E-CONOM

Online tudományos folyóirat
Online Scientific Journal

Tanulmányok a gazdaság- és társadalomtudományok területéről
Studies on the Economic and Social Sciences

ISSN 2063-644X

XI./1.

http://www.e-conom.hu

2022

E-CONOM

Online tudományos folyóirat I Online Scientific Journal

Főszerkesztő I Editor-in-Chief
SZÓKA KÁROLY

Kiadja I Publisher
Soproni Egyetem Kiadó I
University of Sopron Press

A szerkesztőség címe I Address
9400 Sopron, Erzsébet u. 9., Hungary
e-conom@uni-sopron.hu

A kiadó címe I Publisher's Address
9400 Sopron, Bajcsy-Zs. u. 4., Hungary

ISSN 2063-644X

DOI: 10.17836/EC.2022.1.031

NGUYEN, ZSOFIA[1]

The promised opportunities and economic realities of 5G

This study examines the emerging trends and best practices in adapting to 5G. It forecasts the contribution to gross domestic product (GDP) that countries are expected to leverage the new mobile network to their overall benefit. The findings suggest that despite complex political tension and supply chain disruptions impeding the rollout progress of 5G on the global scale, 5G still presents the potential of being a transformative socioeconomic catalyst for transformations that redefine work functions and rewrite the rules of competitive economic advantage. The profound effects range widely, from the positive impacts on human and machine productivity to ultimately elevating the living standards for people worldwide.

Keywords: 5G, telecommunications, technology, supply disruptions, economic contributions, value chain
JEL Codes: L960, L980, O320

Az 5G ígért lehetőségei és gazdasági realitásai

A tanulmány az 5G-hez való alkalmazkodás új trendjeit és legjobb gyakorlatait vizsgálja. Előrejelzi, hogy az országok bruttó hazai termékéhez (GDP) az új mobilhálózat várhatóan milyen mértékben járul hozzá. Az eredmények azt sugallják, hogy az 5G globális szintű bevezetésének előrehaladását akadályozó bonyolult politikai feszültségek és ellátási lánc zavarok ellenére az 5G még mindig magában hordozza annak lehetőségét, hogy olyan hatásos társadalmi-gazdasági katalizátor legyen, amely újrafogalmazza a kompetitív gazdasági előnyöket. A hatások széles skálán mozognak, az emberi és gépi termelékenységre gyakorolt pozitív hatásoktól kezdve az emberek életszínvonalának globálisan érzékelhető emeléséig.

Kulcsszavak: 5G, távközlés, technológia, ellátási zavarok, gazdasági hozzájárulások, értéklánc
JEL-kódok: L960, L980, O320

[1] The author is a Ph.D. student at the University of Sopron Alexander Lamfalussy Faculty of Economics (zsofia.trang.nguyen@phd.uni-sopron.hu)

Introduction

5G generally refers to the combination of technologies, standards, and services that comprise the next (fifth) generation of wireless technologies. Enterprises see 5G as a game-changing opportunity for consumer and business applications by providing wide-spread, ultra-broadband, and near real-time connectivity.

In recent years, 5G has been talked about in professional and general news media and by significant technology and telecommunication companies worldwide. According to CB Insights' Earnings Transcript tool (2020), at its peak in Q3'18, "5G" was mentioned over 1,000 times, up more than 100% from Q4'17. Corporates like Nokia, Qualcomm, Ericsson, Broadcom, and Verizon have all discussed the implications of 5G and plans for technology and service deployment.

IHS Markit estimates that in 2035, 5G technologies combined will enable 13.2 trillion USD of global economic outcome and the international 5G value chain to generate $3.6 trillion in economic output and support 22.3 million jobs (*Table 1*).

However, this new technology adaptation comes with significant investment needs. The same study evaluates that the 5G value chain will invest an average of $235 billion annually to continuously develop and maintain the 5G technology base within network and business application infrastructure (Campbell et al., 2019).

Table 1: The Economic Contributions in USD of the 5G value chain in 2023

Country	Gross Output	Employment
China	1,130B	10,9M
United States	786B	2.8M
Japan	406B	2.3M
Germany	171B	706K
South Korea	128B	732K
France	124B	448K
United Kingdom	114B	519K
Rest of the World	757B	3.9M
Global Total	***3.6T***	***22.3M***

Source: IHS Markit, 2019

As 5G technologies are on the brink of becoming a reality, more research is needed to understand the economic impact of these technologies. Previous studies on behalf of several industry players indicate that the potential for financial gains is growing. However, little independent research has already been conducted on the topic.

Thus, the objective of this study is three-fold:

- First, investigate how much global economic value is realized as an output of investment by the 5G value chain by analyzing investment trends and decisions made by governments, wireless network providers, and technology providers and linking them to increased global and regional economic activity and value generation.
- Second, compare localized trends and practices to develop distinct, above average, or market-leading advantages by analyzing the investment decisions, incentive structures, and sectoral technology focus differences. This will enable the research team to spot best practices and successful acceleration strategies on the global market.
- Third, analyze how the rollout of 5G networks disrupts the global technology landscape and supply chain, thereby creating secondary knock-on effects that lead to new or previously underutilized fields to generate massive unique economic benefits.

Given that the maturity and availability of 5G are expected to rise sharply over the coming years from its current infancy, the research team may consider broadening the scope of the study to get a comprehensive picture of the costs and economic benefits of this technology revolution.

Literature Review

Wireless communication generations

Wireless communications were first introduced over a century, but they were not until the early 1980s that they became commercially feasible for consumer service (Webb, 2007).

The study on the evolution of mobile communication from Pereira and Sousa (2004) evoked that the first-generation (1G) of wireless technology systems came with cellular telephony systems, allowing for mobile voice calls. The second-generation (2G) improved voice calling and introduced text messaging via SMS (and later media messaging via MMS). This ultimately helped the cellular industry gain widespread adoption in the early 2000s. Upgrades in 2G technologies later introduced data transmission (EDGE) at limited speeds. However, it was not until 1998 that third-generation (3G) technologies allowed for media-rich applications like mobile internet browsing and video playback. The most advanced iterations of 3G can reach speeds up to 4 Mbps.

The fourth-generation (4G) reached real-world speeds between 10 – 50 Mbps, depending on the carrier. Later advancements in 4G technologies (LTE) brought download speeds up to 150-350 Mbps. The increased speeds enabled new connected solutions such as mobile online gaming, live stream HD-TV, group video conferencing, connected home solutions, and mobile payment. However, given the latency (the delay before data transfer) of 4G LTE networks, industries like transportation or healthcare cannot build a reliable enough connection to steer critical systems (Dahlman et al., 2013).

The fifth-generation (5G) networks will impact these mission-critical systems while providing the necessary infrastructure for connected technologies. Early deployment of 5G networks can reach 700 – 3025 Mbps (3.025 Gbps) and significantly reduce latency to near-instant levels at 1-10 milliseconds (Yousaf et al., 2017). 5G's quantum leap in connectivity creates a tremendous opportunity for numerous industries and sets the stage for large-scale disruption. Industries such as healthcare, manufacturing, and auto are already adopting technologies and becoming more connected (Alliance, 2015).

Once 5G becomes widespread, the effect on these industries could be transformative for three main reasons. First, 5G devices are lower latency, enabling faster transmission of more extensive data streams. Second, 5G devices are more reliable, enabling better data transmission in extreme conditions. Third, 5G is more flexible than Wi-Fi and can support a broader range of devices, sensors, and wearables (Nordrum–Clark, 2017).

5G major components and stakeholder groups

At the highest level, 5G networks can be separated into the following distinct major components and stakeholder groups (Guowang et al., 2016).

Spectrum: Wireless signals transmit over the air on a range of frequencies on the electromagnetic spectrum. To avoid interference between the various signals, the allocation of multiple slices of the spectrum for different use is controlled by Governmental bodies. Wireless communication has a certain amount and sections (generally between 600 MHz and 2.7 GHz.) of its allocated spectrum. Allocation of the spectrum is usually done through government-led public auctions. Wireless network providers cannot use more spectrum than they have been given. However, in some countries, governments retain the rights to owning the spectrum and operating a national wireless network provider.

Wireless network providers: are communication service providers that build and operate the technical infrastructure required to provide a wireless network. They own the complete telecom infrastructure for hosting and managing mobile communications between the subscribed mobile users with users in the same and external wireless and wired telecom networks.

Wireless network infrastructure technology manufacturers: are technology companies that make the key components necessary for providing a wireless network. For 5G, only Ericsson, Nokia, and Huawei are currently able to offer scalable technologies that can enable national deployments of these new generation networks (Market Reports World, 2019).

Wireless connection technology manufacturers: are technology companies that make the components necessary for connecting to a wireless network (e.g., ZTE, Samsung, LG, Juniper, Cisco Systems, Fujitsu, Qualcomm, CommScope).

Wireless network users: are individuals (2C) and businesses (2B) subscribing to access the wireless network.

5G networks use cases

Fig 1 shows that at the end of 2019, there are 55 available commercial 5G networks already deployed or under deployment around the globe (VIAVI solutions, 2019), with Nokia citing a further eight commercial deals signed but not announced as of the writing of this paper (Nokia, 2019). These networks generally have limited use and coverage, mainly focusing on cities and other large congestion areas such as industrial zones. However, according to economists at IHS Markit (2017), there are already large-scale over 10.000 network relays in South Korea and China.

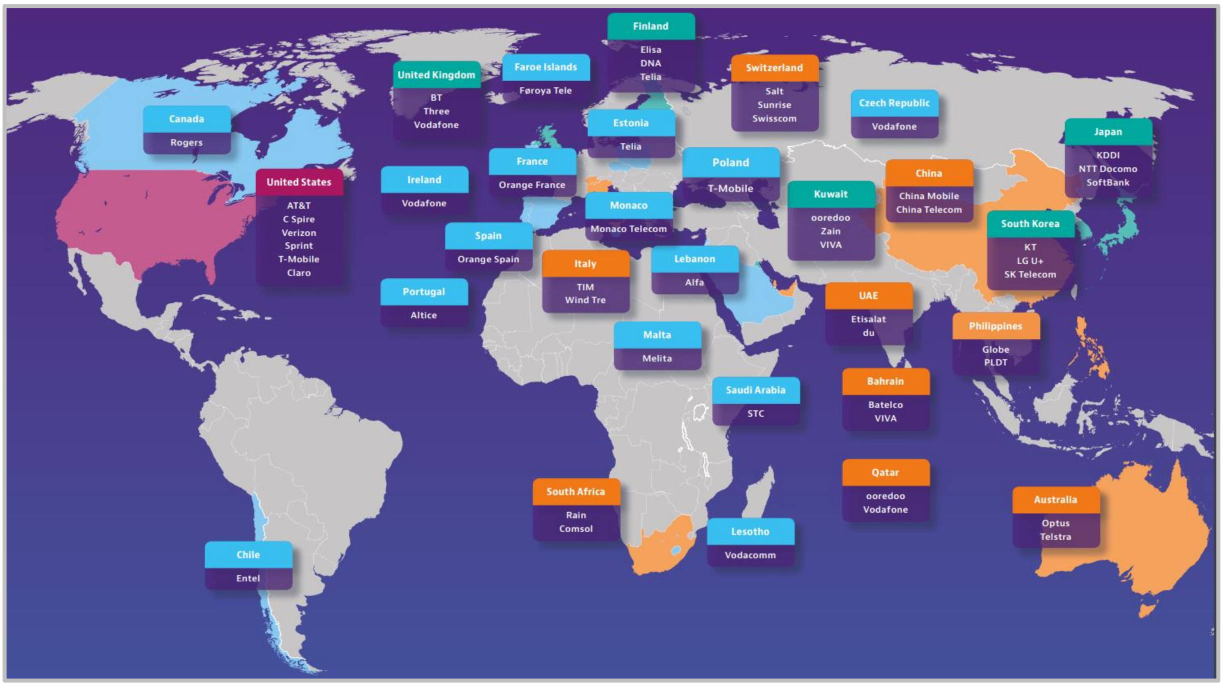

Figure 1: The deployment plan of 5G network around the globe in 2019
Source: VIAVI Solutions (2019)

5G technologies will be utilized primarily in 3 ways (Elayoubi et al., 2016):

1. Enhanced Mobile Broadband (eMBB): Two critical elements of eMBB will push adoption and value outcome in the 5G economy. The first is expanding cellular coverage into a more expansive range of structures, including office buildings, industrial

parks, shopping malls, and large venues. The second is enhanced capacity to handle a significantly greater numeral of devices using high volumes of data, specifically in localized areas. The net result of these two advancements is that end-users will have an improved and more compatible experience using mobile broadband applications regardless of location. The use cases of eMBBB include (1) Enhanced indoor wireless broadband coverage, (2) Enhanced outdoor wireless broadband, (3) Fixed wireless broadband deployments, (4) Enterprise teamwork/ collaboration/ training/ education, (5) Augmented and virtual reality (AR and VR, respectively), (6) Extending mobile computing, (7) Enhanced digital signage. The eMBB use cases are most likely to have a near-term impact. These are primarily an attachment of the existing 4G value proposition and should see a moderately rapid uptake in the market as 5G networks evolve commercially feasible. While there are going to be significant impacts on global economic activities as a result of the eMBB use cases (such as operators now being capable of offering stadium coverage services, AR/VR capabilities, and reinforcing extended mobile computing), because these are primarily enhancements to existing services, the net economic impact of 5G will be less transformative than with the MIoT and MCS cases.

2. Massive Internet of Things (MIoT): 5G will build upon earlier investments in traditional Machine-to-Machine (M2M) and IoT applications to enable significant increases in economies of scale that drive adoption and utilization across all sectors. 5G's improved low power requirements, the ability to operate in licensed and unlicensed spectrum, and the ability to provide more profound and flexible coverage will drive significantly lower costs within MIoT settings. This will, in turn, enable the scale of MIoT and will cause a much greater uptake of mobile technologies to address MIoT applications. The MIoT use cases are where we start to see the transformative impact of 5G. The use cases of MIoT include (1) Asset tracking, (2) Smart agriculture, (3) Smart cities, (4) Energy/utility monitoring, (5) Physical infrastructure, (6) Smart homes, (7) Remote monitoring, (8) Beacons and connected shoppers. Many of these applications are being serviced today by a mix of older generations of cellular and low-power wireless technologies operating in unlicensed spectrum. These technologies will continue to improve upon the extended low-power operation capabilities and the capability to utilize both licensed and unlicensed spectrum, addressing a much larger segment of the M2M and IoT markets and reducing costs because of economies of scale.
3. Mission Critical Services (MCS): MCS designates a new market opportunity for mobile technology. This substantial growth area for 5G will help applications that require high reliability, ultra-low latency connectivity with solid security and availability. This will allow wireless technology to deliver an ultra-reliable connection imperceptible from wireless to aid applications such as autonomous vehicles and remote processes of complex automation equipment where defeat is not an option. The use cases of MCS include (1) Autonomous vehicles, (2) Drones, (3) Industrial automation, (4) Remote patient monitoring/telehealth, and (5) Smart grid. The use cases recapitulated in this section indicate many genuinely new applications for mobile technologies. The potential to support highly reliable applications, ultra-low latency, and widely available networks with solid security creates significant growth opportunities. Many use cases are still emerging markets (autonomous vehicles, commercial drones, and remote medical treatment), so growth will depend on market innovation, the development of appropriate regulation, and the deployment of 5G networks. As a result, change may take longer to accelerate, but given the broad implications of some of these use cases, the overall impact on society is expected to be tremendous.

With these exciting new use cases, the question is raised would consumers be willing to pay for all of these, and are there commercially feasible proto-use cases that could pave the way for the complete build-up of 5G networks that would provide a significant return on investment expected by the industry (Frankston, 2020).

Ericsson's 5G mobile subscription use case roadmap (*Fig 2*) suggests multiple phases of 5G adoption. For instance, home wireless broadband and premium smartphone experiences that authorize content to be downloaded in seconds are predicted to go mainstream within one year of the 5G launch and draw high consumer interest and willingness to pay. A proportion of smartphone users globally are inquisitive about a 5G hot zone service that offers ultra-high speeds and trustworthiness in demanding locations like airports, shopping streets, and office space. These are followed by gaming-related use cases, like cloud game streaming services with low lag and VR cloud gaming, which consumers expect to go mainstream within one to two years of the 5G launch. Moreover, most MCS use cases are at least three to five years away from mainstream adoption by consumers, with more complex technologies like autonomous driving or beyond-line-of-sight drones taking even longer (Ericsson, 2019).

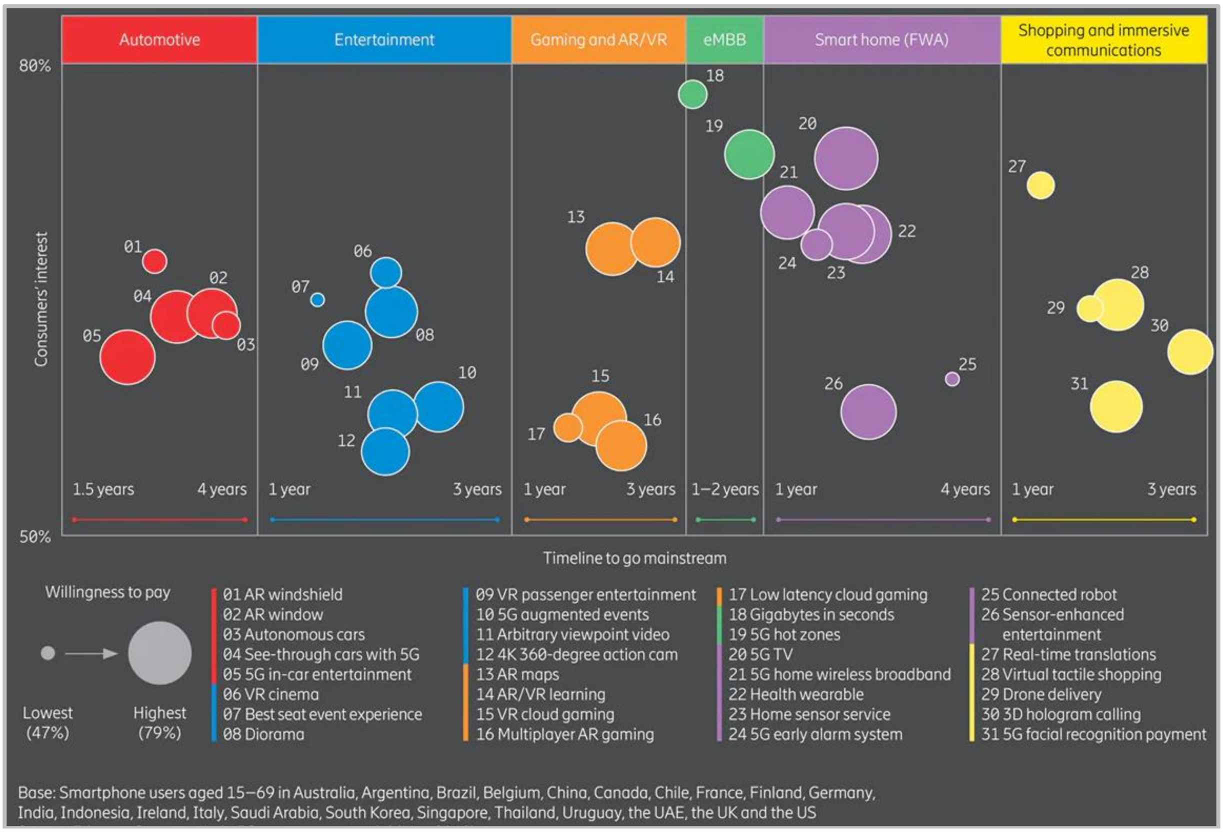

Figure 2: Ericsson's 5G mobile subscription use cases roadmap
Source: Ericsson (2019)

The estimated cost to build a 5G network for up to 50,000 subscribers

5G promises to provide low latency coverage for significant data streams that power applications like IoT devices, semi-autonomous vehicles, and augmented reality. Despite the massive increase in data and usage, calculating the actual cost of laying the physical groundwork for 5G-enabled devices remains a challenge for the provider. Dano (2021) has estimated the total cost to build a 5G non-standalone Evolved Packet Core for up to 50,000 subscribers ranging from $250,000 to $1.2 million, depending on the vendor supplying the 5G equipment, the volume or size of the overall deal. For instance, smaller rural operators pay more per site than Verizon or AT&T build out 100,000s sites.

The same study suggested there are three leading wireless network equipment vendors– Huawei (China), Nokia (Finland), and Ericsson (Sweden). The US congress allocated nearly $2 billion to pay US wireless network operators to replace equipment made by China due to security threats to national security. *Table 2* shows that this replacement significantly differs in proposed costs at the low and high end of the spectrum. The pricing range is 20-35% higher for open and integrated RAN. The mMIMO eNodeB cost estimates are as much as four times the Chinese vendors currently offer for equivalent hardware and other network elements. However, the list is limited to only IoT software licenses associated with core network nodes, suggesting that $2 billion will not be enough to replace Chinese with Western 5G equipment.

Table 2: The range of estimated costs for 5G replacement equipment

	Range of Estimated Costs	
Description	**Low**	**High**
Bundled BBU/RRH (Base Band Unit/Remote Radio Head)		
Fixed Wireless		
nonMIMO (Multiple-Input and Multiple-Output) eNodeB with 3 sectors, single spectrum band of up to 20 MHz/sector. Fixed Wireless features. Range due to Low Power radio (20W) vs High Power radio (up to 320W). Price includes Remote Radio Units (RRU), Base Band Unit (BBU), Ancillaries, Software Features, and Capacity Licensing. Price excludes antennas, tower cabling, tower ancillaries and over voltage protection (OVP)	$ 27,000.00	$ 56,000.00
mMIMO eNodeB with 3 sectors, single spectrum band of up to 20 MHz/sector. Fixed Wireless features. Range due to Low Power radio (120W) vs High Power radio (up to 240W). Price includes Radio+Antenna, BBU, Ancillaries, Software Features, and Capacity Licensing. Price excludes tower cabling, tower ancillaries and over voltage protection (OVP).	$ 85,000.00	$ 115,000.00
Mobility Wireless - nonMIMO		
nonMIMO eNodeB with 3 sectors, single spectrum band of up to 20 MHz/sector. Fixed Wireless features. Range due to Low Power radio (20W) vs High Power radio (up to 320W). Price includes RRHs, BBU, Ancillaries, Software Features, and Capacity Licensing. Price excludes antennas, tower cabling, tower ancillaries and over voltage protection (OVP)	$ 45,000.00	$ 69,000.00
Mobility Wireless - mMIMO		
mMIMO eNodeB 3 Sector Per Band (64T64R 20 MHz 1 Band FWA - 64T64R 60 MHz 1 Band with Advanced Mobility Features)	$ 85,000.00	$ 368,172.00
Bundled Open-RAN		
Macrocell 4G 20MHz Carrier (Bundle - Antennas, RU/RRU, BBU Software, GPS Receiver, STU (Subscriber Terminal Unit), RIU (Radio Interface Unit), Mechanical Mounting, Cables and Connectors, SFPs (Small Form-Factor Pluggable))	$ 39,000.00	$ 52,000.00
Macrocell - 5G Sub6 100MHz Carrier (Bundle - Antennas, RU/RRU, BBU Software, GPS Receiver, STU, RIU, Mechanical Mounting, Cables and Connectors, SFPs)	$ 91,000.00	$ 125,000.00
Macrocell - 5G mmWave (Bundle - RU/RRU, BBU Software, GPS Receiver, DU (Open RAN Distributed Unit), Mechanical Mounting, Cables and Connectors, SFPs)	$ 45,000.00	$ 60,000.00

Source: Widelity/FCC

Potential economic benefits 5G networks will generate

As displayed previously, the first 5G deployments are already underway, but the industry remains untapped potential. However, deployments and marketing efforts in most markets have focused more on the consumer markets, impacting the 5G enterprise market potential (Falahy & Alani, 2017). The expansion of the current scope of consumer-related service revenues is predicted to remain close to stagnant at an annual growth rate of just 0.75 percent in the next decade, which is not enough to cover the deployment costs in large markets such as the US, China or Western Europe.

If the rollout of 5G networks is faster than expected, the expectations across industries are that the ramp-up of advanced 5G-enabled use cases such as MIoT and MCS will likely happen later. It has taken industries longer to shift into more cultivated digitalization use cases, as they are still making basic functionality. Much of this can be connected to process-oriented hurdles and an industry's capability to rebuild the required qualifications for deployments. Thus, the growth projection of 5G-enabled revenue potential is projected to be around 3.8BN USD (*Fig 3*), representing a revenue increase of about 35% by 2030 (Arthur–Ericsson, 2019).

This increase will be very unevenly split between various regions across the globe. Those regions that invest heavily in connectivity solutions are more likely to attract additional investment and revenues from new services and applications, capturing a more significant portion of the industry spend. Large markets such as North America or China will capture the lion's share of the investment by their sheer size. However, if smaller markets such as central-eastern Europe can capitalize on a low number of dedicated use cases such as the 5G enabled test-track for self-driving technologies in Hungary (Claudia, 2019), they might significantly enhance their ability to capitalize on 5G's economic potential.

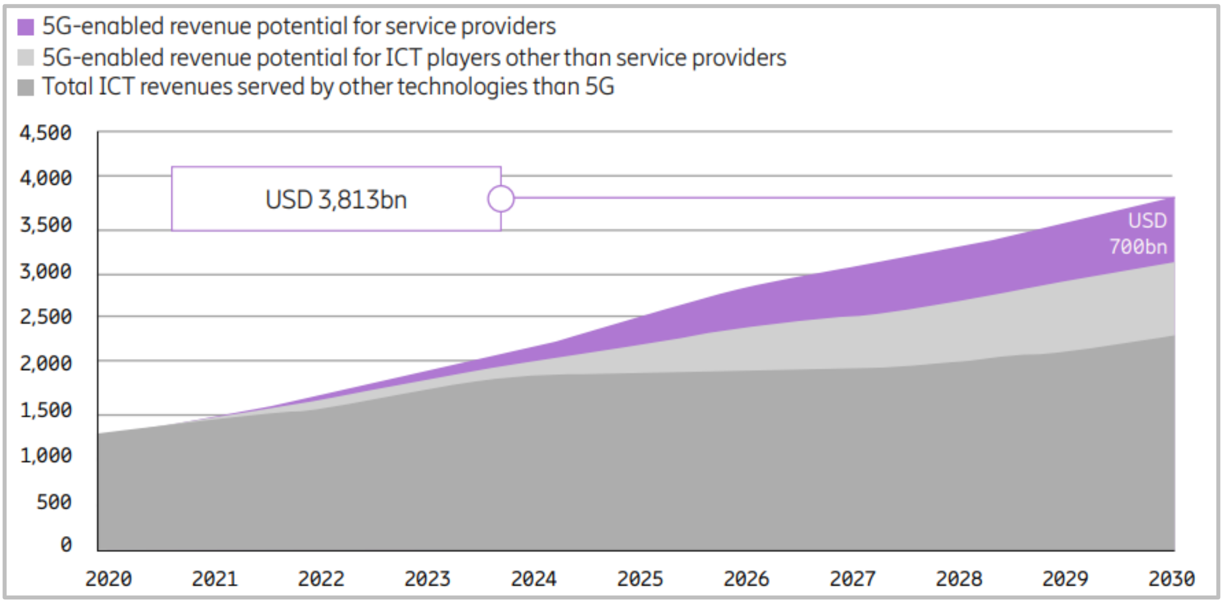

Figure 3: The 5G network-enabled revenue potential between 2020–2030
Source: Ericsson, 2019

Main Observation

After the comprehensive literature review was conducted, the main observation of this study is that 5G is the next generation of mobile/wireless technology that follows 4G. For consumers, 5G will provide faster mobile broadband. For enterprises, 5G will support billions of devices for IoT and new classes of services that require low latency and high reliability. For operators, 5G will reduce operating costs and lead to new sources of revenue. However, 5G also comes with its challenges regarding the rollout and investments. It is estimated that operators have already invested more than $ 300 billion, implying that the cost of services will be high initially; whether consumers or businesses, it ultimately gets passed on to the users.

Estimating the accurate cost of building an actual 5G network is complicated due to the high number of factors involved. Some costs are already applied by reusing the existing 2G and 3G frequencies and evolving 4G networks. Some costs depend on who the vendor is; This means incremental costs because of the implementation of new 5G antennas, increased backhaul capacity, and other equipment, such as transmission equipment. However, calculating the incremental or fully allocated cost of a 5G service is essential for operators to understand the investments and returns. Moreover, for investors in telecoms stocks, mobile operator revenue, profitability, and cash flow are under pressure, leading to share price weakness.

5G offers fast speeds of connection and the possibility of significantly increasing the number of internet-connected devices owned and operated by consumers. 5G may or may not be profitable because much depends on users' willingness to pay more for the 5G network than other services. More research is needed to understand whether a large number of consumers are interested in the incremental improvements that 5G offers, especially the reliability of their mobile service. Consumers also need to understand the value propositions of 5G beyond mobile broadband to help them make a purchase decision. The potential profit of 5G at this stage of development is from enterprise customers who are researching ways to create enhanced digital customer experiences within contained spaces, such as media and entertainment, retail, or even restaurants because 5G provides faster speeds, more reliable connections, and lower latencies capabilities to transform the user experience. Once consumers have experienced these benefits of 5G for themselves, they are much more likely to recognize the value 5G offers in their daily lives.

On the other hand, consumers need to upgrade to 5G-capable devices to use the 5G network. So levels of take-up, at the moment, remain unknown. However, operators are committed to deploying 5G because 5G is an opportunity to drive further intelligent connectivity and collaborate across industries. As 5G is already deployed and many more countries are eager to do the rollouts, the big challenge and departure are the dynamic behavior of configuration changes because operators do not have the background. Moreover, it must be done quickly, meaning it must be automated. As the case may be, measuring the success of the first rollout of 5G will likely dictate further coverage plans for potential rollouts of 5G in the coming years. For now, 5G is a commercial and competitive imperative to establish a service. Operators also need to do so because they do not have enough capacity on their 4G networks components, affecting download speeds in dense areas. Turning these imperatives into accurately costed and profitable lines of business is the challenge that faces the telecoms industry today.

Another factor that will impact the speed, success, and profitability of the 5G rollouts is the availability of a 5G antenna. There are only three suppliers – Huawei (China), Nokia (Finland), and Ericsson (Sweden). Huawei is the leader in producing antennas in volume and to the required specifications. However, the US has banned Huawei from using American-made and controlled technology (e.g., software, hardware, chip design). Several Western nations and other key American allies (e.g., Australia, New Zealand, Japan, Singapore) have banned Huawei components in their national 5G infrastructures based on security concerns. These nations face additional costs and delays in building their 5G infrastructures. It is unclear at this point who will cover these extra costs. It is a complex question of diplomacy, geopolitics, and protectionism.

In the view of this study, there are three possible ways to resolve this situation:

1. First, return to the status quo by finding a way for China and Huawei to make a concession and have the US lift the current ban; this will renewable Huawei to gain access to American-made and controlled technologies and produce more secured 5G network solutions en masse. This is the fastest way to realize the socio-economical benefits of 5G on a global scale and limit the balkanization of technology – meaning each geographical region to develop its own, not interoperable products, platforms, and standards.
2. Second, western nations and American allies would need to significantly ramp up production of 5G equipment to meet the rapidly expanding demand. Most countries already possess the required advanced manufacturing technologies. However, the utilization of these technologies to support mass production requires significant investment, which historically made it less economically viable than production in low-cost off-shore countries. Changing this paradigm would be possible through increased government intervention (direct or indirect). However, it could be at the detriment of the social consensus (e.g., workers' rights, environmental concerns, etc.)
3. Third, China is the world's largest manufacturer with the ability to manufacture products at scale and low cost; however, China lacks the solvent capabilities to design and produce Western equivalent advanced technologies. To meet efficiency and security standards, China would need to look beyond replicating existing technology en masse; this requires significant investment from early education and research up to academia and national laboratory level. China has already started this education investment in

> the past decades. However, the West established these norms and principles of independent research over a century ago. Therefore, China needs to speed up to independently produce western equivalent advanced technologies.

The political matters surrounding this needs to be resolved because mobile operators have stated that the speed and coverage of the 5G rollout are highly dependent on the volumes of available suitable radio antennas.

Additional pressure is due to the complex global situation due to the covid-19 pandemic. The global supply chain crisis is distributed geographically and across the supply chain to spread the risk of disruption throughout the supply chain required for 5G equipment manufacturing. It is not that Huawei, Ericsson, and Nokia need to produce the 5G components; they also need raw materials and minerals from other countries. That is a problem when new issues are likely to pop up in the weeks and months ahead, as more contagious strains of China's zero-covid policy and the war in Ukraine continues, cutting Russia out of the global supply chain for software and minerals.

The widespread availability of 5G mobile phones is also likely to be a significant factor in the speed of 5G take-up. There are relatively few mobile phone manufacturers with the capacity and technological capability to produce 5G mobile phones at scale in the short term. We know at least Apple, Samsung, Xiaomi, LG, ZTE, and Huawei to be capable of this, but others may do too.

The limitations of this study are based on opinion, judgment, and evidence-based interpretation of findings.

Conclusion

The projections in this study represent the economic realities of 5G technology, considering that 5G presents the potential to be a transformative socioeconomic catalyst for changes that redefine work processes and rewrite the rules of competitive economic advantage. The profound effects range widely, from the positive impacts on human and machine productivity to eventually heightening the living standards for people worldwide.

The transformation to 5G is complex as well as existing. In contrast, it is no longer a question of "if" but "when"; the operators must carefully judge cost and timing. Scholars may expand their research to predict which industry 5G has the most extensive global financial impact in value creation, so the enterprise can carefully plan on the go-to-market position. Further research is also needed to understand how consumers see values in 5G and how much consumers are willing to pay for 5G services and device upgrades based on national levels.

The other complicating situation is the political tension surrounding advanced technology competition between China, the US, and its allies. These political tensions need to be resolved to increase 5G coverage on a global scale.

Covid has shown that people want increased connectivity and flexibility across the developed world. These social changes will likely shape the progress of technology well into the following decades. Meaning 5G rollouts will happen regardless of various disruptions currently impeding its progress.

Acknowledgment

Zsofia Nguyen acknowledges the support of the University of Sopron research staff, dr. habil. Zoltan Pogatsa's supervision and Bence Horvath for his insights into the telecommunication industry and geopolitics.

References

Al-Falahy, N. – Alani, O. Y. (2017): Technologies for 5G networks: Challenges and opportunities. IT Professional, 19(1), 12–20. DOI: https://doi.org/10.1109/mitp.2017.9

Alliance, N. G. M. N. (2015): 5G white paper. Next-generation mobile networks, white paper, 1.

Campbell, K. – Diffley, J. – Flanagan, B. – Morelli, B. – O'Neil, B. – Sideco, F. (2017): The 5G economy: How 5G technology will contribute to the global economy. In IHS Economics and IHS Technology. Qualcomm Technologies.

CB Insights (2020): What Is 5G? Understanding the Next-Gen Wireless System Set To Enable Our Connected Future. https://www.cbinsights.com/research/5g-next-gen-wireless-system/

Dahlman, E. – Parkvall, S. – Skold, J. (2013): 4G: LTE/LTE-advanced for mobile broadband. Academic press. DOI: https://doi.org/10.1016/b978-0-12-419985-9.00001-5

Dano, M. (2021): Here's how much a 5G wireless network really costs. Light Reading. https://www.lightreading.com/open-ran/heres-how-much-5g-wireless-network-really-costs/d/d-id/769114

Elayoubi, S. E. – Fallgren, M. – Spapis, P. – Zimmermann, G. – Martín-Sacristán, D. – Yang, C. – Jeux, S. – Agyapong, P. – Campoy, L. – Qi, Y. – Singh, S. (2016 June): 5G service requirements and operational use cases: Analysis and METIS II vision. In 2016 European Conference on Networks and Communications (EuCNC). 158–162. IEEE. DOI: https://doi.org/10.1109/eucnc.2016.7561024

Ericsson (2019): 5G consumer potential. https://www.ericsson.com/498f26/assets/local/reports-papers/consumerlab/reports/2019/5g-consumer-potential-report.pdf

Frankston, B. (2020): Consumer Technology vs. 5G. IEEE Consumer Electronics Magazine. DOI: https://doi.org/10.1109/mce.2020.3037418

Guowang, M. – Jens, Z. – Ki, W. S. (2016): Fundamentals of Mobile Data Networks. Cambridge University Press, ISBN 1107143217. DOI: https://doi.org/10.1017/cbo9781316534298.002

Little, A. D. – Ericsson (2019): 5G for business: a 2030 market compass. https://www.ericsson.com/assets/local/5g/the-5g-for-business-a-2030-compass-report-2019.pdf

Market Reports World (2019): Global 2G, 3G, 4G & 5G wireless network infrastructure market professional survey by manufacturers, regions, countries, types, and applications, forecast to 2024.

Nokia (2019): 5G contracts. https://www.nokia.com/networks/5g/5g-in-action/

Nordrum, A. – Clark, K. (2017): Everything you need to know about 5G. IEEE Spectrum, 27.

Patricolo, C. (2019): Test track for self-driving cars opens in Hungary. Emerging Europe. https://emerging-europe.com/business/test-track-for-self-driving-cars-opens-in-hungary/

Pereira, V. – Sousa, T. (2004): Evolution of Mobile Communications: from 1G to 4G. Department of Informatics Engineering of the University of Coimbra, Portugal.

VIAVI Solutions (2019): The State of 5G Deployments. https://www.viavisolutions.com/en-us/literature/state-5g-deployments-2019-poster-chart-en.pdf

Webb, W. (ed.) (2007): Wireless communications: The future. John Wiley & Sons.

Widelity/FCC (2011): The range of estimated costs for 5G replacement equipment. https://img.lightreading.com/2021/04/769114/8058.jpg

Yousaf, F. Z. – Bredel, M. – Schaller, S. – Schneider, F. (2017): NFV and SDN–Key technology enablers for 5G networks. IEEE Journal on Selected Areas in Communications, 35(11), 2468–2478. DOI: https://doi.org/10.1109/jsac.2017.2760418