater number of users, and coverage • Low operating and deployment costs • Backward compatible[68] • Faster speeds. 3.5G network could support up to 2mbps internet speed	• Costly infrastructure, equipment, and implementation
4G	
• Promised a much higher peak speed of 100Mbps when mobile and 1Gbps when stationary, although the available average speed is rarely as fast[69] • Enhanced security and mobility • Reduced latency • Enabled Voice over LTE network (VoLTE), i.e. uses IP packets for voice	• Expensive hardware and infrastructure (due to backward incompatibility with 3G) • Wide deployment and upgrades are time-consuming • The speed is not as promised, and hence, not enough capacity for connecting a large number of devices

5G IN INDIA

Endnotes

1   https://telecom.economictimes.indiatimes.com/news/covid-19-telecom-regulator-to-initiate-industry-dialogue-on-broadband-speed-and-reliability/76124581

2   https://www.mckinsey.com/~/media/mckinsey/industries/technology%20media%20and%20telecommunications/telecommunications/our%20insights/connected%20world%20an%20evolution%20in%20connectivity%20beyond%20the%205g%20revolution/mgi_connected-world_discussion-paper_february-2020.ashx

3   https://www.zdnet.com/article/5g-initial-use-cases-are-going-to-be-all-about-business/

4   It should be noted that not all respondents answered all questions. Hence the graphs in subsequent chapters may depict variance in the number of responses received.

5   Live Mint (2016), https://www.livemint.com/Politics/kZ7j1NQf5614UvO6WURXfO/88-of-households-in-India-have-a-mobile-phone.html

6   Statista (2020), https://www.statista.com/statistics/257048/smartphone-user-penetration-in-india/

7   https://www.techradar.com/in/news/5g-and-smart-cities-everything-you-need-to-know

8   *See* The Policy Forum at AT&T. "5G" policyforum.att.com. Available at https://policyforum.att.com/innovation/5g/. Accessed on 10th January, 2020.

9   ITU Media Centre. "5G - Fifth generation of mobile technologies" itu.int. Available at https://www.itu.int/en/mediacentre/backgrounders/Pages/5G-fifth-generation-of-mobile-technologies.aspx. Accessed on 8th January 2020.

10   What do you think will be the use of an upgraded technology from 4G to 5G? Single choice options were given to respondents to choose from. 455 respondents answered this question.

11   What comes to your mind when you hear the term 5G?

12   Husenovic, Kemal. *Setting the Scene for 5G: Opportunities & Challenges*. ITU Publication, 2018. Available at https://www.itu.int/dms_pub/itu-d/opb/pref/D-PREF-BB.5G_01-2018-PDF-E.pdf. Accessed on January 08, 2020.

13   Which of the following use cases of mobile internet related services are you most eagerly looking forward to? 463 respondents answered the question.

14   Zennaro, M. *Introduction to the Internet of Things*. ITU Publications 2017. Available at https:/
      /www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/SiteAssets/Pages/Events/2017/
      Nov_IOT/NBTC%E2%80%93ITU-IoT/Session%201%20IntroIoTMZ-new%20template.pdf.
      Accessed on March 03, 2020

15   *Ibid.*

16   *Ibid.*

17   Do you possess any of the following devices? 463 respondents answered this question.

18   KPMG. *Converging 5G and IoT: a faster path to smart manufacturing. KPMG* Publication June
      2019. Available at https://assets.kpmg/content/dam/kpmg/xx/pdf/2019/06/converging-5g-
      and-iot-a-faster-path-to-smart-manufacturing.pdf. Accessed on February 05, 2020

19   5G Americas. *5G-The Future of IoT*. 5G Americas Whitepaper, November 2019, available at
      https://www.5gamericas.org/wp-content/uploads/2019/07/
      5G_Americas_White_Paper_on_5G_IOT_FINAL_7.16.pdf, accessed on January 09, 2020.

20   Please tick the appropriate reasons for not using any of the devices mentioned above. You
      may tick multiple options. 463 respondents answered this question.

21   Ghosh, Mohul. "Airtel 5G Rolled Out In Kolkata, Bengaluru – 5G Wave Hits India" trak.in.
      Available at https://trak.in/tags/business/2017/09/28/airtel-5g-rollout/. Accessed on
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      Available at https://www.thequint.com/tech-and-auto/tech-news/why-india-5g-network-
      smartphone-not-likely-2019. Accessed on January 10, 2020.

23   Verma, Shubham. Realme X50 Pro 5G is in India and it is a phone with many firsts,
      indiatoday.in. Available at https://www.indiatoday.in/technology/features/story/realme-x50-
      pro-5g-is-in-india-and-it-is-a-phone-with-many-firsts-1651132-2020-02-29.

24   by which year do you think 5G will become available in Delhi? 463 respondents answered
      this question.

25   Mention the year by which you expect that service to be available in your city. 463
      respondents answered this question.

26   Which of the following factors do you perceive to be challenges associated with 5G? 376
      respondents answered this question.

27   What is your opinion about deployment of 5G globally? 463 respondents answered this
      question.

28   Analysts have suggested that the delay in 5G spectrum allocation will also result in the final
      commercial deployment of 5G in India. In November 2019, Ericsson said in its Mobility
      Report that it would come to India in 2022. Nokia recently said that it is coming in 2021.
      There are other expert estimates that suggest 2021 to be the expected year of 5G
      deployment. *See* the Ericsson Report here.; https://www.livemint.com/technology/tech-
      news/don-t-rush-to-buy-5g-phone-there-s-no-network-yet-11582741322126.html;
      opinions of other experts may be seen here, here and here.

29   Telenor exits India as Airtel acquires local arm to fight Reliance Jio, available at: https://
      www.hindustantimes.com/business-news/telenor-exits-india-as-airtel-acquires-its-
      operations/story-Lt5i5JDUafAnLvAfm6GdHP.html

30 Vodafone, Idea are ready for the big fight with Reliance Jio on its own turf, available at: https://www.businesstoday.in/sectors/telecom/vodafone-idea-merger-will-it-stop-users-from-shifting-to-reliance-jio-airtel/story/248356.html

31 All you wanted to know about AGR, available at: https://www.thehindubusinessline.com/opinion/columns/slate/all-you-wanted-to-know-about-agr/article30008124.ece

32 Subramanian, Vekatraman. "*Indian telco sector faces potential bankruptcies and steep capex cutbacks to cope with October court decision*" mtnconsulting.biz. Available at https://www.mtnconsulting.biz/indian-telco-sector-faces-potential-bankruptcies-and-steep-capex-cutbacks-to-cope-with-october-court-decision/. Accessed on February 05, 2020.

33 AGR: DoT seeks 20 years' time for recovering dues from Telcos, moves Supreme Court for modification of its orders, available at: https://www.barandbench.com/news/litigation/agr-dot-seeks-20-years-time-for-recovering-dues-from-telcos-moves-supreme-court-for-modification-of-its-orders

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35 TRAI, "Wireless Data Services In India: An Analytical Report". Available at https://main.trai.gov.in/sites/default/files/Wireless_Data_Service_Report_21082019_0.pdf. Accessed on February 18, 2020.

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39 Khan, Danish. "India does not need 5G yet: Vodafone Idea" economictimes.indiatimes.com. Available at https://economictimes.indiatimes.com/industry/telecom/telecom-news/users-internet-of-things-iot-services-dont-need-5g-as-yet-voda-idea/articleshow/68088840.cms?from=mdr. Accessed on January 10, 2020.

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41 DoT Report, Making India 5G Ready. Available at: https://dot.gov.in/sites/default/files/5G%20Steering%20Committee%20report%20v%2026_0.pdf?download=1

42 A standard is a document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. Standards have special significance in the domain of Information and Communication Technologies (ICT): addressing needs for interconnection

and interoperability which is particularly important for open markets, where mobile users can 'mix and match' equipment and services, and where suppliers can benefit from economies of scale. https://www.etsi.org/standards/why-standards

43   https://tsdsi.in/indias-5g-technology-tsdsi-rit-moves-another-step-forward-at-itu/

44   CUTS Report, titled Standards Development and the 5G Opportunity Mapping the way forward for India's telecommunications industry. Available at: https://cuts-ccier.org/pdf/Report-Design_in_India_to_Maximize_5G_Opportunities.pdf

45   If 5G is launched and your mobile handset or network operator does not support it at the time, which of them are likely to change in order to adopt 5G sooner? 376 respondents answered this question.

46   https://spectrum.ieee.org/tech-talk/telecom/wireless/5-myths-about-5g

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52   *See* for instance, the recommendations of Samsung and Nokia in this regard.

53   A feature phone is a basic mobile phone with much more limited computing capabilities than a smartphone. A feature phone runs on proprietary firmware, with third-party software support through a platform like Java ME. A feature phone may or may not include internet capabilities. Where internet capabilities are available, the features are very basic – email client and web browser with limited capabilities. Mobility Arena. "What is the difference between a smartphone and a feature phone?" mobilityarena.com. Available at https://mobilityarena.com/difference-between-smartphone-feature-phone/. Accessed on January 10, 2020.

54   a smartphone is a mobile phone that has advanced functions similar to a personal computer. Those computing functions include an operating system, ability to install and run downloaded apps, email and web browsing. Essentially, a smartphone is a mobile computer. Mobility Arena. "What is the difference between a smartphone and a feature phone?" mobilityarena.com. Available at https://mobilityarena.com/difference-between-smartphone-feature-phone/. Accessed on January 10, 2020.

55   BGR. "Smartphones in India set to overtake feature phones, both now at par for first time" bgr.in. Available at https://www.bgr.in/news/smartphones-overtake-feature-phones-india-market-at-par-first-time-november-2018-idc-report-quarterly-mobile-phone-tracker/. Accessed on January 10, 2020.

56   Khan, Danish. "2G Feature phones are here to stay for a while: Qualcomm" gadgetsnow.com. Available at https://www.gadgetsnow.com/tech-news/2g-feature-phones-are-here-to-stay-for-a-while-qualcomm/articleshow/66914710.cms?from=mdr. Accessed on January 10, 2020.

57   Elgan, Mike. "Why 5G will disappoint everyone" computerworld.com. Available at https://www.computerworld.com/article/3310067/why-5g-will-disappoint-everyone.html. Accessed on January 10, 2020.

58   Rysavy Research. *LTE to 5G, Rysavy Research/5G Americas*. August 2018. Available at https://www.5gamericas.org/wp-content/uploads/2019/07/2018_5G_Americas_Rysavy_LTE_to_5G-_The_Global_Impact_of_Wireless_Innovation_final.pdf. Accessed on January 10, 2020.

59   *Ibid.*

60   Please select the factors that you would consider while purchasing your next mobile handset. 376 respondents answered this multiple-choice question.

61   Global mobile Suppliers Association "*LTE and 5G Market Statistics – January 2020*" gsacom.com. Available at https://gsacom.com/download.php?id=7533. Accessed on February 05, 2020.

62   Khan, Danish "*India can become 2nd largest 5G market in 10 years: Huawei*" economictimes.indiatimes.com. Available at https://economictimes.indiatimes.com/industry/telecom/telecom-news/india-can-become-2nd-largest-5g-market-in-10-years-huawei/articleshow/68145041.cms. Accessed on February 05, 2020.

63   Frequency Modulation (FM) is a method of modifying frequency of carrier signal in order that the receiver can obtain the desired transmitted information.

64   A system whereby spectrum is divided up into frequencies and then assigned to users. Only one subscriber at any given time is assigned to a channel. The channel therefore is closed to other conversations until the initial call is finished, or until it is handed-off to a different channel. For instance, if A call B and the call is connected on a specific frequency, that frequency will remain occupied until the call is complete. *See* ITU's primer on access technologies: https://www.itu.int/osg/spu/ni/3g/technology/index.html#Access%20Technologies. Accessed on January 10, 2020.

65   GPRS introduced packet switching as against circuit switching. This means that for transmission of message from source to destination, a physical connection is not created before the transmission. The message is converted into small manageable packets and each packet may take a different path to reach the destination. At the destination, the packets are assembled and put in order. *See* 3GPP's primer on 2G technologies: https://www.3gpp.org/technologies/keywords-acronyms/102-gprs-edge. Accessed on January 10, 2020.

66   The technology in EDGE is same as GPRS. However, the coding and transmission of data is more sophisticated which results in better internet speed.

67   Latency is the delay between a user's action and a web application's response to that action, often referred to in networking terms as the total round-trip time it takes for a data packet to travel. https://blog.stackpath.com/latency/

68   The capacity of a system to be interoperable with the previous generation of that technology.

69   Global Average is less than 20 Mbps. India is still under 10 Mbps. *See* Boyland, Peter. *The State of Mobile Network Experience: Benchmarking mobile on the eve of the 5G revolution*. OpenSignal, 2019. Available at https://www.opensignal.com/sites/opensignal-com/files/data/reports/global/data-2019-05/the_state_of_mobile_experience_may_2019_0.pdf. Accessed on January 10, 2020.

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