THE ADVANCE TO 5G[1]

5G is the fifth generation of cellular network technology. When fully deployed, 5G networks will transmit at speeds that are 100 times faster than current 4G technologies. The major factors driving the development of 5G are (i) increasing demand for broadband services delivered over mobile networks, and (ii) development of the Internet of Things (IoT). Once in place, 5G networks will change virtually all industries.

5G will use high radio frequencies with massive bandwidths, dense base stations, and dramatically greater numbers of antennas. Development of these dense networks will require huge upfront investments and collaboration of multiple market participants in setting common standards, building up infrastructure and deploying the network.

1. INTRODUCTION

This brief puts 5G into historical context and explains why it is indeed a paradigm shift in mobile technologies. Even though the development of 5G is underway, standards are still evolving and may never fully converge. As with earlier generations, firms have plenty of room for mistakes when they make investments that are specific to particular customers.[2] Completing the shift will require overcoming major transition issues.

The brief also provides detailed information about countries and firms that are leading the advance to 5G and the consequences for them. One other issue looms large – the potential "splinternet" between China and US. The brief addresses this significant issue as well.

In Section 2, we review prior generations of mobile technology. In Section 3, we explain why 5G is a paradigm shift. In Section 4, we identify various social issues with the advance to 5G. In Section 5 we discuss implications for the China-US relationship.

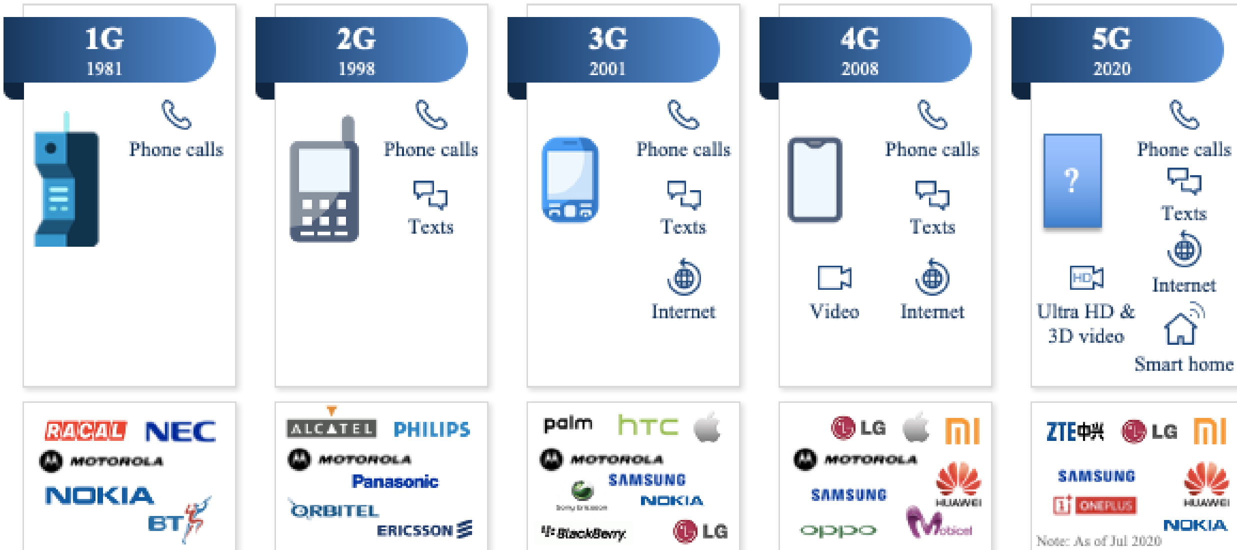
2. 1G to 4G

Your professor worked at the Antitrust Division of the US Department of Justice and recalls that a senior executive from AT&T came and briefed a small group of economists about something called "cellular radio" and its potential use in major US cities. As we walked out of the interior conference room, we were unsure about the technology, why it mattered, and why we received a briefing. Of course, that was at the beginning of a new mobile communications technology. Since then, the world has moved from 1G to 4G, each a major step in functionality and impact.

The chart below summarizes the functional improvements along the way:

[1] This brief has been prepared for *Economic Analysis of High-Tech Industries*, August – December 2023, by Raymond Albuero, Jakub Madej, Aneta Gasiewska and Edward A. Snyder.

[2] Specific investments can lead to opportunistic behavior. Students who have taken Competitive Strategy at Yale SOM might recall the case on multi-sided platforms (XBOX), where the winning standard attracted the most users and other platforms failed.



Advent of mobile communications: 1G

In 1979, Nippon Telegraph and Telephone (NTT) in Tokyo launched the first generation of mobile networks known as 1G (BrainBridge, 2019). In 1984, NTT covered the whole Japan in terms of rolling out of 1G. The technology of 1G had several drawbacks such as poor coverage and low sound quality. Roaming capability between various operators was not supported. There were also compatibility issues between systems operating on different frequency ranges. One of the major issues of 1G was encryption. As calls were not encrypted, anyone with a radio scanner could drop in on a call. 1G's challenges with quality and security motivated efforts to develop 2G.

Encrypted calls and text messages: 2G

Under the Global System for Mobile Communication (GSM) standard, the second generation of mobile networks, or 2G, was launched in Finland in 1991. Unlike 1G, the calls in 2G were encrypted. The quality of digital calls improved with less static.

2G technology created new ways to communicate. Users could send text messages (SMS), picture messages, and multimedia messages (MMS) using their phones. 2G was a major step toward a more compelling digital future of communication. Consumers and businesses adopted digital technologies on a scale never seen before.

With initial speeds of about 9.6 kbit/s, networks invested in more advanced 2G infrastructure. Transmissions speeds increased to 40 kbit/s. Through Enhanced Data rates for GSM Evolution (EDGE) connection, speed of 500 kbit/s was offered. Despite the improvement in quality and security, transmission speed remained a challenge during the 2G era.

Video and VoIP: 3G

Even though network protocols had not been standardized, third generation or 3G was launched by Japan's NTT DoCoMo in 2001. With 3G, users could access data from any location in the world, as the 'data packets.' International roaming services became possible. 3G technology increased data transfer speed four times compared to 2G. This led to the increased adoption of services like video conferencing, video streaming, and voice over IP (e.g., Skype). Personal data assistants like Blackberry, which was launched in 2002, gained traction because of their powerful features made possible by 3G connectivity. In 2007, iPhone was introduced in the market, starting the era of smartphones. With the booming popularity of smartphones and ever-increasing demand for faster data transfer, 3G networks operated at capacity.

<u>High-quality video streaming over mobile: 4G</u>

4G was first deployed in 2009 in Stockholm, Sweden and Norway. Using the Long-Term Evolution (LTE) 4G standard, 4G became available for millions of consumers and the video-streaming industry using mobile technologies got traction. Fast mobile web access reached up to 1 gigabit per second for stationary users. This speed facilitated gaming services, HD videos and HQ video conferencing. Unlike 2G to 3G transition, which only required SIM card switching, specifically designed mobile devices were needed to support 4G. Device manufacturers leveraged this fact to drive revenues by introducing new 4G-ready handsets. A perfect example are Apple and Samsung reaching all time high market capitalizations of USD 1.6 trillion and USD 0.3 trillion respectively. Even though 4G is the current standard around the globe, some regions face network patches and low 4G LTE adaption. For example, according to the mobile data platform Ogury, UK residents can only access 4G networks 53 percent of the time.

3. 5G IS A PARADIGM SHIFT

As indicated, the major factors driving the development of 5G: (i) increasing demand for broadband services delivered over mobile networks, and (ii) buildout of the Internet of Things (IoT) including for machine-to-machine (M2M) applications. (Global Mobile Suppliers Association, 2015) The shift to 5G takes place, therefore, in the context of major ecosystems for smartphones and the IoT.

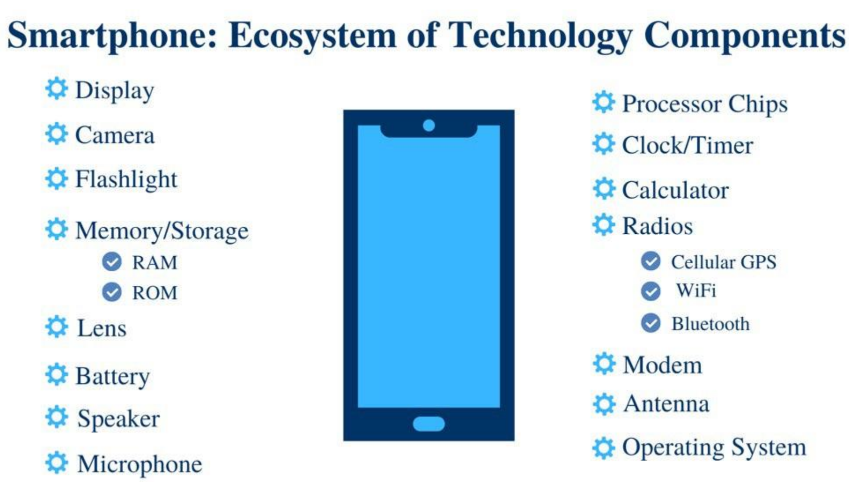


Figure 2. Technology components of a smartphone

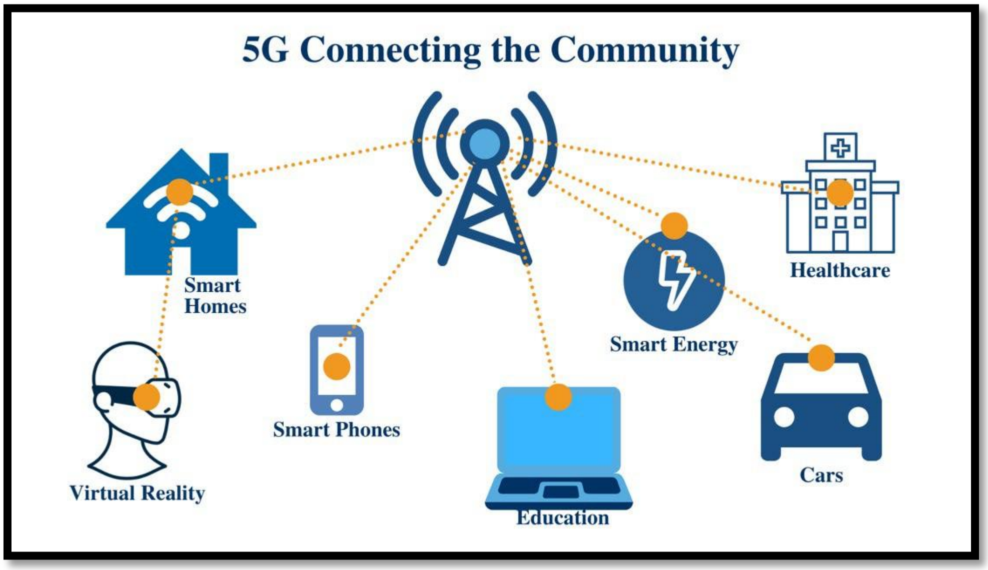


Figure 3. 5G connecting the community. Source: EMF Explained 2.0

Assuming that supporting infrastructure is in place to enable next-generation mobile data transfer, the performance goals of 5G are (Lavallée, 2016):

a. Up to 1000 times increased in bandwidth, per unit area
b. Up to 100 times more connected devices
c. Up to 10Gbps connection rates to mobile devices in the field
d. Maximum of 1ms end-to-end round-trip delay (latency[3])
e. Up to 90 percent reduction in network energy utilization

If achieved, 5G users could download a two-hour movie in 3.6 seconds. The current 4G standard, by comparison, allows to perform the same task in about six minutes.

[3] Latency refers to how much time it takes for a signal to travel to its destination and back. As such, lower latency is better.

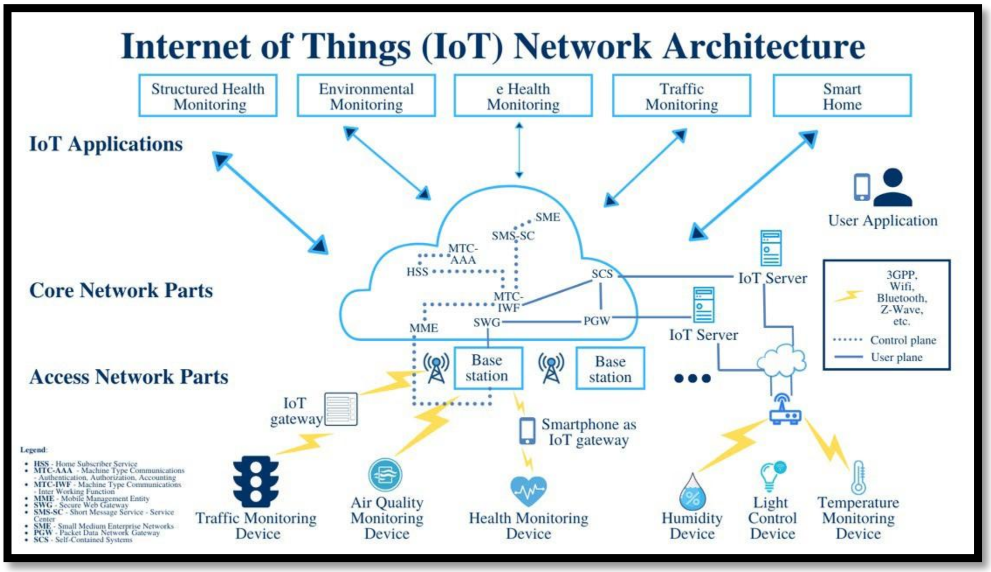


Figure 4. IOT Network Architecture. Source: ResearchGate

A main difference between 5G mobile standard and the previous generations is the diversity of applications supported (Chandramouli et al., n.d.). Interconnectivity among diverse devices, from household equipment, through wearables and industrial machinery will enable machines to self-organize and cater to diverse needs. The process of constant adaptation to user behavior and environmental conditions will eventually give rise to new use cases and business models, many of which have not been conceived yet. According to Chandramouli, Liebhart and Pirskanen, 5G connectivity will impact the following areas:

- Real world mobility. The way we travel and experience our environment;
- Virtual mobility. The way we can control remote environments;
- High performance infrastructure. The way the infrastructure supports us;
- 4th Industrial Revolution. The way we produce and provide goods

Achieving full potential of 5G networks is predicated on the availability of physical infrastructure, providers, financial investors and public-private partnerships (Deloitte, 2017). According to Frost & Sullivan (2019), 5G infrastructure includes three main components: Radio Access Network (RAN), Transport Networks, and Core Networks that provide multi-point access for users. As opposed to previous generations of cellular networks, 5G relies on much smaller and more densely deployed antennae, attached to existing physical infrastructure like poles and buildings, rather than massive cell towers (Abbosh & Downes, 2019). A dense network will allow to carry signals at a higher speed and with higher reliability. (Radio Access Network, Transport Networks, Core Networks). Infrastructure investment costs are borne by traditional communications service.

Work on the fifth-generation technology started in 2008, when NASA and Machine-to-Machine Intelligence (M2Mi) Corp started collaboration to develop IoT, M2M technology and 5G. This time, the technology was being developed in parallel in several locations, including the 5G R&D program in South Korea. In 2012, New York University founded a 5G-focused NYU WIRELESS.

As a result, bandwidth will be increased to gigabits per second, as opposed to current megabits, and therefore the connection speed might be even 100x higher than achieved with the current technology. As far as technical features are concerned, 5G is expected to be on par with wired broadband systems, including the fastest fiber-optic technology.

5G, with hyper-fast transmissions from anywhere (Deloitte, 2018), will enable a new level of connectivity, moving beyond connecting people through their mobile phones to connecting an unlimited number of devices, which exchange data all day, every day. Unlike today, when data exchange is limited by the number of people and the amount of time they have for consuming information, it will not be constrained by the human factor, with machines constantly exchanging information without our interference. Thus, 5G technology stands to accelerate innovation and dramatically improve productivity, affecting all areas of economy.

One area where 5G is poised to enable realization of the so-called *trapped value* is the emerging Internet of Things (IoT).[4] IoT means systems of interrelated computing devices and other machines communicating with each other over a network without requiring human-to-human or human-to- computer interaction (Abbosh & Downes, 2019). While IoT is associated with gadgets that perform random individual tasks like making coffee or switching on the lights, in the future it stands to completely transform how we interact with our possessions and with each other.

With superior connectivity, 5G will enable to transform every industry, from banking to healthcare (See briefs on implications of 5G on four industries). This will rise to innovations such as telemedicine, remote surgeries, and remote vital sign monitoring to save lives. Take healthcare as an example. While wearable device data provides somewhat helpful input to general health monitoring, it has immense potential to change the way treatments are prescribed, administered and personalized. Medical appointments over the phone, although on the rise in the COVID-19 pandemic, could be taken to the next level if patients are able to perform complex testing procedures from their living room using connected robots or print prosthetics on their own 3D printers.

4. COUNTRIES AND FIRMS LEADING THE ADVANCE TO 5G

As of 2023, South Korea, China, the United States, and the United Arab Emirates lead implementation and deployment of 5G technology[5]. Three telecom carriers in South Korea namely KT, LG Uplus and SK Telecom rolled out live commercial 5G services in December 2018.

5G Deployment in South Korea, China and USA

Country	Firms	Extent of 5G Deployment

[4] Trapped value is the failure to convert the possibilities created by new technologies into activities in the real world. It might arise from the market players knowing that a certain opportunity to create value is available, but not knowing how to unlock it.

[5] https://www.statista.com/statistics/1215456/5g-cities-by-country/, https://www.ookla.com/articles/state-of-worldwide-5g-2022.

South Korea	Collaboration of the three carriers: SK Telecom, LG Uplus, and KT Corp	• South Korea is the leader among other countries of 5G deployment. As of 2023, it has rolled out the technology to 85 cities. • The government estimated about 90 percent of country's mobile users will be on a 5G network by 2026. • KT Corp successfully completed a trial of a system from NEC Corp using extremely high frequencies for transmitting data at up to 3.2 Gbps (gigabits per second) in the Taebak Mountains.
China	China Mobile, China Telecom, and China Unicom	• China launched 5G network in October 2019 • China ranks next to South Korea with regards to 5G deployment. The country had rolled out 5G in 356 cities by 2023. • The best coverage for the 5G network is in Beijing, Shanghai, and Shenzhen. • It is estimated that the Global System for Mobile Communications (GSMA) projects will have 460 million 5G connections by 2025.
US	AT&T Inc. (T), Verizon Communications Inc. (VZ), Sprint Corp. (S), and T-Mobile US Inc. (TMUS)	• In 2023, there were 503 cities where 5G has been deployed. • Sprint has implemented mobile 5G in Atlanta, Chicago, Dallas-Fort Worth, Houston, Kansas City, Phoenix, Los Angeles, New York City, and Washington, D.C. • AT&T has rolled out its mobile 5G+ network live for consumers in parts of 35 cities and 190 markets.

As of April 2023, 5G was reportedly available in 92 countries[6].

Leadership in 5G means being positioned to push the leading edge of innovations throughout society. China and the US, with large domestic markets, can realize network effects as they pursue those innovations. (Deloitte, 2017). Given that the value of the service depends on the number of users, the first-mover advantages may provide a sustainable leadership position. The stakes are, therefore, huge. Consider Shinsegae I&C, a South Korean retailer that is already leveraging the power of 5G technology (Jaewon, 2019). The company partnered with SK Telecom to provide augmented reality and virtual reality, and big data services to its customers. Through this technology, Shinsegae I&C will create virtual stores with augmented reality services on its online and offline platforms. A new era of marketing and retailing is underway.

Technical background

There are ten leading suppliers in the 5G New Radio infrastructure market. These are the firms

[6] https://www.bisinfotech.com/5g-is-now-available-in-2497-cities-across-92-countries/.

that demonstrated leadership in the development and deployment of 5G infrastructure and solutions to the mobile communications market.

Four major suppliers: Ericsson, Huawei, Nokia and ZTE, provide a full range of 5G infrastructure solutions. They signed a range of contracts and agreements.

5G Infrastructure Providers

Supplier	Country	Company's Offering	Remarks
Affirmed Networks	Massachusetts, USA	Core Network	▪ More than 100 customers around the world including Tier 1 and Tier 2 mobile service providers ▪ Solutions are all software-based and the company has no hardware offerings
Cisco	California, USA	Transport Network Core Network	▪ Primary focus on broader and more general enterprise market, in addition to Communication Service Provider (CSP) market
Ericsson	Stockholm, Sweden	Radio Access Network Transport Network Core Network	▪ Offers network equipment, services, and software solutions to service providers around the world
Fujitsu	Tokyo, Japan	Radio Access Network Transport Network	▪ Customer base for its 5G Infrastructure solutions is primarily Japan and US
Hewlett Packard Enterprise	California, USA	Core Network	▪ Global customer base ▪ Supplies "infrastructure for the infrastructure"
Huawei	Shenzhen, China	Radio Access Network Transport Network Core Network	▪ Global customer base ▪ 60 percent of contracts in Europe
Mavenir	Texas, USA	Radio Access Network Core Network	▪ Offerings are all software-based, no hardware ▪ 250+ CSP customers in 140 countries
Nokia	Helsinki, Finland	Radio Access Network Transport Network Core Network	▪ Primary customers are CSPs ▪ Customers in all regions of the world
Samsung	Suwon, South Korea	Radio Access Network Core Network	▪ Focus on both 5G devices and 5G infrastructure ▪ Operates in 80+ countries globally

ZTE	Shenzhen, China	Radio Access Network Transport Network Core Network	▪ Secured 25 commercial 5G contracts and had shipped over 50,000 5G base stations. ▪ Has been working with 60 operators around the world in 5G-related cooperation agreements

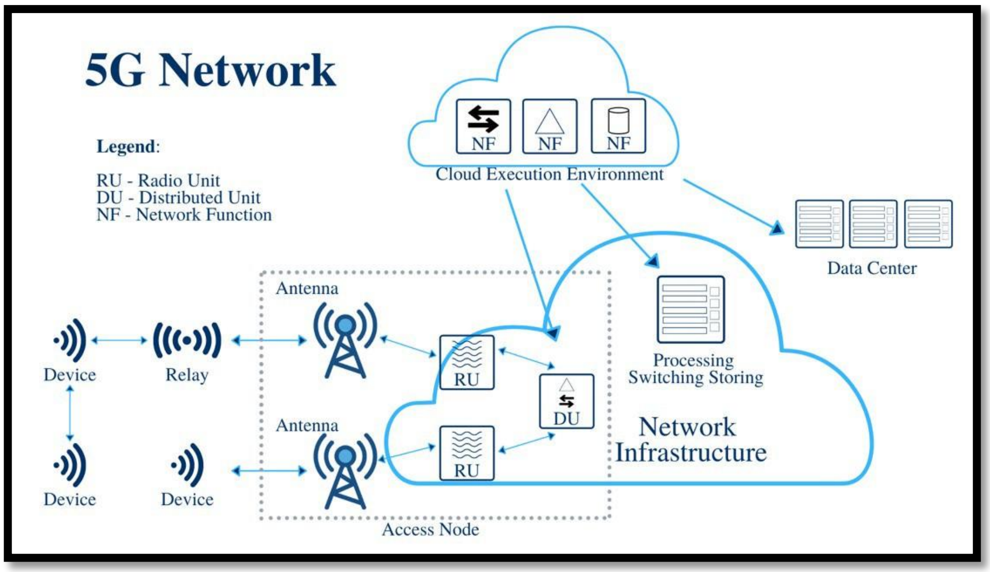


Figure 5. 5G Network. Source: IAENG 2017

Functional performance criteria for 5G infrastructure (Global Mobile Suppliers Association, 2015)

Parameter	Value
Latency in the air link	<1ms
Latency end-to-end (device to core)	<10ms
Connection density	100x compared with LTE
Area capacity density	1Tbit/s/km2
System spectral efficiency	10bit/s/Hz/cell
Peak throughput (downlink) per connection	10Gbit/s
Energy efficiency	>90 percent improvement over LTE

The last entry is worthy of emphasis: 5G will reduce energy consumption dramatically.

5. MAJOR ISSUES WITH THE TRANSITION TO 5G

This section enumerates the concerns being raised in the deployment of 5G such as issues on spectrum, standard and technology adoption, health problems, data privacy, inequality, ownership and governance.

Spectrum Issues

Although 5G network will leverage the spectrum in existing wireless communications networks bands up to 6GHz, and from 30GHz and upwards, an outstanding issue is the use of spectrum bands between 6GHz and 30GHz (Global Mobile Suppliers Association, 2015). National bodies like Ofcom in the UK suggested considering spectrum from 6GHz to use for 5G, while in the US, the FCC suggested looking only at frequencies from about 24 GHz. The uncertainty and agreement on the spectrum use have an impact on the 5G development. Meanwhile, NTT DoCoMo's 5G development plans were focused on the use of sub-6GHz spectrum. Research-based approach on usage of higher frequencies was adopted by multiple vendors.

Standards (No Deus ex Machina)

Under the standards set in IMT-2020, the 3rd Generation Partnership Project (3GPP) identified 5G New Radio (NR) system specifications as candidate 5G mobile communication system (S. Henry et al., 2020). In July 2020 the International Telecommunication Union (ITU) endorsed 3GPP 5G technology as International Mobile Telecommunications-2020 (IMT-2020) 5G standard (Bannerman, 2020).[7] IMT-2020 is an extension of the ITU's existing family of global standards which served as basis for 3G and 4G mobile systems (ITU, 2015).

It is important, however, to recognize that the ITU has no authority. As is typical, its roadmaps are incomplete and subject to change. Indeed, standards continue to evolve with progress to a new generation, change once a new generation of technology is in place, and are adapted to the requirements of individual customers.

Even as 5G is being deployed deployments, several foundational issues remain unresolved. These concern e.g., spectrum management for 5G usage, security of the network supply chain, data sharing and infrastructure development.

In the face of uncertainties concerning standards and customer demand, individual firms can make bets that pay off as well as mistakes. During the 4G era, Intel and Sprint invested in WiMAX instead of 4G LTE, its competitor technology, by launching ahead the competition (Marek, 2018). However, the technology failed to attract widespread support from equipment vendors and wireless operators. Then, Sprint adopted LTE. Therefore, adopting the standard set by ITU would be the best route for cellular providers. Intel, an iconic company with huge resources, was left behind.[8]

A more recent example involves Nokia. The Finnish company invested in chip for 5G technologies that is more expensive and uses more energy (Woo, 2020). Wireless carriers, as result, are buying cheaper and more energy-efficient versions offered by Huawei and Ericsson.[9]

As indicated by the table below, the history of standards confirms that risk and uncertainty are important features of the ecosystem for mobile technologies.

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[7] See: „*5G: The complicated relationship between ITU and 3GPP*" medium.com, February 1, 2020
[8] See: "*Where did it all go wrong for Intel?*" FT.com, July 9, 2020
[9] See: "*Nokia, Hurt by Costly 5G Chip Mistake, Struggles to Catch Huawei*" WSJ.com, July 6, 2020

Comparison of Different Mobile Technologies

Generation	Deployment	Standard	Services	Technology	Switching	Core Network	Bandwidth
1G	1970 - 1980	AMPS	Only voice	Analog	Circuit Switching	PSTN	2 kbps
2G	1980 - 1990	GSM IS-95 JDC iDEN	Digital voice Short messaging	Digital	Circuit Switching	PSTN	14-64 kbps
2.5G	2000 - 2003	GPRS EDGE	Digital voice, Short messaging	GPRS	Packet switching for data transfer	PSTN	14-64 kbps
3G	2000	UMTS (WCDMA)	Integrated High quality audio, video and data	Broad bandwidth CDMA/IP Technology	Packet	Packet N/W	2 Mbps
3.5G	2006 - 2010	HSDPA HSUPA	High speed voice/data Video	HSPA	Packet	GSM TDMA	14.4 Mbps 1-3 Mbps
4G	2010	LTE-TDD LTE-FDD Mobile WiMAX	Dynamic information access, wearable devices	WiMAX LTE	All packet	Internet	100 Mbps
5G	2020-2023	IP broadband LAN/W AN/PAN WWWW	Dynamic information access, wearable devices with AI capabilities	5G NR LTE-M	All packet	Internet	1 to 10 Gbps

Source: http://www.iaeng.org/publication/IMECS2017/IMECS2017_pp619-623.pdf

Within 5G, there is currently a lot of uncertainty around the prevailing standard for low-power, wide-area networks (LP-WAN) connectivity. While from the user perspective the options do not have to be mutually exclusive, cellular carrier providers will be forced to choose a technology to deploy to meet the narrowband IoT applications (Hwang, 2020).

<u>Health</u>

Over 230 scientists from more than 40 countries who expressed serious concern on the increasing exposure to electromagnetic fields (EMF) generated by electric and wireless devices (5G Appeal, 2018). Several recent scientific publications have shown that EMF has effects on living organisms. These effects include possible cancer risk, cellular stress, increase in harmful free radicals, genetic damages, structural and functional changes of reproductive system, learning and memory deficits, neurological disorders, and negative impacts on general well-being in humans. There is also growing evidence that EMFs affects both plants and animals.

<u>Data privacy and customer protection</u>

The advent of IoT and connected devices will provide device manufacturers with opportunities collect to vast amounts of customer data. Machine learning and AI are able to uncover insights about user behavior that may go far beyond what the user themselves is aware of (Downes, 2017). This opens up new possibilities to influence customer behaviors.

Implementation of 5G wireless networks created concerns because of the Chinese involvement (Reuters, 2020). The allegations came from risk of backdoors enabling surveillance of the network equipment sourced from Chinese vendors like Huawei. It is known that Chinese laws, such as the Internet Security Law, requires companies and individuals to assist the state intelligence agency on the gathering of information whenever requested.

Already today, a number of companies have been reported to misuse the power that comes with providing their services. For example, one smartphone-enabled garage door opener "fired a customer" who published a bad review by remotely disabling that customer's service. As customers use smart devices in an increasing number of daily activities, from setting their room temperatures to monitoring the health of their children, they will become more susceptible to the negative effects of such actions.

Another major concern relates to how data is stored and protected. As the volume of services increases, it becomes increasingly more difficult for individual customers to verify whether services they sign up for provide sufficient security. Yet hacking attacks might have dire consequences, particularly as far as smart vehicles, household security equipment, or health sensors are concerned.

The design of 5G networks, i.e., the fact that they rely on widely distributed infrastructure, makes them more prone to cyberattacks. As 5G networks rely on software-, rather than hardware-based digital routing, illegal activities are harder to spot due to no physical data storage locations (Giva, 2019). This translates into a higher number of potential entry points of attack and more difficult monitoring. Furthermore, current laws and regulations are generally deemed insufficient to sustain technological changes brought about by 5G.

As more sensors get connected to the network, real-time data about people's movement and use of physical infrastructure will be collected and intravenously shared, potentially compromising public and individual safety.

In the US, relatively lax federal oversight over data privacy is partially complemented on state and local level. Some of the strictest regulations are California's upcoming policies, which will ban price discrimination based on customers' opt-in into data sharing schemes and enable customers to prohibit sale of their data (FitzGerald, 2019).

The EU General Data Protection Regulation (GDPR), which came into effect in 2018, was the first large-scale regulation addressing data protection and privacy (Preimesberger, 2020). Although it implemented data management policies at an unprecedented scale, many experts still refer to it as "a tip of the iceberg."

Deepening the digital divide

Urban areas in the US both have better access to broadband connection and are improving it at a faster rate than rural and underserved communities. On average, 90 percent of Americans have access to what the Federal Communications Commission defines as high-speed internet (25 Mbps downstream/3 Mbps upstream). Yet only 61 percent of the rural population have access to 25/3 fixed broadband (Federal Communications Commission, 2016).

Additionally, given the aging, less efficient TDM network, broadband in rural areas is typically far more expensive than in urban and suburban environments (Deloitte, 2017). Given the scale of the investment required to upgrade physical infrastructure to enable 5G, few firms are incented to invest in high-speed broadband to underserved geographies. Satellites may be the solution.

Another issue concerns whether the digital divide would have a time component to it. Just as the developing world was able to leapfrog the developed economies in certain areas of the economy (e.g. mobile payments) due to the absence of legacy technologies, regions currently underserved by broadband carriers might in the future be positioned for faster technological development.

Ownership and governance

The 5G economy will introduce a new level of complexity to policymaking and regulation as new business models emerge and the old ways of delivering goods and services are either dramatically altered or abandoned completely (Campbell et al., 2017). Areas where policy and regulatory modernization will be required for a 5G-ready world include public safety, cyber security, privacy, spectrum allocation, public infrastructure, healthcare, spectrum licensing and permitting, and education, training and development.

The challenge for policymakers in the 5G economy is that they must be prepared to address the ubiquity of 5G in everyday life without creating regimes that stunt the continued innovation that will be critical to the success of the 5G economy. Policies that safeguard the ability of firms to take risks, make investments, and continue the relentless pursuit of innovation – particularly rules governing intellectual property protection – are the optimal vehicle for leveraging and capturing the full value of the 5G economy.

Although the infrastructure is owned by the telecommunication companies, the success of the 5G depends on defined government policy and framework. The number facility such as compact grid of base stations and antennas depends on the densification of the area (Telenor Group, 2018).

Therefore, the denser areas require more base stations and antennas. These could be poles, lamp posts, street cabinets, advertising signs, etc. Telecom companies are working to integrate these infrastructures to private and government owned assets. The role of local and central government is critical in allowing telecom companies to establish or lease access to sites, antennas, equipment etc. The government should ease out in regulations that restrict or make it difficult in gaining access to these base stations or sites.

Technology

To fully transition to 5G, wireless carriers still need to bid for the higher spectrum bands. The bidding in the US for 28 GHz alone reached $690 million in December 2018.

Another challenge would be 5G antennas which can only beam out over short distances. Therefore, antennas will be smaller for 5G network and more of them will be installed on buildings or homes to compensate for their shorter range. For the cities, extra repeaters are needed to spread out the waves and extend range while maintaining consistent speeds in more densely populated areas. Because of this, carriers will still use lower-frequency bands to cover wider area until 5G network progresses.

To build the network, a huge capital is required so carriers need to raise the money to do it by increasing customer revenue (D'mello, 2019). Similar with LTE that incurred higher initial cost, probably this will be same with 5G. The cost needed for the laying the groundwork for something new altogether. According to Heavy Reading's Mobile Operator 5G Capex, the total global spending on 5G is set to reach $88 billion by 2023.

6. IMPLICATIONS FOR CHINA – US RELATIONSHIP

One of the major issues faced by the 5G technology involves geopolitics. With the security concerns cited by former President Trump, Huawei was banned from America's telecom networks and denied access to important intellectual property from American supplier. US has been strong-arming its allies to reject the Chinese gear. Australia has done so, while Britain may restrict Huawei to peripheral parts of their networks. The countries where Huawei is banned, telecom operators choose to rely on more expensive alternative like Finland's Nokia, Sweden's Ericsson or South Korea's Samsung.

Supply of 5G services is also an object of a political dispute. The US government has raised concerns over two Chinese suppliers, Huawei and ZTE, with strong ties to the Chinese government, a fact that could pose a security risk. In the process of 5G NR deployment, both Trump and Biden administrations have been lobbying allies around the world to avoid these Chinese suppliers. The following countries banned one or both companies:

- Australia blocked both Huawei and ZTE[10]
- Japan effectively banned both suppliers
- New Zealand blocked Huawei
- Other countries, such as the UK and Canada, have not decided yet, while much of Europe

[10] https://www.caixinglobal.com/2018-08-23/huawei-zte-banned-from-5g-sales-in-australia-101318101.html.

has decided against banning either company.

China is aiming to get a first-mover advantage in the 5G technology. According to Andres Carvallo, CEO of consulting company CMG and a telecommunications market expert, 5G is where China will try to exercise its power and influence. China has its top-down directives and government policies to be ahead in the tech race and take advantage in 5G technology. Unlike America which has a piecemeal approach in launching 5G, China is rolling out 5G nationwide in 40 cities from its three major state-owned carriers. China built more than 600,000 stations in just three months between April and June 2023, and a total of 3 million stations.[11] According to PRC's Ministry of Industry and Information Technology, 5G base stations in China cover all urban areas of prefecture-level and county-level cities.

China has erected a "Great Firewall" for political reasons ("A Virtual Counter-Revolution," 2010). While US and Australia discuss plans to create a similar firewall to block child pornography or weapon-making instructions. For the governments, internet is too important to ignore. They are finding ways to enforce laws in the digital realm. The Chinese government are leveraging the technology to stop employees accessing websites and online services. This is the reason why Google at first censored its Chinese search service because there was no other way to be widely accessible in the country.

With this divide of use in telecom gears, there is a likelihood of incompatibility in IOT which will be a major concern (Vaitheeswaran, 2020). US will escalate the issue of security in dealing with Huawei's hardware. The 5G technology has been a unified global standard for networking however with this divide multinational firms with operations in Shenzhen and Silicon Valley cannot use the same IOT systems in both. This will be handicapping the development of IOT devices relying on the seamless 5G network where possible interoperability issues among the market surfaces.

Even if a splinternet emerges, there are many potential scenarios. Between the "no split" and "complete split" is a distribution of outcomes. Will a splinternet mainly implicate mobile carriers? Will IoT be split? Will the split encompass smart devices? And whatever the extent of the split, will there be "work-arounds?" Just as nature abhors a vacuum, markets and industries try to

[11] https://www.scmp.com/news/china/science/article/3228259/china-built-more-5g-base-stations-3-months-us-did-2-years.

eliminate frictions. Those with insights on these intermediate versions of a splinternet and how to navigate the frictions will have substantial advantages over those who are simply on the "wrong side."

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