

5G: By: Leandro A Salud & Hongjiao Liu
From Technology to Geopolitics



Global TechnoPolitics Forum

5G: From Technology to Geopolitics

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FOREWORD

This white paper on 5G is a perfect exemplar of the Global TechnoPolitics Forum's mission of probing at the intersection of technology and geopolitics. 5G technology offers tremendous advances from predecessor mobile technologies, which were primarily confined to cell phones, especially in speed and low latency (the time between a user action and a response), making possible machine-to-machine communications in autonomous vehicles or other devices in the Internet of Things. Leonardo Antonia Salud and Hongjiao Liu clearly outline the technical issues and choices countries face in moving from existing 4G networks to the much more advanced, but also expensive, 5G technology. They include case studies of developing regions of the world, where money is in short supply but networks often are both long and sparse.

At the same time, 5G is increasingly bound up with geopolitics. Given legacy systems, geopolitics begins with choices about potential suppliers. The dominant suppliers will, in turn, become central to what standards are developed. And 5G is caught up in the increasing competition between the United States and China over technological supremacy, a conflict the authors assess in careful detail. The United States has argued that Huawei, the dominant player at present, is a security risk because of its close ties to Chinese government and intelligence officials. By contrast, skeptics suspect that argument is primarily a means to frustrate China's technological advance. Meanwhile, many countries, especially in Europe, are caught in the middle, concerned about the security risk but attracted to Huawei on economic grounds. We commend this wide-ranging and thoughtful analysis to you and would welcome any comments.

The Global Techno Politics Forum is an innovative new organization that strives to shape the public debate and facilitate global coordination at the intersection of technology and geopolitics. The Forum is independent and nonpartisan, and the analyses and suggestions in this paper are the authors' alone. Yet, the Forum's work is very much that of the team, and we salute the entire team for this effort.

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INTRODUCTION

In July 2018, the annual meeting of the Five Eyes alliance was held in Canada, where China's leading 5G vendor - Huawei - was at the top of the agenda. In the months that followed, the United States, Australia, New Zealand, Canada, and the United Kingdom launched a campaign against Huawei to prevent service providers from supplying its equipment in their 5G networks and to encourage other countries to follow suit.¹ Since then, 5G politics and controversies have created confusion over what 5G technology is and how it will affect the world. Therefore, this paper provides a foundational and holistic understanding of 5G, through the lens of both technology and geopolitics, to disentangle the conflicting narratives that surround it. First, this paper defines what 5G technology is, explains how the 5G infrastructure builds on previous generations, identifies relevant use cases in various industries, and assesses today's leading 5G vendors. Second, this paper discusses how 5G will impact economies, security and most importantly, geopolitics. A final section analyzes, through three representative use cases, how developing and emerging economies will navigate the technical, economic, and geopolitical choices surrounding 5G rollout.

¹ Yves Engler, "Canada's Membership in the Five Eyes Alliance Promoting Conflict with China," *Canadian Dimension*, July 3, 2020.
<https://canadiandimension.com/articles/view/canadas-membership-in-the-five-eyes-alliance-driving-conflict-with-china>.

PART ONE

5G Technology

5G is the fifth generation standard for broadband cellular networks.² As the successor to 4G, 5G will not only provide a simple upgrade to the speed of cellular networks, but also expand the role of cellular networks as we know it. 5G outcomes are defined in [three main utilization categories](#):³

1. **Enhanced Mobile Broadband (eMBB)**: provides a bit rate over 10 Gbps and speeds at 10 to 100 times faster than 4G.⁴ It will serve to enhance the user experience for existing applications and any internet-based activities on a mobile device that are data-intensive and require high bandwidth.⁵ Multimedia, such as 8K video streaming and immersive gaming, are prominent examples of use cases enabled by eMBB.
2. **Ultra-reliable and Low-Latency Communication (URLLC)**: significantly reduces the time delay between a user action and its resulting response. This provides near real-time communication to enable new technology applications that require minimal delay and service interruption such as driverless cars, traffic control, industrial interconnection, automation, and remote surgery. The driverless car in particular is an apt example that illustrates the importance of high reliability and low latency. These vehicles require split-second response capabilities to communicate with the network and other driverless

² Ketanpreet Kaur, Shailesh Kumar, and Anupam Baliyan, "5G: A New Era of Wireless Communication," International Journal of Information Technology, 12 (2018): 619. <https://doi.org/10.1007/s41870-018-0197-x>.

³ Radiocommunication Sector of ITU, "IMT Vision – Framework and Overall Objectives of the Future Development of IMT for 2020 and Beyond," International Telecommunication Union, September 2015, 4. https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-1!!PDF-E.pdf.

⁴ Ketanpreet Kaur, Shailesh Kumar, and Anupam Baliyan, "5G: a New Era of Wireless Communication," 620.

⁵ Gabor Megyaszi, "5G Technology and Enabled Use Cases," Eficode, Accessed April 13, 2021. <https://www.eficode.com/blog/5g-technology-use-cases#:~:text=eMBB%20use%20cases%20are%20data,immersive%20event%20experience%2C%20and%20telemedicine>.

cars and constant connection to maintain safety on the road.

3. **Massive Machine Type Communication: (mMTC):** enables the full realization of the Internet of Things (IoT) by allowing the network to accommodate a large number of connected devices that communicate with each other. Its focus is mainly on the information interaction between people and things, and its main usage scenarios include vehicle networking, intelligent logistics and intelligent asset management. The strength of mMTC is that it allows a large number of adjacent devices to get a smooth communication connection at the same time.

5G network standards are not expected to be met all at once and instead will be rolled out in phases, with eMBB coming first and the URRLC and mMTC following after.⁶

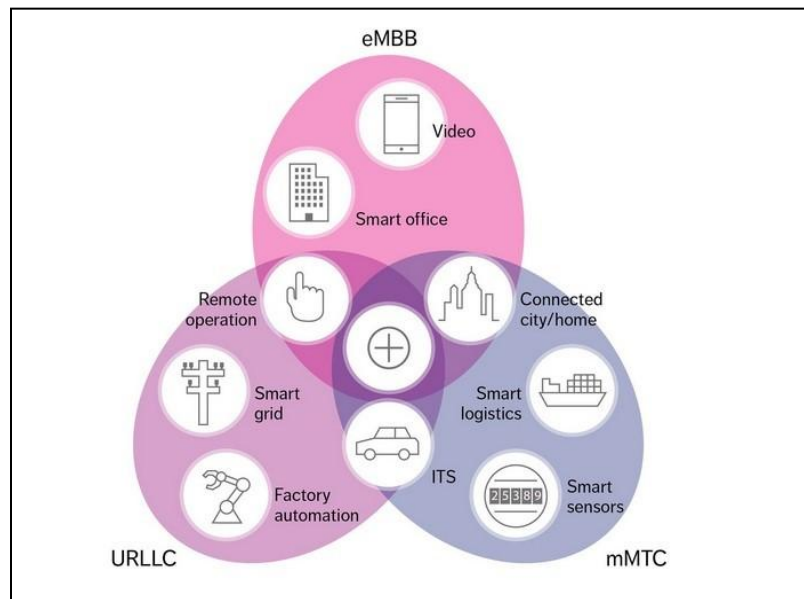


Figure 1.1. The three main utilization categories as visualized through a venn diagram.⁷

⁶ GSMA, “THE 5G GUIDE A REFERENCE FOR OPERATORS,” April 2019, 52.

https://www.gsma.com/wp-content/uploads/2019/04/The-5G-Guide_GSMA_2019_04_29_compressed.pdf

⁷ Upendra Kumar Tiwari, “5G New Radio Interface: CP-OFMD Scenario in EMBB,” Network Manias, March 2, 2018.

<https://www.netmanias.com/en/post/blog/13237/5g-new-radio/5g-new-radio-interface-cp-ofmd-scenario-in-embb>.

INFRASTRUCTURE

The shift from 4G to 5G will require new infrastructure elements to meet the three main updated standards of eMBB, uRLLC, and mMTC.

CELLULAR NETWORK BASICS

_____ Cellular networks provide wireless connectivity to devices which are known as user equipment (UE). In previous generations of cellular networks, UE referred to smartphones and tablets, but with 5G, it will include new devices such as driverless cars, industrial equipment, robots, home appliances, medical devices, military equipment and more. A cellular network consists of two types of sub-networks:

1. The **Radio Access Network (RAN)** connects UE to the cellular network and manages spectrum resources to meet quality of service requirements for users.⁸ The RAN consists of base stations (BS) equipped with antennas, each providing coverage over a specific geographical area.
2. **The Core Network (CN)** is the piece of the network that connects the RAN to the external network (i.e. the internet). The CN establishes the communication capabilities for different users and manages communication channels. The CN is considered to be the more sensitive part of the overall infrastructure when it comes to security.

While both the core network (CN) and radio access network (RAN) will be upgraded, most 5G innovations have occurred in the RAN so far - known as 5G New Radio (NR) standards. This has allowed some 5G deployments to enjoy the initial benefits of 5G, specifically eMBB. However,

⁸ Mojtaba Vaezi, and Ying Zhang, *Cloud mobile networks*. Vol. 5, no. 3. Springer, 2017, 8.
<https://doi.org/10.1007/978-3-319-54496-0>.

changes to both the RAN *and* the CN will be needed to reach the newer and more sophisticated 5G outcomes such as URLLC and mMTC.

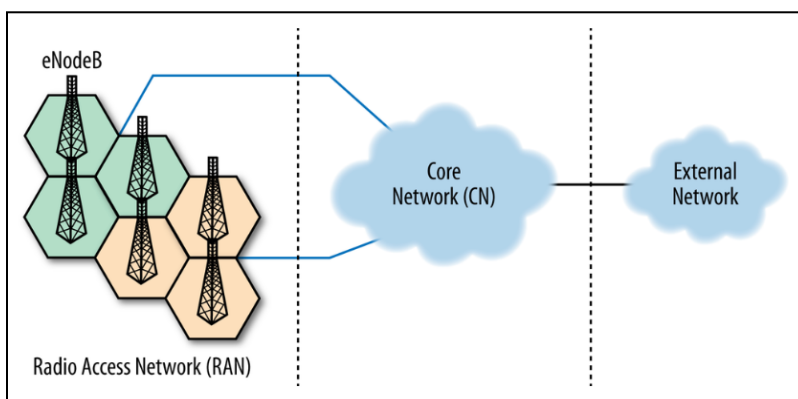


Figure 1.2. Simplified Diagram showing the connection between the Radio Access Network and Core Network.⁹

KEY ELEMENTS

The key elements needed to meet 5G standards are:

1. Mixed Spectrum

Mixed spectrum environments will play a central role in reaching 5G capability.

Spectrum refers to the set of electromagnetic frequencies used for communications and radar and is the key commodity that defines how a cellular network functions and which devices it can accommodate.¹⁰ Spectrum is categorized into three different bands: low, medium and high, each with their own unique advantages and disadvantages.

⁹ Sookocheff, Kevin. "How Does LTE Work?" Kevin Sookocheff. July 30, 2019. <https://sookocheff.com/post/networking/how-does-lte-work/>.

¹⁰ Jeffrey Reed, Marius Vassiliou, and Syed Shah, "The Role of New Technologies in Solving the Spectrum Shortage [Point of View]," Proceedings of the IEEE 104 no. 6 (2016): 1163 <https://doi.org/10.1109/jproc.2016.2562758>.

Table 1.1. Comparison of spectrum bands.

Spectrum Band	Frequency	Characteristics
Low	<3 GHz	Travels long distances with very little interruption at relatively lower speed.
Medium	3 - 24 GHz	Merges the characteristics of low and high band spectrum. Travels moderate distances and at moderate speed.
High	>24 GHz	Travels shorter distances at a higher speed.

Most current cellular networks operate using low-band spectrum,¹¹ taking advantage of its ability to cover large geographical areas with minimal interruption. The use of high-band spectrum, despite its higher speed capabilities, is relatively rare due to its inability to travel long distances. For 5G requirements to be met, the use of low, medium, and high-band spectrum will be vital. For instance, the higher speed capabilities of high-band spectrum will be needed to serve use cases that require high bit rates and low latency communications. While low-band spectrum will be needed to provide consistent and reliable coverage, especially in the areas that high-band spectrum cannot reach. Therefore, unlike the one-size-fits-all 4G network architecture, the 5G network must be flexible and adaptable to serve a wider range of devices.¹² Thus, flexibility and adaptability can only be achieved through the use of mixed spectrum.

¹¹ Riley Davis, “What is Spectrum? A Brief Explainer,” CTIA, June 5, 2018. <https://www.ctia.org/news/what-is-spectrum-a-brief-explainer>.

¹² Mansoor Shafi et al., “5G: A Tutorial Overview of Standards, Trials, Challenges, Deployment, and Practice,” IEEE Journal on Selected Areas in Communications 35 no. 6 (2017): 1203. <https://ieeexplore.ieee.org/abstract/document/7894280>.

2. Massive MIMO

Massive MIMO (multiple-input multiple-output) technology will play a crucial role in enabling mixed spectrum environments and the use of high-band spectrum in particular. High-band spectrum, also known as high frequency millimeter wave (mmWave), does not travel long distances compared to low-band spectrum. This is because the higher the frequency, the higher its propagation loss. That is to say, the high-band spectrum tends to lose its signal as it travels farther and farther. To address this issue, the massive MIMO system typically uses at least 64 antennas (much greater than the number of antennas used in 4G) equipped with beamforming capabilities to increase both coverage and precision. Beamforming antennas use special techniques to mitigate propagation loss by focusing and steering signals towards users more precisely.¹³

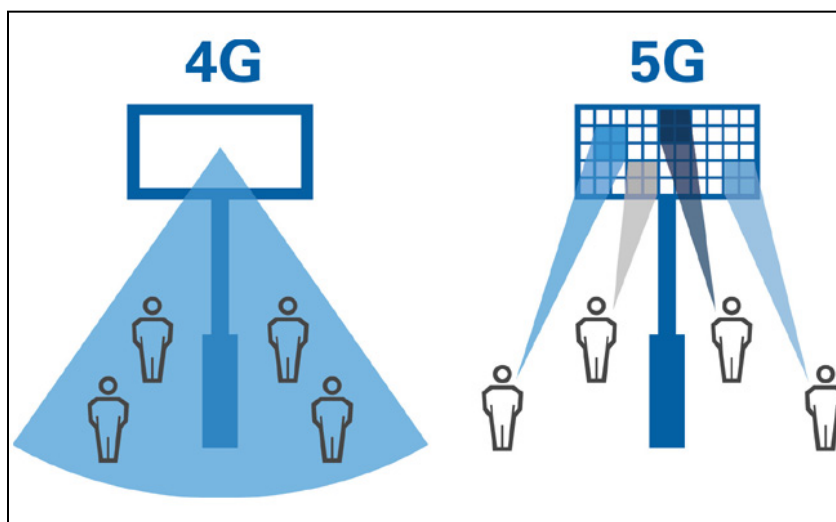


Figure 1.3. 4G MIMO antenna vs 5G massive MIMO antenna.¹⁴

¹³ Yu-Ngok Ruyue Li et al., “Beam Management in Millimeter-Wave Communications for 5G and Beyond,” IEEE Access 8 (2020): 13288. <https://ieeexplore.ieee.org/abstract/document/8947954>.

¹⁴ Charles Schroeder, “Exploring the Future of 5G,” Microwave Journal. November 19, 2018. <https://www.microwavejournal.com/blogs/23-5g-and-beyond-national-instruments/post/31371-exploring-the-future-of-5g>.

3. Network Slicing and Virtualization

Network slicing enables the 5G network to serve more connected devices by allowing several virtual networks with different bandwidth, latency, and power requirements to run on the same physical infrastructure.¹⁵ In practice, this means that instead of building one physical network that serves autonomous vehicles, one that serves mobile devices, and another that serves health care devices, the 5G network will be divided into multiple virtual networks, or *slices*, so that it can serve all of these use cases from the same physical network. Furthermore, networks will be increasingly virtualized using Software Defined Networking (SDN) and Network Function Virtualization (NFV) which will allow for the management of network slices in real time. Network slicing will give 5G networks the ability to handle a large number of simultaneous communications in a wide variety of industries while benefiting from economies of scale. Additionally, network slicing will be useful in providing radio and networking resources for vertical industries that have no physical infrastructure.¹⁶

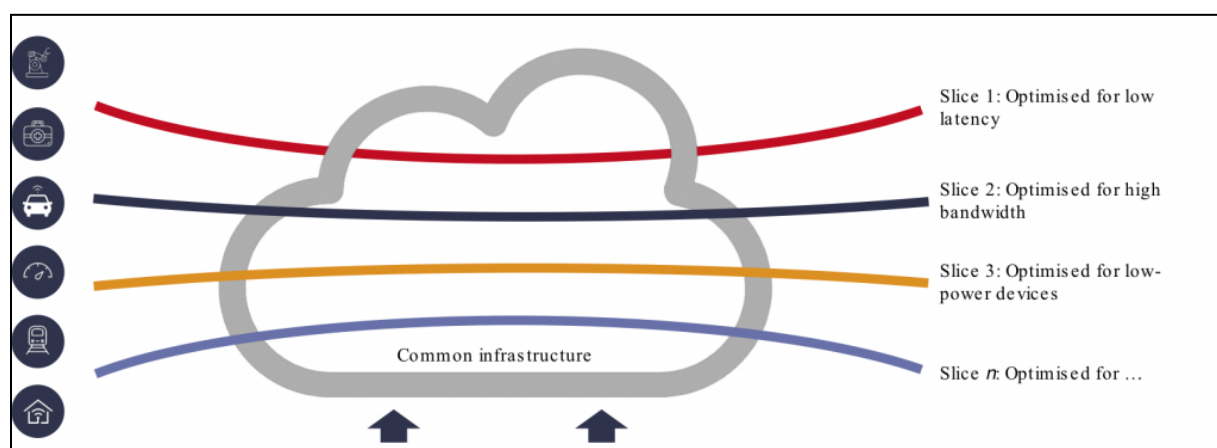


Figure 1.4. Network Slicing.¹⁷

¹⁵ Ericsson, Review of 5 Key facts about 5G Radio Access Networks, 2020. <https://www.ericsson.com/495922/assets/local/policy-makers-and-regulators/5-key-facts-about-5g-radio-access-networks.pdf>.

¹⁶ Alcardo Alex Barakabitze et al., “5G Network Slicing Using SDN and NFV: A Survey of Taxonomy, Architectures and Future Challenges.” *Computer Networks* 167 (2020):106984. <https://doi.org/10.1016/j.comnet.2019.106984>.

¹⁷ Richard Lim, “What Is 5G Network Slicing and Why Is It Important?,” STL Partners, Accessed September 19, 2021. https://stlpartners.com/telco_cloud/what-is-5g-network-slicing/.

DEPLOYMENT MODELS

In deploying 5G architecture, providers have two options, Standalone (SA) and Non-Standalone (NSA). The NSA deployment method adopts 5G technology for its base stations to support high-speed connection, while the part of the network that handles data and communication management uses the existing 4G core network.¹⁸ Therefore, NSA is a hybrid of 4G and 5G. On the other hand, SA deployment adopts all aspects of 5G technology.¹⁹ In effect, NSA deployment will upgrade the network to the extent that it can support eMBB at 5G standards while opening up some opportunities for new IOT (IoT) use cases. NSA deployment however will not be able to support features such as network slicing and uRLLC and therefore cannot support as wide a range of use cases as SA deployment can. Table 1.2 displays the differences between the two 5G deployments.

Table 1.2. SA vs. NSA

	Standalone (SA)	Non-Standalone (NSA)
Characteristics	<ul style="list-style-type: none"> ● 5G Core Network + 5G Base Stations ● Deploys the full 5G core and radio networks 	<ul style="list-style-type: none"> ● 4G Core Network + 5G Base Stations ● Leverages existing 4G networks
Investment	High	Low to Medium
Services	Supports all use cases	Supports only eMBB use cases
Latency	Low	High

¹⁸ Teral, Stephane, “5G Best Choice Architecture IHS Markit Technology | White Paper,” 2019, 4-5. <https://www.redestelecom.es/siteresources/files/894/48.pdf>

¹⁹ Ibid, 5-6.

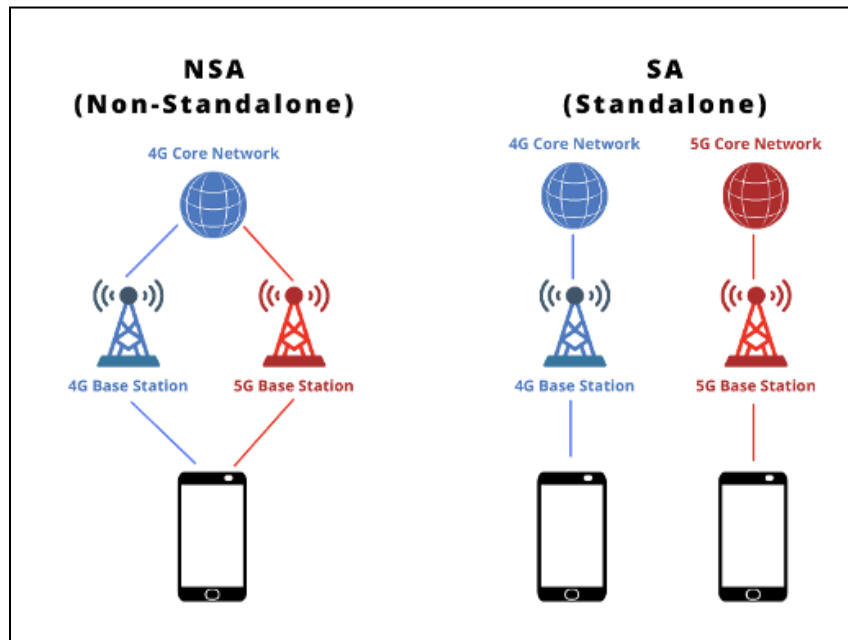


Figure 1.5. NSA vs. SA Core Network

The time and capital investment needed for SA deployment far exceeds that of NSA deployment and is economically unviable for many operators if they want to achieve full eMBB coverage in a short period of time. Although NSA is not a necessary stage for 5G, it has become the main choice for operators when deploying 5G at the outset to use as a transition phase from 4G to 5G SA.

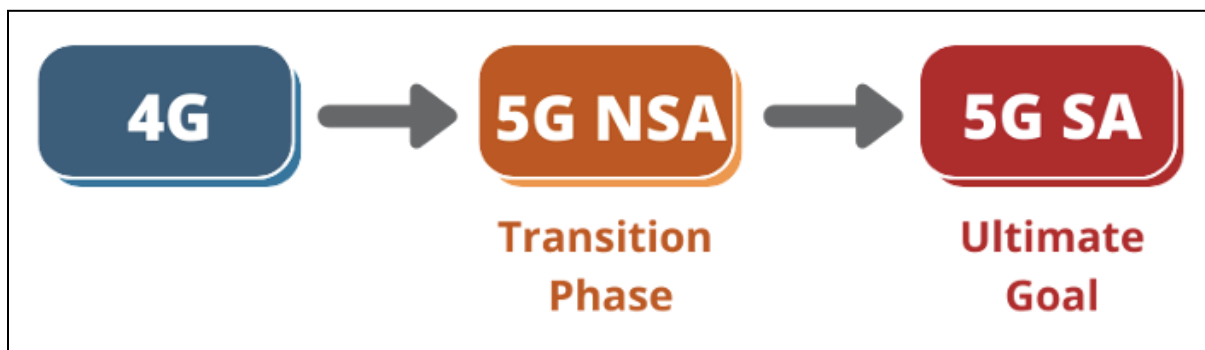


Figure 1.6. 4G to 5G Deployment Phases.

OPEN RAN

Open RAN is a network structure that “opens” the radio access network by allowing interoperability between RAN equipment from different vendors.²⁰ Prior to the 5G era, interoperability was de-emphasized in favor of functional capability, meaning that most radio network components came from one vendor.²¹ Due to new network advancements in 5G, most notably the virtualization of the RAN, mobile network operators are exploring multiple options to build, increase, and optimise their 5G connectivity. Those who support open RAN argue that it will promote market competition, network flexibility and performance, and vendor security through improved resource utilisation and cost-saving, support for customized networks, faster innovation, and reduced vendor lock-in.²²

As the development of open RAN is still at an early phase, its cost-effectiveness is an issue for some mobile operators due to the operational complexity and re-training needed to manage multiple vendors at once. Open RAN development is supported by the [O-RAN Alliance](#), a community of mobile network operators, equipment providers, and research institutions.

APPLICATIONS

_____5G increases the range of devices that mobile networks can serve through unprecedented flexibility and scalability through the confluence of enhanced speed, low latency and reliability, and machine to machine communication. Therefore, 5G encompasses an ecosystem that not only includes the networks themselves, but also the devices and equipment

²⁰ “Open RAN Explained: Innovation and Flexibility,” Ericsson, September 8, 2021.
<https://www.ericsson.com/en/openness-innovation/open-ran-explained>.

²¹ “Open RAN Explained,” Nokia, Accessed September 13, 2021.
<https://www.nokia.com/about-us/newsroom/articles/open-ran-explained/>.

²² “Open and Virtualised Radio Access Networks: An Explanatory Guide for Policymakers Open and Virtualised Radio Access Networks,” GSMA, February 2021, 5.
https://www.gsma.com/publicpolicy/wp-content/uploads/2021/02/GSMA_Open_and_Virtualised_Radio_Access_Networks_An_Explanatory_Guide_for_Policymakers.pdf.

that they enable, all with their own particular regulatory, logistic and trade issues. In turn, 5G applications will have a bearing on the overall trajectory of the 5G era. While this section identifies some 5G applications, the regulatory, logistic and trade issues of 5G applications are given less attention in this paper as it focuses on providing a foundational understanding of 5G by explaining what this paper deems as the central part of the 5G ecosystem - the 5G network. Broadly, 5G will power several industry categories such as healthcare, utilities, media, industrial manufacturing, and financial services.²³ Below are some specific examples of 5G use cases within these industries.

Industry 4.0

5G technology is one of the key enablers of Industry 4.0. Also known as the fourth industrial revolution, industry 4.0 will optimize the automation and computerization of industrial processes that began with industry 3.0 through the use of smart devices to increase efficiency and productivity. This change is supported by three technological trends — connectivity, intelligence and flexible automation. Use cases for 5G in Industry 4.0 are related to remote support and time-critical process control in factories. Some examples of specific use cases in industry 4.0 are predictive maintenance, asset tracking, power and heat management, machine vision and autonomous guided vehicles (AGVs).²⁴ 5G's low latency and high communication performance also keep connections stable during applications in factories to help avoid emergency stops and safety issues. Across all manufacturing use cases, estimates indicate that the introduction of IoT enabled by 5G will lead to 8.5% operational cost savings and for some use cases, a return on investment of over 9 times over 5 years.²⁵

²³ Wilson Chow, "The Global Economic Impact of 5G," PwC. Accessed 7 August 2021, 3-5 .
<https://www.pwc.com/gx/en/tmt/5g/global-economic-impact-5g.pdf>

²⁴ GSMA, "Factory Efficiency 5G Era IoT Use Cases and Benefits," November 2020, 5-7.
<https://www.gsma.com/iot/wp-content/uploads/2020/11/2020-11-GSMA-Manufacturing-Benefits-Props-Factory-Efficiency.pdf>

²⁵ GSMA, "Factory Efficiency 5G Era IoT Use Cases and Benefits," 4.

Smart Cities

The Smart City interconnects various low-power digital devices via IoT.²⁶ Its vision is a shared, secure and scalable infrastructure that enables human possibilities in a smart, secure, and sustainable way.²⁷ Applications of 5G in smart cities span different verticals such as energy, healthcare, manufacturing, media and entertainment, and automotive and public transport.²⁸ Specific use cases include intelligent street lighting, which incorporates sophisticated sensors to increase public safety, energy efficiency, and cost-saving. Another example is smart parking, which helps drivers locate the most convenient and available parking spaces through real-time monitoring of traffic conditions and parking facilities.²⁹

Autonomous Vehicles

5G will be a key technology to improve the reliability of vehicle communications, making vehicles smarter and creating a safer driving experience through increased automation and autonomy.³⁰ 5G enables direct communication between devices over short distances to ensure V2V (Vehicles to Vehicles) communication. For example, when a mobile vehicle makes a sudden turn, it first sends a signal directly to the vehicle behind it allowing the control system of the following vehicle to respond immediately.³¹ In addition, 5G supports the connection of V2I (Vehicles to Infrastructure) communication, such as traffic lights and bus stops which can reduce

²⁶ Anh Phan and Shoab Tahir Qureshi, "5G Impact on Smart Cities," ResearchGate, March 2017, 3.

https://www.researchgate.net/publication/315804922_5G_impact_On_Smart_Cities.

²⁷ 5GPPP. "Service Performance Measurement Methods over 5G Experimental Networks," May 25, 2021, 7.

https://zenodo.org/record/4748482/files/Service%20performance%20measurement%20methods%20over%205G%20experimental%20networks_short_version_08052021%20Final.pdf.

²⁸ Ali Gohar and Gianfranco Nencioni, "The Role of 5G Technologies in a Smart City: The Case for Intelligent Transportation System" Sustainability 13, no. 9, 5188 (2021): 3. <https://doi.org/10.3390/su13095188>.

²⁹ Ali Gohar and Gianfranco Nencioni, "The Role of 5G Technologies in a Smart City," 15-16.

³⁰ Kersten Heineke et al., "McKinsey Center for Future Mobility Development in the Mobility Technology Ecosystem-How Can 5G Help?," McKinsey, June 2019, 6-8.

<https://www.mckinsey.com/~media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/Development%20in%20the%20mobility%20technology%20ecosystem%20how%20can%205G%20help/Development-in-the-mobility-technology-ecosystem-how-can-5G-help.pdf>.

³¹ Keping Yu et al., "Deep Learning-Based Traffic Safety Solution for a Mixture of Autonomous and Manual Vehicles in a 5G-Enabled Intelligent Transportation System," IEEE Transactions on Intelligent Transportation Systems, 1–11, December 22, 2020, 4338. <https://doi.org/10.1109/tits.2020.3042504>.

the number of car accidents, improve traffic flow and increase the efficiency of public transport.³² 5G will also support complementary use cases such as track sharing and real-time local updates.

E-Health

The COVID-19 pandemic has put a huge strain on healthcare systems all over the world, which has overwhelmed healthcare facilities and disrupted the delivery of regular healthcare services. To prevent the re-emergence of this situation, the healthcare sector in every country must be equipped with new solutions to effectively respond to emerging challenges. The capabilities of 5G technology can develop solutions for a variety of health-related use cases such as telehealth, supply chain management, self-isolation, contact tracing and rapid health service deployment.³³ Moreover, 5G technology can provide real-time, remote and highly mobile digital healthcare services to patients under the limitation of human resources and medical instruments. In addition, the application of 5G technology can help improve medical efficiency and diagnosis, increase the operational efficiency of hospitals, and reduce their operating costs. 5G can help enable a whole new healthcare ecosystem and meet many patients and hospital needs accurately, conveniently and efficiently while being cost-effective.

5G STANDARDIZATION

Consensus is critical to the cohesiveness of 5G standards as opposed to operators developing 5G networks in isolation. Establishing clear 5G standards is essential to the development of devices and consumer equipment, helping to ensure device interoperability and allowing for innovation and market competition.

³² Ali Gohar and Gianfranco Nencioni, "The Role of 5G Technologies in a Smart City," 11-12.

³³ Yushan Siriwardhana et al., "The Role of 5G for Digital Healthcare against COVID-19 Pandemic: Opportunities and Challenges." ICT Express, June 2021, 251. <https://doi.org/10.1016/j.ict.2020.10.002>.

The standardization of 5G technology is mainly carried out through the 3rd Generation Partnership Project (3GPP),³⁴ an umbrella term for a group of standards organizations which develop protocols for mobile telecommunications.³⁵ The 3GPP has been instrumental in the development and commercialization of 5G technology standards. The organization was founded in the 3G era, and developed global specifications for mobile systems and has continued to develop specifications into the 4G and 5G eras.³⁶ The 3GPP uses a system of “releases”, which defines specifications at a given point in time but also allows for the addition of new features in subsequent releases. To date, the 3GPP has published the following releases:

Table 1.3. Standard Releases from 2018 - 2022.³⁷

	Status	Characteristics
Release 15 ³⁸	Completed In 2018	<ul style="list-style-type: none"> Regarded as the first full set of 5G standards but is seen as an "Incomplete Release." Focused on eMBB scenarios to meet urgent commercial needs in the market.
Release 16 ³⁹	Completed In 2020	<ul style="list-style-type: none"> Regarded as the first "Full Release " of 5G standards. Focused on URLLC and other IoT scenarios.
Release 17 ⁴⁰	Expected to be completed in 2022	<ul style="list-style-type: none"> Increased focus on industrial IoT and URLLC Supports IoT applications more comprehensively, including enhanced technologies (e.g. network slicing and network automation enhancements).
Release 18 ⁴¹	In the discussion and decision phase	<ul style="list-style-type: none"> The prioritization process on Rel-18 features should be complete by the end of 2021.

³⁴ 3GPP, “Releases,” Accessed September 13, 2021. <https://www.3gpp.org/specifications/releases>.

³⁵ “3GPP,” Wikipedia, February 20, 2021. <https://en.wikipedia.org/wiki/3GPP>.

³⁶ Wesley Chai, “What Is 3GPP (3rd Generation Partnership Project)?” SearchNetworking. Accessed June 29, 2021. <https://www.techtarget.com/searchnetworking/definition/3rd-Generation-Partnership-Project-3GPP>.

³⁷ 3GPP, “Releases,”

³⁸ 3GPP, "Release 15," Accessed 2 May 2021. <https://www.3gpp.org/release-15>.

³⁹ 3GPP, "Release 16," Accessed 2 May 2021. <https://www.3gpp.org/release-16>.

⁴⁰ 3GPP, "Release 17," Accessed 2 May 2021. <https://www.3gpp.org/release-17>.

⁴¹ 3GPP, "Release 18," Accessed 2 May 2021. <https://www.3gpp.org/release18>.

LEADING VENDORS

The level of complexity and sophistication of the 5G infrastructure is so great that only a few vendors have the technology, talent development, training and expertise to provide a full 5G upgrade. Therefore, policy makers and service providers must be highly selective when choosing who to source 5G equipment from, as they will likely be reliant on this equipment in the long-term.

A report by Gartner,⁴² a global research and advisory firm, conducted an analysis of ten 5G vendors. Gartner mapped different 5G vendors with respect to two main categories: 1) completeness of vision and 2) ability to execute. Completeness of vision takes into account the 5G vendor's understanding of the market, marketing strategy, product offering strategy, industry strategy, geographic strategy, and innovation. Ability to execute considers the 5G vendor's actual products and services that are currently offered in the market, financial health, market responsiveness and track record, marketing execution, and customer experience.

“... policy makers and service providers must be highly selective when choosing who to source 5G equipment from, as they will likely be reliant on this equipment in the long-term.”

⁴² Kosei Takiishi et al., “Magic Quadrant for 5G Network Infrastructure for Communications Service Providers,” Gartner. February 17, 2021. <https://www.gartner.com/doc/reprints?id=1-25APZOEI&ct=210222&st=sb>.



Figure 1.7. Quadrant mapping 5G vendors

China’s Huawei, Sweden’s Ericsson, and Finland’s Nokia are considered the leaders in 5G, scoring highly in both completeness of vision and ability to execute. Other prominent 5G vendors such as Samsung and ZTE are positioned as visionaries because they provide some aspects of 5G technology but lack certain characteristics and accomplishments that prevent them from being considered leaders. For instance, while Samsung has provided promising innovations to 5G technology and has a substantial presence in its domestic market of South Korea, its lack of presence in 2G, 3G and 4G networks impedes its ability to compete with the

likes of Huawei, Nokia and Ericsson because service providers tend to prefer incumbent vendors when upgrading to a new standard. ZTE also has a strong 5G portfolio, but its lack of market share in 4G prevents it from being competitive in 5G NSA deployment, the preferred deployment method for most telecommunications providers at this time. Lastly, 5G vendors that are positioned as niche players do not possess the same level of comprehensiveness as leaders and visionaries, however they do provide specific 5G network pieces. With the possibility of open RAN, these niche players may have the opportunity to specialize in their products and services to maintain a position in the 5G market but do not occupy the same level of importance as 5G leaders. Therefore, this paper will focus on the three leaders in 5G, Huawei, Ericsson and Nokia.

Huawei

As a leading 5G vendor, Huawei scores the highest in completeness of vision according to the Gartner report. Huawei is particularly noted for its high level of innovation. For instance, it has the highest number of 5G contributions defined by the 3GPP as well as the highest number of 5G patents⁴³ in large part due to its heavy investment in R&D. Huawei also offers a 5G portfolio that has more “scale and breadth” than its competitors by providing a highly diverse range of products and features such as scenario-based beamforming antennas, network slicing, and AI-based network operation.⁴⁴ Huawei’s diverse portfolio makes it well suited for vertically integrated industries in particular. Due to a high level of state support, Huawei also offers its equipment at cheaper prices than its main competitors.⁴⁵

⁴³ IPlytics, “Who Is Leading the 5G Patent Race? A Patent Landscape Analysis on Declared SEPs and Standards Contributions,” IPlytics, February 2021, 3-5.

https://www.iplytics.com/wp-content/uploads/2021/02/Who-Leads-the-5G-Patent-Race_February-2021.pdf

⁴⁴ Kosei Takiishi et al., “Magic Quadrant for 5G Network.”

⁴⁵ John Lee, “The Rise of China’s Tech Sector: The Making of an Internet Empire,” LOWY Institute, May 4, 2017.

<https://www.lowyinstitute.org/the-interpreter/rise-china-s-tech-sector-making-internet-empire>.

Huawei's high level of innovation, low price offerings, and scale and breadth of its 5G portfolio allows it to maintain the top position in market share for telecommunication providers at approximately 26% as of Q1 of 2021, compared to approximately 16% for both Nokia and Ericsson.⁴⁶ Huawei also maintains its 5G leadership position by having a sound global strategy. It has secured 5G contracts in Asia and some European countries⁴⁷ and has leveraged its preexisting 4G deals to gain traction in the Middle East and parts of Latin America.⁴⁸ Lastly, Huawei has claimed to have built 140 5G networks in 59 countries,⁴⁹ compared to 93 networks built by Ericsson⁵⁰ and 67 for Nokia.⁵¹

Ericsson

Sweden's Ericsson is particularly strong in market execution, exemplified by its end-to-end offerings in 5G based on Gartner's assessment. Ericsson leads the pack in dynamic spectrum sharing (DSS) which allows for the integration of 5G NR with 4G [LTE](#) (otherwise known as NSA deployment). The Ericsson Radio System,⁵² which is designed to support a wide variety of network scenarios and remote installation of 5G NR, has allowed Ericsson to launch 5G networks much earlier than other 5G vendors. As a result, it leads all vendors in 5G trials and launches as of April 2021.⁵³ However, providers have noted that Ericsson lacks the flexibility and adaptability to create a tailored 5G package for their clients.⁵⁴

⁴⁶ Stefan Pongratz, "Key Takeaway—1Q 2021 Total Telecom Equipment Market," Dell'Oro Group. June 15, 2021. <https://www.delloro.com/key-takeaway-1q-2021-total-telecom-equipment-market/>.

⁴⁷ Kosei Takiishi et al., "Magic Quadrant for 5G Network."

⁴⁸ David Sacks, "China's Huawei Is Winning the 5G Race. Here's What the United States Should Do to Respond," Council on Foreign Relations. March 29, 2021. <https://www.cfr.org/blog/china-huawei-5g>.

⁴⁹ Juan Pedro Tomás, "Huawei Claims to Be Involved in Half of Global 5G Networks." RCR Wireless News, February 22, 2021. <https://www.rcrwireless.com/20210222/5g/huawei-claims-involved-half-global-5g-networks>.

⁵⁰ Ericsson, "144 commercial 5G agreements or contracts with unique operators," May 20, 2021. <https://www.ericsson.com/en/5g/contracts>.

⁵¹ "5G Contracts" Nokia, Accessed September 13, 2021. <https://www.nokia.com/networks/5g/5g-contracts/>.

⁵² "Ericsson Radio System," Ericsson, September 7, 2021. <https://www.ericsson.com/en/portfolio/networks/ericsson-radio-system>.

⁵³ Julber Osio and Erik Keith, "67 Markets Worldwide Have Commercial 5G Services," S&P Global Market Intelligence, May 11, 2021.

<https://www.spglobal.com/marketintelligence/en/news-insights/research/67-markets-worldwide-have-commercial-5g-services>

⁵⁴ Kosei Takiishi et al., "Magic Quadrant for 5G Network Infrastructure for Communications Service Providers," ibi

Nokia

Finland's Nokia boasts a strong 5G profile and has recently gained traction in the number of 5G contracts secured. Like Huawei and Ericsson, Nokia maintains a strong position in the telecommunications market due to its high number of 4G LTE deals, which in part gives it a competitive edge in securing 5G contracts over niche players and visionaries. Nokia differentiates itself from other 5G vendors as the first leading vendor to join the O-RAN alliance,⁵⁵ affording Nokia some thought leadership in Open RAN. However, Nokia's 5G product and service quality are weak compared to Huawei and Ericsson in terms of performance, responsiveness and cost-effectiveness.

Comparison of Leading 5G Vendors

The leading 5G vendors share two important characteristics: 1) the ability to provide key 5G infrastructure capabilities in both the Core Network and Radio Access Network and 2) a preexisting global presence in the telecommunications equipment market, marked by leadership in 4G LTE as well as previous generations. However, precisely ranking leadership among 5G vendors is not a straightforward process. It requires consideration of multiple metrics such as patent ownership, the number of 5G contracts, the quality of R&D and more. Furthermore, the varying levels of transparency within self-reported studies and the different methodologies used by experts make it difficult to identify the strongest 5G vendor definitively. Therefore, this paper acknowledges that Huawei, Nokia and Ericsson are the leading 5G vendors but offers a qualitative assessment to allow policy makers and service providers to compare the strengths and weaknesses of each vendor in terms of their technological offerings and market characteristics.

⁵⁵ "Open RAN," Nokia, Accessed September 13, 2021.

<https://www.nokia.com/networks/portfolio/radio-access-networks-ran/open-ran/>.

Table 1.4. Comparison of leading 5G vendors

5G Vendor	Strengths	Weaknesses
Huawei	<p>Flexible and Extensive 5G Portfolio: The scale and breadth of its 5G portfolio is unmatched by other 5G vendors. This allows Huawei to create flexible 5G packages to meet the unique requirements of each service provider.</p>	<p>Controversial Reputation: Geopolitical pressures have hampered Huawei’s ability to secure 5G deals, especially in Europe and North America, which may hinder Huawei’s growth in the long-term.</p>
	<p>High Innovation: Due to heavy investment in R&D, it owns the most 5G patents and has submitted the most contributions to the 3GPP.</p>	<p>Supply Chain impacted by sanctions: U.S. trade sanctions have caused a chip shortage for Huawei. This may have long-term ramifications on Huawei’s overarching 5G supply-chain.</p>
	<p>Cost-Effective: Funding from the Chinese government allows Huawei to sell its equipment at cheaper prices.</p>	<p>Opposes Open RAN: Service providers may want to avoid Huawei if vendor diversification in the RAN is desired.</p>
Ericsson	<p>Strong end-to-end package: Offers a strong and reliable end-to-end 5G package.</p>	<p>Low Flexibility: Lacks flexibility, making it less able to adapt to specific provider needs.</p>
	<p>NSA Deployment: Especially strong in providing NSA deployment due to the Ericsson Radio System and expertise in Dynamic Spectrum Sharing.</p>	
Nokia	<p>Open RAN leadership: The first of the three leading 5G vendors to join the O-RAN alliance, affording it some level of leadership in Open RAN standard setting and making it an attractive vendor for providers who are pursuing an Open RAN 5G architecture.</p>	<p>Products and Services are relatively weak: Products and services are comparatively weak in terms of performance, responsiveness and cost-effectiveness.</p>

PART TWO

5G CHALLENGES AND OPPORTUNITIES

The full realization of 5G networks will substantially expand the role of mobile networks, making them responsible for massive amounts of data at all levels of the value chain in multiple industries. The novelty of 5G technology therefore gives rise to both challenges and opportunities. In terms of challenges - all types of stakeholders will have to navigate economic uncertainties, new security issues, and the politics of vendor selection. With respect to opportunities, 5G leaders in particular will have the chance to seize substantial economic gains, attain a larger role in the standard setting process of mobile technologies, and promote and safeguard their own visions of internet governance.

ECONOMIC CHALLENGES

While 5G delivers a more efficient network experience and numerous use cases, it is also very expensive to build. Based on historical trends, each generation of mobile networks is more expensive to deploy than the last. Excluding the necessary upgrades to existing base stations and core networks, the upfront investment cost for 5G deployment is influenced by the size and concentration of potential users.⁵⁶ Therefore, the cost of 5G investment is much higher in sparsely populated rural areas than in densely populated urban areas. Moreover, the choice of spectrum bands for 5G use will also affect the final cost of delivering 5G. While the upfront investment costs for 5G are currently inconclusive, countries are spending significant amounts of money to deploy 5G. As of March 2021, according to a report by Boston Consulting Group (BCG), a total investment of approximately US\$360 billion will be required to realize the full 5G

⁵⁶ Australian Government Department of Infrastructure, Transport, 2018. "Impacts of 5G on Productivity and Economic Growth." Communications, April 9, 2018.
<https://www.communications.gov.au/departamental-news/impacts-5g-productivity-and-economic-growth>.

vision in Europe by 2025. An investment of US\$180 billion will be needed to build the complete infrastructure and another US\$180 billion to upgrade broadband speeds to 1Gbit.⁵⁷ According to the Mobile Economy China report of 2021 by the Global System for Mobile Communications Association GSMA (GSMA), domestic mobile operators in China will invest nearly \$210 billion in networks between 2020 and 2025 and 90% of which will be spent on 5G.⁵⁸

Different countries and service providers will need to be aware of investment costs and options needed for 5G rollout. For instance, given that 5G will be very expensive to build, many countries will be better suited to taking the NSA approach (integrating 5G with existing 4G networks) before transitioning to a full 5G experience. Furthermore, because 5G will use high spectrum bands which require a high density of base stations, it may be ill-advised to build 5G in sparsely populated rural areas. Lastly, the demand side of 5G has to be considered. The return on investment for novel devices like autonomous vehicles and E-health equipment is relatively uncertain. If there is no demand for the new devices that 5G enables, investing in 5G immediately may not be the wisest decision. Therefore, a country's unique market characteristics need to be closely scrutinized to ensure it has the means to support 5G offerings and achieve high returns on investment.

⁵⁷ European Telecommunications, "Connectivity & Beyond. How Telcos Can Accelerate a Digital Future for All," Telekom, March 2021, 16.

<https://www.telekom.com/resource/blob/623182/db6da48b23979a829a470a436be8b1a9/dl-210325-studie-boston-connsul-group-etno-data.pdf>

⁵⁸ GSMA, "The Mobile Economy China 2021," GSM Association, February 2021, 19.

https://www.gsma.com/mobileeconomy/wp-content/uploads/2021/02/GSMA_MobileEconomy2021_China_Eng-1.pdf

SECURITY ISSUES

1. Network Compatibility Problems

Due to the sluggish evolution of telecommunications networks, the transfer to a new generation usually takes multiple stages and years.⁵⁹ 5G networks will be used alongside 4G and sometimes even 3G and 2G networks in some regions. Previous generations of networks often endured various attacks including: phone and SMS interception, geo-tracking, and denial of service.⁶⁰ Thus, providers will need to continue solving existing network vulnerabilities while preparing for new ones because the vulnerabilities that existed in previous network generations will be inherited by 5G networks.

2. Network Slicing

Network slicing is based on virtualization technology, which provides logical isolation on shared resources with each slice separated from one another and allocated its own resources and unique security policies. However, when the 5G network infrastructure is collaboratively created by numerous operators or a single 5G network is shared by multiple mobile operators, attackers still can disrupt routine activities by assaulting one of the low-protection network slices.⁶¹ Moreover, multiple types of threats are also possible during the run time of the network slicing, including denial of service (DoS), performance attacks, data exposure and privacy breaches.⁶² In addition, management-related vulnerabilities (such as unauthorized configuration modifications) might persist during runtime, and new threats may appear (such as slice deactivation).

⁵⁹ Positive Technology, "5G SECURITY ISSUES," GSMA, November 2019, 3.

https://www.gsma.com/membership/wp-content/uploads/2019/11/5G-Research_A4.pdf.

⁶⁰ Ruxandra F. Olimid and Gianfranco Nencioni, "5G network slicing: A Security Overview," *IEEE Access* 8 (2020): 100001. <https://ieeexplore.ieee.org/abstract/document/9099823>.

⁶¹ Ruxandra F et al., "5G network slicing: A Security Overview," 100002-100003.

⁶² Ruxandra F et al., "5G network slicing: A Security Overview," 100003.

3. Internet of Things (IoT)

As 5G networks are being used on a large scale, an unprecedented number of IoT devices will be connected to 5G networks. However, IoT-based critical infrastructure is a tempting target for cybercriminals and this unique infrastructure is becoming increasingly vulnerable to cyberattacks and cyber threats.⁶³ The huge variety of IoT devices means malware can easily expand while the continuous and speedy requirements for firmware updates often face user reluctance and present additional vulnerabilities. Furthermore, the sheer scale of 5G networks that accommodates such a large number of IoT devices might create a single point of failure, in which malicious actors can attack multiple devices, in different industries, all at once.

4. Untrusted Vendor Problem

Due to the novelty and complexity of 5G, many countries will source 5G equipment and expertise from leading 5G vendors to upgrade and build their networks. As such, the risk comes from providing network access to potentially untrustworthy vendors. The magnitude of this risk is compounded with 5G, as the network will be connected to a large number of devices potentially giving vendors access to large swaths of data. Dr. Melissa Griffith, a researcher and expert on cybersecurity, describes the untrusted 5G vendor problem as follows: “If someone builds your house, they know the layout and may have kept a spare key to get in.”⁶⁴ Although this security concern applies to all 5G vendors in theory, it is primarily aimed at Chinese vendors like Huawei.

⁶³ Amir Djenna, Saad Harous, and Djamel Eddine Saidouni, “Internet of Things Meet Internet of Threats: New Concern Cyber Security Issues of Critical Cyber Infrastructure,” *Applied Sciences* 11 no. 10 (2021): 1-3. <https://doi.org/10.3390/app11104580>.

⁶⁴ Melissa Griffith, “Emerging Technologies and Great Power Competition.” Webinar by World Affairs Council Orange County, February 26, 2021.

GEOPOLITICS

5G leaders will have the chance to seize substantial economic gains through the telecommunications industry. However, 5G leadership also gives countries the chance to attain a larger role in the standard setting process of mobile technologies and promote and safeguard their own visions of internet governance which has increasingly turned 5G into a geopolitical issue due its implications on world order.

LEADERSHIP IN THE TELECOMMUNICATIONS INDUSTRY AND ITS IMPACT ON ECONOMY

With each transition to a new generation of mobile networks, first-movers receive significant economic gains. During the 2G era, Europe took the lead by taking a unified approach to 2G networks. The European Telecommunications Standards Institute (ETSI) created and refined a single standard - the Global System for Mobile Communications (GSM) - so that European telecommunications companies could more easily develop their 2G networks. European 2G leadership generated massive benefits for European countries in terms of employment, balance of trade, and intellectual property creation.⁶⁵ It also catalyzed the growth of telecommunications equipment suppliers like Nokia and Ericsson and made them integral to the competitiveness of their countries of origin. For instance, during the 2G era, Nokia exports accounted for 24% of all Finnish exported goods and services⁶⁶ while Nokia shares accounted for 70% of the market value of the Helsinki stock exchange.⁶⁷ The benefits of mobile generation leadership only further increased as mobile networks became more sophisticated.

⁶⁵Recon Analytics, "How America's 4G Leadership Propelled the U.S. Economy." CTIA, April 16, 2018, 4. https://api.ctia.org/wp-content/uploads/2018/04/Recon-Analytics_How-Americas-4G-Leadership-Propelled-US-Economy_2018.pdf.

⁶⁶ OECD, *OECD Economic Surveys: Finland 2002*, OECD Publishing, 2002, 21. <https://books.google.com/books?id=5b3LXKJpiEOC&pg=PA21&lpg#v=onepage&q&f=true>.

⁶⁷ Recon Analytics, "How America's 4G Leadership", 4.

By the 4G era, the U.S. gained a leadership position after the Federal Communications Commission (FCC) enacted regulations that allowed for greater flexibility in spectrum allocation and speedier cell tower siting.⁶⁸ This allowed AT&T and Verizon to quickly deploy 4G LTE networks at scale making the U.S. one of the first countries to achieve a full 4G LTE network upgrade. The benefits of 4G leadership were massive for the U.S. economy. From 2011 to 2019, the U.S. wireless industry GDP grew by 253%, added over 16.7 million new jobs, and added US\$690.5 billion to overall GDP (accounting for 10% of total GDP growth).⁶⁹

China is the first country in the world to have a government-led and planned 5G test. Since 2013, the Ministry of Industry and Information Technology (MIIT), together with the National Development and Reform Commission (NDRC) and the Ministry of Science and Technology (MOST), established the IMT-2020 (5G) Promotion Group to drive the creation of 5G standards through a collaborative framework with the EU, the United States, Japan, and Korea. In addition, the Chinese government has also developed corresponding support policies based on national strategies including the 13th Five-Year Plan and Made in China 2025. The Ministry of Industry and Information Technology (MIIT) has released a 5G development roadmap, with the goal of making 5G a critical infrastructure for China's economic and social development. The Development and Reform Commission (NDRC) also issued a guidance document for information infrastructure construction projects in 2018, directing the construction of 5G networks in at least five cities to create sustained coverage.

In terms of spectrum allocation, the Chinese government has adopted a different management model than most Western countries. For example, most countries hold a bidding process to auction spectrum to operators and do not receive government support in the construction process. China, on the other hand, clearly treats 5G as an infrastructure to be built

⁶⁸ Recon Analytics, "How America's 4G Leadership", 4.

⁶⁹ Recon Analytics, "The 4G Decade: Quantifying the Benefits," CTIA, July 29, 2020. <https://www.ctia.org/news/report-the-4g-decade-quantifying-the-benefits>.

and actively supports the construction of 5G networks. Finally, since China's three major domestic carriers are state-run enterprises, these companies will make significant efforts to build networks in rural and remote areas with the support of the government. For 5G, only projections can be made of the economic impact it will have; however, historical trends indicate that the value will be immense. A report by IHS Markit estimates that by 2035 the 5G value chain will drive US\$3.8 trillion of economic output and support 22.8 million jobs, most of which will be in China.⁷⁰

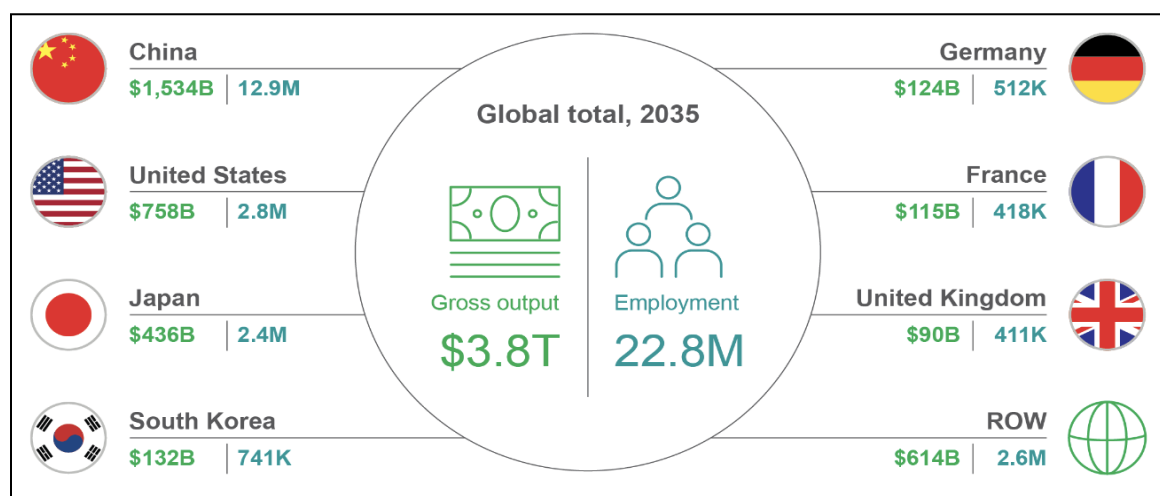


Figure 2.1. The economic contribution of the 5G value chain by 2035.⁷¹

STANDARD SETTING

Standard setting is another benefit of mobile network leadership because it allows one to set the standards for network infrastructures, define specifications for future devices, and thereby more effectively produce and export domestic technologies.⁷² For instance, the Big Tech companies in the U.S. took advantage of new 4G LTE capabilities to produce a host of new

⁷⁰ IHS Markit, “The Role of 5G in a Post-Pandemic World Economy,” Qualcomm, November 2020, 3-4. <https://www.qualcomm.com/media/documents/files/the-5g-economy-in-a-post-covid-19-era-report.pdf>.

⁷¹ Ibid, 4.

⁷² Milo Medin and Louie Gilman, “The 5G Ecosystem: Risks & Opportunities for DoD,” Defense Innovation Board, April 3, 2019, 6-7. https://media.defense.gov/2019/Apr/03/2002109302/-1/-1/0/DIB_5G_STUDY_04.03.19.PDF.

devices and applications. In turn, as these new devices and applications were sold around the world, the U.S. was able to “build a global ecosystem of network providers, device manufacturers, and app developers that shaped the future of 4G and the experience of all other countries implementing it.”⁷³ Standards setting also dictates how money flows throughout the mobile network ecosystem, in which companies who set the industry standard will receive royalty payments from smaller companies participating in the ecosystem.⁷⁴ The benefits of standard setting in 5G are multiplied because 5G networks encompass multiple industries. Furthermore, the novelty of 5G means that the leaders of the 5G era will have control over global order in ways that we cannot predict.

Politics within the Standard Setting Process

The past decade has seen NATO countries take the position that international law, facilitated and informed by multistakeholder bodies, should regulate cyberspace.⁷⁵ In 2011, China along with Russia and several Central Asian countries introduced a different approach to internet governance through the Shanghai Cooperation Organization (SCO) which promoted the primacy of the nation-state as a regulator of cyberspace.⁷⁶ The contrasting approaches to internet governance between NATO countries and China and Russia reflects the ideological differences between liberal democracies and authoritarian states, and these differences manifest in the standards setting process of mobile networks as well. Since the 2G era, mobile network standards have been set by the confluence of agencies, industry organizations, government institutions, and public-private partnerships through standardization bodies. Therefore, European and American leadership in previous mobile generations meant that

⁷³ Milo Medin and Louie Gilman, “The 5G Ecosystem: Risks & Opportunities for DoD,” 72.

⁷⁴ Eurasia Group, “Eurasia Group White Paper: The Geopolitics of 5G.” November 15, 2018, 8. [https://www.eurasiagroup.net/siteFiles/Media/files/1811-14%205G%20special%20report%20public\(1\).pdf](https://www.eurasiagroup.net/siteFiles/Media/files/1811-14%205G%20special%20report%20public(1).pdf).

⁷⁵ Mikk Raud, China and Cyber: Attitudes, Strategies, Organisation. CCDCOE, 2016, 7. https://ccdcoe.org/uploads/2018/10/CS_organisation_CHINA_092016_FINAL.pdf.

⁷⁶ Brigid Grauman, “Cyber-Security: The Vexed Question of Global Rules,” Analysis & Policy Observation, February 21, 2012, 4. <https://apo.org.au/node/28268>.

standards were set primarily through multi-stakeholder organizations such as the GSMA and 3GPP that facilitate exchange between stakeholders from bottom-up.⁷⁷

In recent years, China has increased its activity in the standards setting process by submitting written contributions and gaining leadership positions in many standardization bodies to promote its own version of technology standards.⁷⁸ For instance, China held the most leadership positions in the 3GPP at the end of 2020.⁷⁹ China's approach to standards setting contrasts that of the U.S. and Europe in that it prefers a multilateral approach, as evidenced by its special focus on the International Telecommunication Union (ITU), because multilateral bodies function under a more state-driven context.⁸⁰ One study found that China had submitted the most written contributions from 2009-2020 to the ITU-T at 3,021 compared to just 405 for the U.S. Additionally, Houlin Zhao of China is currently serving as the Secretary General of the ITU. As the 5G transition goes on, the participation of 5G leaders within their standards organizations will play a pivotal role in shaping the global ecosystem of mobile networks.

⁷⁷ Kersten Heineke et al., "Networks and Geopolitics: How Great Power Rivalries Infected 5G." Oxford Information Labs, 2020, 9. https://oxil.uk/publications/geopolitics-of-5g/Geopolitics_5G_Final.pdf.

⁷⁸ Dominique Lazanski, "China, Huawei and 5G Standards in the UK," *Forbes*, April 27, 2019. <https://www.forbes.com/sites/dominiquelazanski/2019/04/27/china-huawei-and-5g-standards-in-the-uk/?sh=73f8d8732fbd>.

⁷⁹ Julia Voo, "Shaping Global Technology Governance: Why the U.S. Must Adopt a Proactive Approach to Technical Standards for Long Term Security," Penn Project on the Future of U.S. - China Relations, Accessed September 13, 2021, 24. http://cpb-us-w2.wpmucdn.com/web.sas.upenn.edu/dist/b/732/files/2020/10/Julia-Voo_Shaping-Global-Technology-Governance_Final.pdf.

⁸⁰ Mark Montgomery and Theo Lebryk, "China's Dystopian 'New IP' Plan Shows Need for Renewed US Commitment to Internet Governance." Just Security, April 13, 2021. <https://www.justsecurity.org/75741/chinas-dystopian-new-ip-plan-shows-need-for-renewed-us-commitment-to-internet-governance/>.

Table 2.1. Key Standardization Bodies in the Telecommunications Industry developing 5G standards.⁸¹

Body	Description	Approach to Standards Setting
3GPP	<p>Mission: Studies technical specifications for radio access and core networks. Technical specifications are transposed into standards by seven telecommunications standard development organizations (organizational partners) from Asia, Europe and North America. The Organizational Partners can also invite other organizations (market representation partners) as advisors.</p> <p>5G Work: Developing technical specifications for radio access and core networks for 5G NSA and SA deployment.</p>	Multi-stakeholder
ITU	<p>Mission: Allocates global spectrum, develops technical standards to ensure that network and technologies interconnect, and improves access to Information and Communication Technologies (ICTs) in underserved communities.⁸² As a United Nation agency, it operates using a government-led and multilateral approach through 193 member states.</p> <p>5G Work: The radio communication sector for the ITU (ITU-R) negotiates technical specifications and international regulations for spectrum use in 5G.</p>	Multilateral
GSMA	<p>Mission: Represents the policy and regulatory interests of the mobile industry and advocates on the behalf of its members to governments and institutions to achieve scale and interoperability for new mobile technologies.</p> <p>5G Work: Developing frameworks and guidance for the 5G ecosystem including network slicing, IoT, spectrum harmonization, and security.</p>	Multi-stakeholder

⁸¹ Kersten Heineke et al., “Networks and Geopolitics”, 9.

⁸² ITU, “About International Telecommunications Union (ITU),” accessed September 13, 2021. <https://www.itu.int/en/about/Pages/default.aspx>

THE HUAWEI DILEMMA

At the center of the 5G geopolitics is Huawei. The controversy stems from the allegation that Huawei has ties to the Chinese government and operates in a legal environment in which the CCP can compel it to divulge sensitive information obtained from its mobile networks. As 5G networks have access to more data than previous generations through 5G-powered industries, there is a growing fear that China will use Huawei as a backdoor for espionage. However, many experts have concluded that the controversy surrounding Huawei may have been manufactured by the U.S. as a strategy in the larger Sino-American conflict to prevent China from increasing its economic competitiveness and cementing its status as a technological superpower.⁸³

China's Technological Agenda

While skepticism of Huawei has escalated considerably during the 5G era, it originated from the wider context of western distrust of China's technological rise. It is no secret that China has committed to using technological innovation as a long-term national strategy to become a global market power. In 2006, China set forth a 15 year plan with the goal of promoting and fostering indigenous innovation in science and technology to become a premier technological power by the mid-21st century.⁸⁴ The 15 year plan has been anchored by government guidance and control, investment in technology research and investment, and regulatory schemes aimed at growing domestic companies while restricting foreign ones.⁸⁵ Firm government support has created an environment where Chinese tech companies can thrive - turning telecommunications companies like Huawei, ZTE, and China Mobile, as well as other

⁸³ Kaan Sahin and Didi Kirsten Tatlow, "Berlin's Preliminary 5G Decision Limiting Damage and Learning Lessons," DGAP Policy Brief, 2019, 2-3.

https://dgap.org/sites/default/files/article_pdfs/dgap_policybrief_nr3-nov2019_5g.pdf.

⁸⁴ ITU, "The National Medium-and Long-Term Program for Science and Technology Development (2006- 2020)," Cybersecurity, Accessed September 13, 2021, 10.

https://www.itu.int/en/ITU-D/Cybersecurity/Documents/National_Strategies_Repository/China_2006.pdf.

⁸⁵ Mikk Raud, "China and Cyber," 12.

tech companies such as Alibaba, Xiaomi, and Baidu into the successful companies they are today.

Given the unique relationship between the Chinese state and technology companies, western analysts have raised concerns around cybersecurity when dealing with Chinese companies. These concerns were only heightened after the Chinese government passed a series of national security laws. For instance, the Counterespionage law of 2014 states that during a counterespionage investigation, ‘citizens and organisations are obligated to provide facilities or other assistance’ and ‘must not refuse’.⁸⁶ Similarly, the National Intelligence Law of 2017 declares that the state “protects individuals and organizations that support, assist and cooperate with national intelligence work,” and that “state intelligence shall use the necessary methods, means and channels to carry out intelligence work at home and abroad according to their work needs.”⁸⁷ These laws have fed the concern that Chinese companies operate in a legal environment in which the state can compel them to divulge sensitive data.

Since China’s technological rise, western governments and security experts from the U.S. and U.K. have argued that there is significant and long-standing evidence of collaboration between the Chinese government and industry “for the purpose of amassing technological secrets.”⁸⁸ For instance, Mandiant, a cybersecurity firm, found that the People’s Liberation Army (PLA) had systematically stolen confidential data from more than 140 organisations across multiple industries.⁸⁹ In 2018, The U.K. government and its allies reported that a group known

⁸⁶ Samantha Hoffman, “Huawei and the Ambiguity of China’s Intelligence and Counter-Espionage Laws,” *The Strategist*, September 12, 2018.

<https://www.aspistrategist.org.au/huawei-and-the-ambiguity-of-chinas-intelligence-and-counter-espionage-laws/>.

⁸⁷ Chinese National People’s Congress Network, “National Intelligence Law of the People’s Republic,” Brown University Department of Computer Science, June 27, 2017, 2-3.

https://cs.brown.edu/courses/csci1800/sources/2017_PRC_NationalIntelligenceLaw.pdf.

⁸⁸ Mikk Raud, “China and Cyber,” 5.

⁸⁹ “Mandiant Releases Report Exposing One of China’s Cyber Espionage Groups.” FireEye. Accessed September 13, 2021.

as Red Apollo acted on behalf of the Chinese Ministry of State Security to steal intellectual property and sensitive data in Europe, Asia, and the U.S.^{90 91} By 2021, about 80% of all economic espionage cases brought by the U.S. Department of Justice involve activities that would benefit the CCP and around 60% of all trade secret theft cases have a connection to China.⁹² Rightly or not, perceptions of Huawei have been influenced by China's reputation within the intelligence community, particularly in western countries.

Huawei Security Concerns

From the beginning of 5G, the United States has promoted the idea that Huawei poses a threat to national security. Governments in the U.K., Canada, Australia and New Zealand and some parts of Europe are expressing the same concern. Many argue that Huawei receives substantial state-support which may indicate that it is subject to government control. Huawei has received as much as US\$75 billion in the form of "grants, credit facilities, tax breaks and other forms of financial assistance" often from China's state controlled banks.⁹³ To further promote the argument that Huawei is controlled by the state, many point out that Huawei's founder - Ren Zhengfei - was a former high-intelligence officer for the People's Liberation Army (PLA). A report by the RAND corporation argued that Ren Zhengfei's connection to the PLA meant that "Huawei maintains deep ties with the Chinese military, which serves a multi-faceted role as an important customer, as well as Huawei's political patron and research and

<https://www.fireeye.com/company/press-releases/2013/mandiant-releases-report-exposing-one-of-chinas-cyber-espionage-groups.html>.

⁹⁰ UK Government, "UK and Allies Reveal Global Scale of Chinese Cyber Campaign," December 20, 2018.

<https://www.gov.uk/government/news/uk-and-allies-reveal-global-scale-of-chinese-cyber-campaign>.

⁹¹ FireEye iSIGHT Intelligence, "APT10 (MenuPass Group): New Tools, Global Campaign Latest Manifestation of Longstanding Threat," FireEye, April 6, 2017.

https://www.fireeye.com/blog/threat-research/2017/04/apt10_menupass_grou.html.

⁹² "Information about the Department of Justice's China Initiative and a Compilation of China-Related Prosecutions since 2018," The United States Department of Justice, July 31, 2020.

<https://www.justice.gov/nsd/information-about-department-justice-s-china-initiative-and-compilation-china-related>.

⁹³ Chuin-Wei Yap, "State Support Helped Fuel Huawei's Global Rise," *Wall Street Journal*, December 25, 2019.

<https://www.wsj.com/amp/articles/state-support-helped-fuel-huaweis-global-rise-11577280736>.

development partner.”⁹⁴ The table below lists different allegations and reports on Huawei over the last two decades from companies, intelligence experts, governments and agencies around the world.

Table 2.2. Allegations and Reports on Huawei.

Year	Issue	Description
2003	Intellectual Property Theft	Cisco sued Huawei, accusing the company of intellectual property theft by copying Cisco’s source code, Cisco’s user interface, and plagiarizing from Cisco’s user manuals. ⁹⁵ Huawei later admitted to copying a “small portion of (Cisco’s) VRP router software, less than 2% of the 1.5 million lines”, ⁹⁶ and thereafter removed all Huawei routers that contained the copied code.
2009	Potential for State-Backed Espionage	Intelligence experts cautioned British Ministers against using Huawei equipment in the building of a new communications network because it could make Britain’s vital services that are reliant on communications networks vulnerable to attacks from China. ⁹⁷
2009	Military Ties	Intelligence Officials investigated allegations that Huawei in Australia was hiring Chinese technicians with links to the PLA. ⁹⁸
2010	Hindering Fair	Option SA, a Belgian telecommunications equipment supplier,

⁹⁴ Evan S. Medeiros et al., “Limited Electronic Distribution Rights,” RAND Corporation, 2005, 218. https://www.rand.org/content/dam/rand/pubs/monographs/2005/RAND_MG334.pdf

⁹⁵ CISCO Systems, and CISCO Technology Inc, “CISCO’S MOTION for PRELIMINARY INJUNCTION,” Newsroom Cisco, February 5, 2003, 8-12. https://newsroom.cisco.com/dlls/Cisco_Mot_for_PI.pdf

⁹⁶ Scott Thurm, “Huawei Admits Copying Code from Cisco in Router Software,” *Wall Street Journal*, March 24, 2003. <https://www.wsj.com/amp/articles/SB10485560675556000>.

⁹⁷ “Britain Could Be Shut down by Hackers from China, Intelligence Experts Warn,” *The Telegraph*, 29 March 2009. <https://www.telegraph.co.uk/news/worldnews/asia/china/5072204/Britain-could-be-shut-down-by-hackers-from-China-intelligence-experts-warn.html>.

⁹⁸ Cameron Stewart. “Huawei in ASIO’s net,” *The Weekend Australian*, September 5, 2009. <https://www.theaustralian.com.au/australian-it-old/huawei-in-asios-net/news-story/08f09e38ac5f5cc9ae6acb7e599f6da8>

	Competition from Excessive State Support	alleged that Huawei and ZTE gained an unfair price advantage in the European market because they are controlled by the Chinese government, giving them undue access to tax breaks, research grants and cheap credit from state-owned banks. ⁹⁹
2010	Military Ties	Indian intelligence agencies were concerned with Huawei's connection to the PLA and the Chinese security establishment leading to the Indian communication ministry placing restrictions on the use of Huawei's equipment in the country. ¹⁰⁰
2011	Potential for State-Backed Espionage	The United States-China Economic and Security Review Commission published a report on the national security implications of telecommunications products from the PRC. The report labeled Huawei as a "national champion" that is "directly subject to direction by the Chinese Communist Party (CCP), to include support for PRC state policies and goals." ¹⁰¹
2013	Potential for State-Backed Espionage	The former head of the CIA and National Security Agency (NSA) alleged that Huawei had shared "intimate and extensive knowledge of the foreign telecommunications system" with the Chinese government based on his review of a Huawei briefing paper when the company was trying to establish itself in the U.S. market. Huawei's global cybersecurity officer described the allegations as "tired, unsubstantiated, defamatory remarks." ¹⁰²

⁹⁹ Matthew Dalton, "Europe Raises Cry over Chinese Technology," *Wall Street Journal*, October 6, 2010. <https://www.wsj.com/amp/articles/SB10001424052748704847104575532131550917748>.

¹⁰⁰ Bharti Jain, "Huawei Part of Chinese Spy Network, Says R&AW," *The Economic Times*, May 7, 2021. <https://economictimes.indiatimes.com/news/politics-and-nation/huawei-part-of-chinese-spy-network-says-raw/articleshow/5900798.cms>.

¹⁰¹ USCC Research Staff, "The National Security Implications Of Investments And Products From The People's Republic Of China In the Telecommunications Sector," U.S. - CHINA Economic and Security Review Commission. January 2011, 9. https://www.uscc.gov/sites/default/files/Research/FINALREPORT_TheNationalSecurityImplicationsofInvestmentsandProductsfromThePRCintheTelecommunicationsSector.pdf.

¹⁰² Sophie Curtis, "Ex-CIA Chief Accuses Huawei of Industrial Espionage," *The Telegraph*. July 19, 2013. <https://www.telegraph.co.uk/technology/news/10191154/Ex-CIA-chief-accuses-Huawei-of-industrial-espionage.html>.

2016	Potential for State-Backed Espionage	Canadian immigration officers rejected visa applications for two Chinese citizens who were employed by Huawei, citing concerns of espionage and government subversion. ¹⁰³
2017	Installation of Backdoors	A report by Freedom House reported that digital activists in Sri Lanka believe that Chinese telecommunication companies like Huawei and ZTE who helped develop Sri Lanka's ICT infrastructure "may have inserted backdoor espionage and surveillance capabilities." ¹⁰⁴
2019	Suspicious Ownership Structure	A report assessing Huawei's ownership structure argued that Huawei's claim of being employee-owned is false and that it may be state-owned. ¹⁰⁵
2020	Installation of Backdoors	A U.S. National Security Advisor claimed to have evidence that Huawei had installed backdoors in its network around the world to "access sensitive and personal information" for the Chinese state. ¹⁰⁶

Huawei has continually denied all allegations through public interviews, press releases, and public relation campaigns.¹⁰⁷ To build trust, it has published several articles, news reports, and white papers to advocate for its commitment to privacy protection and transparency while entering into initiatives and agreements in multiple countries to facilitate clear communication between stakeholders.¹⁰⁸ To date, there has been no publicly released *direct* evidence that

¹⁰³ Ian Young, "Canada Cites Espionage Risk from Two Huawei Employees, Saying It Plans to Reject Their Immigration Applications," *South China Morning Post*, May 4, 2016. <https://www.scmp.com/news/china/article/1941130/canada-cites-espionage-risk-two-huawei-employees-saying-it-plans-reject>.

¹⁰⁴ "Key Developments, June 1, 2016 - May 31, 2017," Freedom House, Accessed September 13, 2021. <https://freedomhouse.org/country/sri-lanka/freedom-net/2017>.

¹⁰⁵ Christopher Balding, and Donald C. Clarke, "Who Owns Huawei?," SSRN 3372669, April 17, 2019, 2. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3372669.

¹⁰⁶ Julian E Barnes, "White House Official Says Huawei Has Secret Back Door to Extract Data," *New York Times*, February 12, 2020. <https://www.nytimes.com/2020/02/11/us/politics/white-house-huawei-back-door.html>.

¹⁰⁷ Aarshi Tirkey, "The 5G Dilemma: Mapping Responses across the World," Observer Research Foundation, May 2020, 13. https://www.orfonline.org/wp-content/uploads/2020/05/ORF_Monograph_5G_Dilemma.pdf.

¹⁰⁸ *Ibid.*, 13 - 14.

proves that Huawei 5G networks have been used as a backdoor for the Chinese government. Instead, the potential for state-backed espionage has been discerned from *circumstantial* evidence, owing to Huawei's ownership structure, military ties, amount of state support it receives, the legal and political environment it operates in, and numerous instances of state-backed espionage of Chinese origin. Therefore, the question remains as to what extent the rhetoric surrounding Huawei is legitimate and the probability that the aforementioned allegations come true. In this way, governments and operators need to be aware of the geopolitical narratives at play before making a decision to use, restrict, or ban Huawei.

The effects of the anti-Huawei campaign

Geopolitical pressures on Huawei have caused telecommunications providers to choose other 5G vendors, and in some cases, for governments to ban the use of Huawei equipment in 5G networks. In fact, seven countries - the U.S., U.K., Sweden, Poland, Romania, Japan, and Australia - have outright banned Huawei. Additionally, an increasing number of countries have used restrictions to make it difficult for telecommunications providers to work with Huawei without actually formally banning it to assuage U.S. concerns without worsening relations with China.¹⁰⁹

“...governments and operators need to be aware of the geopolitical narratives at play before making a decision to use, restrict, or ban Huawei.”

¹⁰⁹ David Sacks, “China’s Huawei is Winning.”

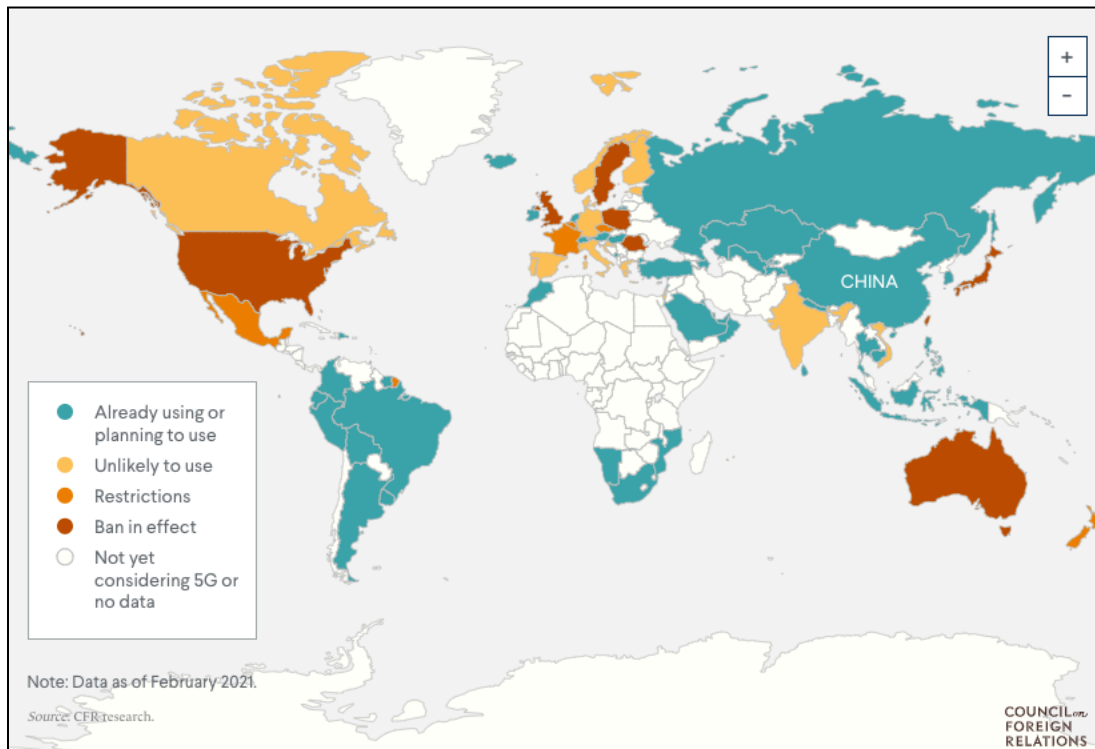


Figure 2.2. Official Approaches to using Huawei equipment in 5G networks.¹¹⁰

“To date, there has been no publicly released *direct* evidence that proves that Huawei 5G networks have been used as a backdoor for the Chinese government. Instead, the potential for state-backed espionage has been discerned from *circumstantial* evidence, owing to Huawei’s ownership structure, military ties, amount of state support it receives, the legal and political environment it operates in, and numerous instances of state-backed espionage of Chinese origin.”

¹¹⁰ David Sacks, “China’s Huawei is Winning.”

Table 2.3. Measures taken to obstruct Huawei

Year	Country	Measure
2018	Australia	The Australian government issued new security guidelines for 5G carriers, effectively banning Huawei and ZTE on the grounds of national security. ¹¹¹
2018	Japan	Japan’s central government issued guidelines that effectively barred ministries and Self-Defense forces from buying telecommunications equipment from Huawei and other Chinese companies. ¹¹²
2019	United States	An Executive Order under the Trump Administration barred U.S. companies from using telecommunications companies that are “subject to the jurisdiction of foreign adversaries to create and exploit vulnerabilities in information and communications technology or services”. ¹¹³
		Huawei was added to the entity list of the Export Administration Regulations (EAR). The list includes entities that are deemed to pose a significant risk to national security and imposes licensing requirements on them. ¹¹⁴

¹¹¹ Catherine Shu, “Australia Bans Huawei and ZTE from Supplying Technology for Its 5G Network,” TechCrunch, August 23, 2018.

<https://techcrunch.com/2018/08/22/australia-bans-huawei-and-zte-from-supplying-technology-for-its-5g-network/>.

¹¹² “Japan Bans Huawei and Its Chinese Peers from Government Contracts,” *Nikkei Asia*, December 10, 2018.

<https://asia.nikkei.com/Economy/Trade-war/Japan-bans-Huawei-and-its-Chinese-peers-from-government-contracts>.

¹¹³ “Securing the Information and Communications Technology and Services Supply Chain,” Federal Register, May 17, 2019.

<https://www.federalregister.gov/documents/2019/05/17/2019-10538/securing-the-information-and-communications-technology-and-services-supply-chain>.

¹¹⁴ “Addition of Certain Entities to the Entity List and Revision of Entries on the Entity List,” Federal Register, August 21, 2019.

<https://www.federalregister.gov/documents/2019/08/21/2019-17921/addition-of-certain-entities-to-the-entity-list-and-revision-of-entries-on-the-entity-list>.

2020	United Kingdom	U.K. legislation banned the use of Huawei equipment from the most sensitive parts of the core network, instructed that operators must stop installing new Huawei equipment, and plans to remove all Huawei equipment from the country's 5G networks by 2027. ¹¹⁵
2020	Sweden	Swedish telecom operators regulators banned Huawei from supplying equipment for 5G networks due to security concerns raised by the Swedish Security Service. The Swedish court upheld the ban in a hearing months later. ¹¹⁶
2020	Belgium	The Belgian government imposed restrictions on using high-risk vendors for 5G networks. This included a ban on using high-risk vendors in the core network and a cap of 35% on using high-risk vendors in the RAN. The restriction did not mention Huawei by name, but analysts have concluded that the measures were aimed at Huawei. ¹¹⁷
2020	Canada	Canada has not formally banned Huawei, but has delayed its decision long enough for its major telecom operators to exclude Huawei. ¹¹⁸

¹¹⁵ "Huawei: UK Bans New 5G Network Equipment from September," *The Guardian*, November 30, 2020. <https://www.theguardian.com/technology/2020/nov/30/huawei-uk-bans-new-5g-network-equipment-from-september>

¹¹⁶ Johan Ahlander and Supantha Mukherjee, "Swedish Court Upholds Ban on Huawei Selling 5G Network Gear," *Reuters*, June 22, 2021.

<https://www.reuters.com/technology/swedish-court-upholds-ban-huawei-selling-5g-network-gear-2021-06-22/>.

¹¹⁷ Laurens Cerelus, "Belgium to Cut down on Huawei Gear," *POLITICO*, June 25, 2020.

<https://www.politico.eu/article/belgium-huawei-restrictions/>.

¹¹⁸ David Ljunggren, "Canada Has Effectively Moved to Block China's Huawei from 5G, but Can't Say So," *Reuters*, August 25, 2020. <https://www.reuters.com/article/us-canada-huawei-analysis-idUSKBN25L26S>.

The ramifications of these geopolitical pressures can also be seen in the growth of 5G contracts and deals for Nokia and Ericsson from 2020 to 2021. For instance, at the beginning of 2020, Huawei led the pack with 91 5G commercial contracts, compared to 86 for Ericsson and 63 for Nokia.¹¹⁹ By 2021, Ericsson and Nokia secured 143 and 230 commercial agreements respectively. So far, Huawei has not released any definitive information on 5G contracts or deals since 2020. What is more, we do not have much information on the value of these contracts and it is important to consider that not all contracts have equal size or value. For example, one contract in China could be larger (revenue) than five or six contracts in other countries. Then there is the question of margins. Due to the size of the markets they preside over, Chinese service providers can exert a lot of downward pricing pressure on vendors that has an impact on the value. It is clear that the Chinese Government has tried to support Huawei to a larger extent in China to balance the losses it has incurred in markets overseas over the last couple of years.

Regardless, the massive growth in the number of commercial agreements for Nokia and Ericsson, despite both vendors having an arguably inferior 5G portfolio, may be indicative of Huawei's deteriorating reputation. Additionally, while Huawei maintains a leading position in market share, its market share decreased by 3 percentage points from 2020 to 2021, while Ericsson and Nokia increased their market share by 4 percentage points and 1 percentage point respectively.¹²⁰ Additionally, the U.S. imposed a trade sanction that prevents countries that use American technology to sell chips to Huawei.¹²¹ Access to chips affects Huawei's supply of 5G related semiconductors that are essential for network management and data storage¹²² and its ability to produce 5G-capable Huawei smartphones, making what was once the world's largest smartphone vendor by market share into the 6th largest in Q1 of 2021.¹²³ The sanction has

¹¹⁹ Aarshi Tirkey, "The 5G Dilemma," 9.

¹²⁰ Stefan Pongratz, "Key Takeaway."

¹²¹ Iain Morris, "Huawei Chips Crisis Shortens Odds on China-US Conflict," *Light Reading*, March 25, 2021. <https://www.lightreading.com/5g/huawei-chips-crisis-shortens-odds-on-china-us-conflict/d/d-id/768303>.

¹²² David Sacks, "China's Huawei is Winning."

¹²³ Sean Vikhyaat, "Huawei Only Held 4% Smartphone Market Share in Q1 2021," *GizmoChina*. June 11, 2021. <https://www.gizmochina.com/2021/06/11/huawei-held-4-smartphone-market-share-q1-2021/>.

significantly slowed Huawei’s revenue growth outside of China¹²⁴ leading many to question whether Huawei can maintain its dominant position as a 5G vendor with its supply chain compromised and geopolitical pressures mounting.

Table 2.3. 5G Vendor Partnerships

Company	Country	5G Vendor(s)	Notes
Safaricom	Kenya	Huawei Nokia	
Telefonica Deutschland	Germany	Huawei Nokia Ericsson	Plans to reduce the use of Huawei equipment to build its core network, and is looking to other suppliers in case Huawei is banned in Germany. Ericsson will build out the core network.
Deutsche Telekom	Germany	Ericsson Huawei	Historically, Deutsche Telekom has relied heavily on Huawei. Amidst political pressure, it awarded a contract to Ericsson to build its 5G network and is taking steps to decrease its reliance on Huawei.
Deutsche Bahn (Railway Company)	Germany	Nokia	Nokia will test Deutsche Bahn’s 5G network for automated rail operations.
Vodafone Germany	Germany	Ericsson	
Smart Axiata	Cambodia	Huawei ZTE	
Cellcard	Cambodia	Huawei ZTE	
du	UAE	Huawei	
Maxis	Malaysia	Huawei	
Vodafone Qatar	Qatar	Huawei	

¹²⁴ Will Knight, “US Sanctions Are Squeezing Huawei, but for How Long?,” *Wired*, April 1, 2017. <https://www.wired.com/story/us-sanctions-squeezing-huawei-how-long/>.

STC Bahrain	Bahrain	Huawei	
Ire	Ireland	Huawei	
Globe Telecom	Philippines	Huawei Ericsson Nokia	Huawei will build 80% of the 5G network, with Ericsson and Nokia building the remaining 20%
O2 UK	UK	Ericsson	Ericsson will extend the Radio Access Network (RAN) rollout across the country.
Bell Canada	Canada	Ericsson	
Telus Corp	Canada	Ericsson Nokia	Telus was initially partnered with Huawei but was pressed by Canada's Department of Innovation, Science and Economic Development to remove Huawei gear from its services.
Rogers Communications	Canada	Ericsson	
MTS	Russia	Ericsson Huawei	MTS already launched its 5G network with Huawei, and is using Ericsson to improve its existing 5G equipment.
Sinch	Sweden	Ericsson	
Orange	France	Ericsson Nokia	
Cyfrowy Polsat	Poland	Ericsson Nokia	
Telecom Italia	Italy	Ericsson	Despite Telecom Italia being one of Huawei's biggest clients in Europe, it is looking to cancel its contract with Huawei.
Tele Greenland	Greenland	Ericsson	
Telenor	Norway	Ericsson Huawei	Telenor will use Huawei for the non-core network aspects of 5G development.
T-Mobile	USA	Ericsson Nokia	

AT&T	USA	Ericsson	
Sprint	USA	Ericsson	
Verizon	USA	Ericsson	
Intel	USA	Nokia	
Swisscom	Switzerland	Ericsson	
Sunrise Communications	Switzerland	Huawei	
Vodafone Spain	Spain	Ericsson	
Vodafone Ireland	Ireland	Ericsson	
Orange Slovensko	Slovakia	Nokia	Nokia will develop Orange Slovensko's RAN.
TPG Telecom	Australia	Nokia	
Spark New Zealand	New Zealand	Nokia	
DoCoMo Pacific	Japan	Nokia	
Softbank	Japan	Nokia	
Iliad	France	Nokia	
A1	Austria	Nokia	
China Mobile	China Hong Kong	Huawei ZTE Nokia	Huawei secured the rights to build 60% of China Mobile's network.
Entel Chile	Chile	Ericsson	Chile is choosing an aggressive, vendor-neutral approach for its 5G expansion; this means that Huawei will not be excluded.
ANTEL	Uruguay	Nokia	

5G vendor partnerships and approaches to Huawei show some trends that allow us to make predictions for Huawei's future. Firstly, the Five Eyes - the U.S., U.K., Canada, Australia, and New Zealand - have taken the strictest stance on Huawei. All have either formally banned Huawei, or at least have implemented restrictions that in practice limit Huawei's presence in the market. Secondly, liberal democracies in the EU have taken a fragmented approach to Huawei, ranging from full bans on the part of Sweden and Poland, restrictions to limit Huawei's presence on the part of Germany and Italy, and fully welcoming Huawei on the part of Switzerland. Lastly, Latin America and some parts of Asia, namely those with developing economies and a less robust infrastructure, are more open to Huawei, perhaps in part due to its cost effectiveness and strong technological offering as well as a stronger inclination to appease China as an economic partner.

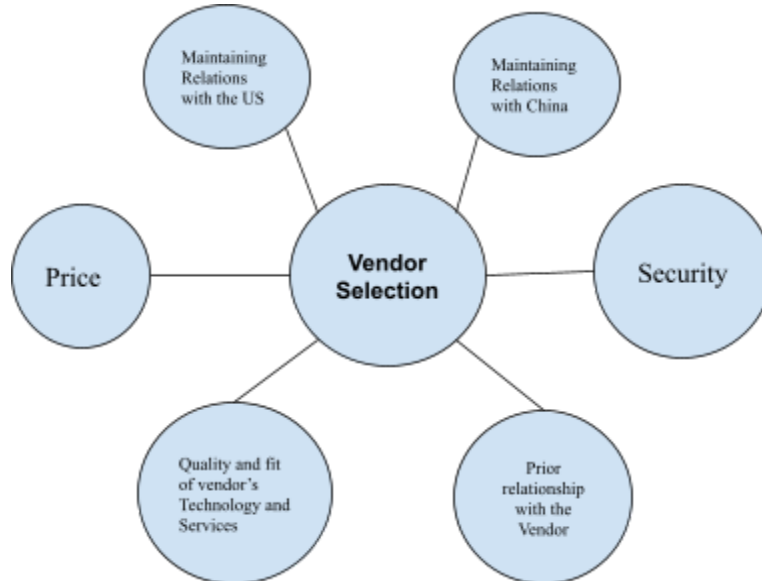


Figure 2.3. Factors that affect vendor selection

INTERNET GOVERNANCE AND VALUE SHAPING

Government officials, analysts and scholars in the U.S. have sparked the debate that China will use Huawei's 5G dominance to fundamentally reshape the internet to promote authoritarian values. China's general approach to internet governance promotes a structure that is tightly controlled by the state, uses censorship prominently, and de-prioritizes data privacy. Thus, some argue that the rising influence of Huawei and China in the wireless industry may have residual effects on internet governance as a whole, allowing them to proliferate technical standards, policies, and norms that challenge western democratic values.

U.S. model of Internet Governance: Freedom of Speech vs Censorship

The U.S. generally uses a highly open and hands-off approach to internet governance with the goal of promoting freedom of speech through the unfiltered exchange of information. This approach is challenged by China's view of the internet as one that should be tightly controlled by the state, for instance, through censorship tactics. A policy example that illustrates this difference in values is net neutrality. It is the principle that internet service providers should not discriminate against any form of internet communications based on the user, content, website, platform, application or device.¹²⁵ Net neutrality has long been a topic of contention in the U.S. since its adoption by the Federal Communications Commission (FCC) in 2005 and has recently come under pressure from large corporations competing for preferential treatment. Nevertheless, as an issue it is treated with the utmost attention because of its implications on free speech.¹²⁶ On the other hand, the principle of net neutrality in China is neither a topic of debate nor a principle that is enforced because it would be detrimental to supporting the primacy of the state. In fact, the principle of net neutrality is directly opposed by the 'Great

¹²⁵ Robert F. Easley et al., "From network neutrality to data neutrality: A techno-economic framework and research agenda," *Information Systems Research*, Forthcoming (2017), 2.

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2666217.

¹²⁶ Kieron O'hara and Wendy Hall, "Four Internets: The Geopolitics of Digital Governance," Centre for International Governance Innovation, December, 2018, 6.

<https://www.cigionline.org/static/documents/documents/Paper%20no.206web.pdf>.

Firewall’, a set of legislative actions and related technologies that allows service providers to filter and block certain types of content.¹²⁷

European Model of Internet Governance: Data Protection and Privacy

The European model of internet governance is challenged by China’s model primarily on the issue of data privacy. European thinking, more so than anywhere else in the world, focuses on data privacy because of its views on “the relationship between personhood and personal data” and “the risks of discrimination as a result of data processing.”¹²⁸ The European concern for data privacy is best exemplified by the [General Data Protection Regulation \(GDPR\)](#) - an EU regulation that takes a strict stance on protecting privacy and has become a model for many privacy laws outside of the EU. In direct contrast to the European model, all data in China is stored, accessible to the government, and unhindered by comparable data protection regulations.¹²⁹

How will China proliferate authoritarian values?

To what extent China and Huawei can use its growing influence in 5G to influence the wider context of internet governance is up for debate. However, one example of note is Huawei’s proposed New Internet Protocol (IP). The concern is that New IP, bolstered by Huawei’s 5G success, will “integrate China’s social credit, surveillance, and censorship regimes into the internet’s architecture” in 6G and beyond.¹³⁰ However, Huawei publicly denied this allegation.¹³¹ Some argue that the technology of 5G itself will allow surveillance states like China to amass data more precisely and efficiently through 5G-powered sensors, security

¹²⁷ Henry L Hu, “The Political Economy of Governing ISPs in China: Perspectives of Net Neutrality and Vertical Integration,” *The China Quarterly*, no. 207 (2011): 524-525. <https://www.jstor.org/stable/41305255>.

¹²⁸ Kieron O’hara and Wendy Hall, “Four Internets,” 7.

¹²⁹ Kieron O’hara and Wendy Hall, “Four Internets,” 8.

¹³⁰ Mark Montgomery and Theo Lebryk, “China’s Dystopian.”

¹³¹ “A Brief Introduction about New IP Research Initiative.” Huawei. Accessed September 13, 2021. <https://www.huawei.com/us/technology-insights/industry-insights/innovation/new-ip#text14>.

cameras, facial-recognition softwares and other surveillance devices.¹³² Others argue that China will influence internet governance through its rising influence in the ITU. For instance, Secretary General Houlin Zhao has been looking to expand the scope of the ITU to cover technologies outside of telecommunications such as internet structure and artificial intelligence (AI).¹³³ Furthermore, China's increasingly influential role in the ITU directly affects its standing in the UN and may allow China to extend its power in areas where it has received scrutiny from the international community for its authoritarian leanings, such as its approach to human rights and refusal to respect international rulings on the South China Sea disputes.

The U.S. response

In response to China's rising influence in telecommunication networks, the U.S. has used a value-led approach to create an opposition between technologies created in democratic countries against those made in China. For instance, it launched the Clean Network program - a framework "based on internationally accepted, technologically neutral standards of digital trust developed by the Center for Strategic and International Studies (CSIS); the [European Union's 5G Toolbox](#); and the [Prague Proposals](#), 5G recommendations from 30 nations."¹³⁴ The State Department affirmed that the program was developed as a global effort, led by an alliance of democracies, to address "the long-term threat to data privacy, security, human rights and principled collaboration posed to the free world from authoritarian maligned actors."¹³⁵ The Clean Network program therefore illustrates how the competition between 5G vendors has transformed into one of political beliefs and values.

¹³² Drew FitzGerald, "5G Race Could Leave Personal Privacy in the Dust." *Wall Street Journal*, November 12, 2019. <https://www.wsj.com/articles/5g-race-could-leave-personal-privacy-in-the-dust-11573527600>.

¹³³ Mark Montgomery and Theo Lebryk, "China's Dystopian."

¹³⁴ Roslyn Layton, "State Department's 5G Clean Network Club Gains Members Quickly," *Forbes*, September 4, 2020.

<https://www.forbes.com/sites/roslynlayton/2020/09/04/state-departments-5g-clean-network-club-gains-members-quickly/?sh=180e55147536>.

¹³⁵ Reuters Staff, "Bulgaria Signs 5G Security Declaration with U.S," *Reuters*, October 23, 2020.

<https://www.reuters.com/article/us-bulgaria-usa-5g-idUSKBN2782X9>.

Value Shaping: A red herring to push U.S. interests?

Some commentators question the authenticity of U.S.-led initiatives that attribute authoritarian values and malicious intent to companies like Huawei. For instance, one article investigated the discourse of open RAN and argued that the U.S. is attributing the notions of transparency, freedom and democracy to those who support open RAN standards (i.e. the U.S. and western Democracies) as a means to exclude those who do not support open RAN (i.e. China).¹³⁶ The different approaches to Huawei between the U.S. and the EU also exhibit how the U.S. may be embellishing its commitment to democratic values to mask the economic interests it has in stunting China's technological ascent.

The U.S. has generally favored the approach of blanket banning Huawei from 5G networks and using the threat of sanctions to discourage other countries from doing business with Huawei. On the other hand, the EU has displayed a more measured approach. Guided by the GDPR and the creation of the 5G Toolbox of Risk Mitigating Measures, some EU states like Germany, France, and Belgium have not banned any specific 5G vendor but have tightened restrictions to ensure that 5G suppliers are trustworthy. In this way, by strengthening internal security measures and policies rather than blanket banning specific companies solely based on their origin, the EU appears more authentic in their commitment to data protection and privacy. Furthermore, the U.S.'s assertion that it is committed to democratic values is undermined by its own conduct in the 2013 Snowden leaks, which revealed that the NSA used surveillance software and backdoor techniques made by Cisco and other U.S. companies to conduct mass surveillance of communications of U.S. citizens and foreign actors.¹³⁷

¹³⁶ Jean-Christophe Plantin, "The Geopolitical Hijacking of Open Networking: The Case of Open RAN," *European Journal of Communication* 36, no. 4 (2021): 408. <https://doi.org/10.1177/02673231211028375>

¹³⁷ "Snowden Revelations," Lawfare, July 15, 2015. <https://www.lawfareblog.com/snowden-revelations>.

In fact, Washington generally views data as a resource to be used by private actors for innovation and value creation.¹³⁸ It is therefore possible that the U.S. is concerned that China can use Huawei's 5G networks and the massive amount of data it processes to further its technological innovation in developing emerging technologies like AI.¹³⁹ Although the U.S. approach to internet governance does not include the same amount of government control as is the case in China, the U.S. military has taken steps to deepen its relationship with Silicon Valley. For instance, the Department of Defense created the Defense Innovation Unit (DIU) to speed up the Pentagon's adoption of emerging technology from Silicon Valley because it realized it needed cutting-edge innovation from high-tech companies to compete with Russia and China.¹⁴⁰ From building AI surveillance tools for Pentagon drones to coding data-mining and facial recognition softwares for Immigrations Customs and Enforcement (ICE), many of the biggest tech companies including Google, Microsoft, Amazon, Dell, IBM and HP have upped their contracts with the US military in the last decade as the Pentagon has become more familiar and integrated with the culture of Silicon Valley.¹⁴¹

World Order and China's entry into the International Stage

China's focus on increasing its representation in the telecommunications industry mirrors initiatives in other domains as part of a geopolitical strategy to become recognized as a leader in global governance and a key contributor in solving global challenges. Beijing has executed this strategy by increasing its participation in existing international organizations like the World Bank, the International Monetary Fund (IMF), the World Health Organization (WHO) and UN agencies while creating its own organizations and institutions such as the SCO and the

¹³⁸ Gregory Treverton and Pari Esfandiari, "DATA: GOVERNANCE AND GEOPOLITICS" Global TechnoPolitics Forum, December 2020, 8. <https://technopolitics.org/wp-content/uploads/2021/Data-Governance.pdf>.

¹³⁹ Graham Allison, and Eric Schmidt, "Is China Beating the U.S. To AI Supremacy?," Belfer Center for Science and International Affairs, August 2020. <https://www.belfercenter.org/publication/china-beating-us-ai-supremacy>.

¹⁴⁰ Patrick McGee, "Silicon Valley reboots its relationship with the US military," *Financial Times*, May 17, 2021. <https://www.ft.com/content/541f0a02-ea27-43a4-b554-96048c40040d>.

¹⁴¹ "Silicon Valley giants have thousands of US military contracts," Institute of Engineering and Technology, July 9, 2020. <https://eandt.theiet.org/content/articles/2020/07/silicon-valley-giants-have-thousands-of-us-military-contracts/>

Belt and Road Initiative (BRI).¹⁴² Additionally, China's ambitions to help establish 5G networks in underserved markets complement its state-backed initiatives in developing countries. The BRI, the Digital Silk Road (DSR), and global health aid provided through the WHO, expand China's international prestige and reputation as a key contributor in solving global challenges while creating a sphere of influence among countries that are increasingly reliant on Chinese aid and expertise.

China's rapid expansion of its influence around the world has been accompanied by accusations from the U.S. that it wants to exercise "hegemony," to which a Chinese Foreign Ministry spokesman, Wang Wenbin, issued the following response at a press conference on July 27, 2020:

"the CPC's goal is to realize the great renewal of the Chinese nation... The CPC is a political party that strives for the well-being of the Chinese people as well as the progress of mankind. China champions and practices the Five Principles of Peaceful Coexistence. China is the largest contributor of peacekeepers among the five permanent members of the Security Council, and has been contributing to the peaceful settlement of the Korean Peninsula nuclear issue, the Iranian nuclear issue and other regional and international hotspots, as well as the response to climate change and other global challenges. In recent years China has contributed over 30 percent to the world economic growth, and has helped a lot in the international response to the financial crisis in Asia and the global financial crisis."¹⁴³

China's growing status in addressing global challenges help to cultivate a global system where a growing number of countries are reliant on China's contributions, and are therefore more amenable to Chinese norms across different issues.

¹⁴² "China's Approach to Global Governance," Council on Foreign Relations, Accessed October 1, 2021. <https://www.cfr.org/china-global-governance/>

¹⁴³ "Foreign Ministry Spokesperson Wang Wenbin's Regular Press Conference on July 27, 2020," Ministry of Foreign Affairs of the People's Republic of China, Accessed October 1, 2021. https://www.fmprc.gov.cn/mfa_eng/xwfw_665399/s2510_665401/2511_665403/t1801240.shtml

As China's influence in the world increases, its ambitions to promote its model overseas are being hampered by heightened worldwide attention on Chinese authoritarianism. As the world's second-largest economy, China cannot be expected to engage in the global order simply on the terms of its rivals, especially since some of China's recent successes are in large part consequences of Western failures.¹⁴⁴ Therefore, China's technological ambitions and initiatives in other domains are part of a larger goal to promote its own model of a nationalist state that is "indifferent to liberal norms (although not always actively hostile to them)".¹⁴⁵ A world order based on this model is characterized by a greater deference to national sovereignty; the expansion of a BRI system that aligns with Chinese economic interests; and a global technological ecosystem composed of authoritarian norms.¹⁴⁶ The U.S. response to Huawei is therefore not just a reaction to Chinese technological dominance, but also a reaction to China's rise which presents an alternative to the current world order. As governments and operators continue to assess their 5G rollout options, they need to be cognizant of the national interests that underlie 5G geopolitics.

"In response to China's rising influence in telecommunication networks, the U.S. has used a value-led approach to create an opposition between technologies created in democratic countries against those made in China."

¹⁴⁴ Rana Mitter, "The World China Wants," *Foreign Affairs*, July 21, 2021. <https://www.foreignaffairs.com/articles/china/2020-12-08/world-china-wants>.

¹⁴⁵ Ibid.

¹⁴⁶ Ibid.

PART THREE

CASE STUDIES OF 5G IN DEVELOPING & EMERGING ECONOMIES

As the geopolitical battle of 5G between the U.S. and China escalates, many countries have been forced to pick sides. Developing countries in Latin America, Southeast Asia, and Africa are interesting case studies because their comparatively low level of infrastructure development and digital connectivity means that geopolitical factors affect the decision making of these regions differently than that of more developed countries.

Latin America as a region has low 4G coverage and currently lacks the infrastructure to support 5G networks. Furthermore, the region depends on both China and the U.S. as trading partners. However, Latin America has greatly deepened its economic ties with China in recent years and has been participating in China's BRI since 2017. According to relevant statistics, Chinese companies invested \$12.8 billion in Latin America in 2019, an increase of 16.5% over 2018 mainly focusing on infrastructure construction such as ports, roads, dams, and railroads in the region.¹⁴⁷ The COVID-19 pandemic has further increased Latin America's dependence on China. China's middle class is driving demand for Uruguayan beef, Chilean copper, Colombian oil and Brazilian soybeans and these commodities helped Latin America weather the storm and cemented China as its main customer.¹⁴⁸

However, Latin America's geographical proximity to the U.S. and historical aversion to long-established alliances that limit its autonomy means that Latin America will want to stay as

¹⁴⁷ Ciara Nungent and Charlie Campell, "The U.S. And China Are Battling for Influence in Latin America, and the Pandemic Has Raised the Stakes," *Time*. December 20, 2020.
<https://time.com/5936037/us-china-latin-america-influence/>.

¹⁴⁸ Ibid.

neutral as possible.¹⁴⁹ Thus, Latin America serves as a battleground region in the geopolitical 5G battle between the U.S. and China. The same is true in Southeast Asia, a region that has maintained frequent economic and trade relations with China because of its geographical proximity while fostering a strong relationship with the U.S. as a trading partner and security guarantor. China has set its sights on many South-East Asian countries as they have become parties to China's BRI, expecting it to provide an impetus to their developing economic environment despite some lingering political tensions. Within the context of the U.S.-China 5G battle, Latin America and Southeast Asia want to maintain healthy relationships with their two biggest business partners to balance multiple interests¹⁵⁰ and face a difficult decision as they decide whether to allow Huawei to participate in their own 5G builds.

Lastly, the case of Sub-Saharan Africa paints a somewhat different story than the aforementioned regions. China and Huawei's influence in Africa is substantially deeper than that of other regions around the world. Due to poor network connectivity in which many countries are still operating on 3G standards with even fewer having reached 4G standards, African countries do not have the luxury of banning any 5G vendor. Huawei in particular has reportedly built 70% of the continent's 4G networks and is building compact rural cell towers to bring internet access to remote areas in Africa where internet penetration is below the global average of 35.2%.¹⁵¹ Given China and Huawei's substantial presence in Africa, they are better positioned than others to help Africa reduce its digital divide.

¹⁴⁹ Oliver Stuenkel, "Latin American Governments Are Caught in the Middle of the U.S.-China Tech War," Foreign Policy, February 26, 2021

<https://foreignpolicy.com/2021/02/26/latin-america-united-states-china-5g-technology-war/>.

¹⁵⁰ Richard Maude, "Trading out of Trouble – Southeast Asia's Trade Prospects in a COVID-19 World," Asia Society Policy Institute, February 3, 2021.

<https://southeastasiacovid.asiasociety.org/trading-out-of-trouble-southeast-asias-trade-prospects-in-a-covid-19-world/>.

¹⁵¹ Amy Mackinnon, "For Africa, Chinese-Built Internet Is Better than No Internet at All," Foreign Policy, March 19, 2019. <https://foreignpolicy.com/2019/03/19/for-africa-chinese-built-internet-is-better-than-no-internet-at-all/>.

LATIN AMERICA

Technology Challenge: Low 4G coverage and slow progress on 5G

The low latency and high transmission speed performance of 5G will provide innovative solutions and help to increase productivity in Latin American industries. In turn, increased productivity will enhance the positive impact mobile technologies and services have on the economies of Latin America. In 2019, the mobile ecosystem accounted for 7% of Latin America's GDP, contributing US\$421 billion in economic value and approximately 1.4 million jobs.¹⁵² 5G is already a reality in some parts of Latin America, with Brazil and Uruguay having launched 5G and Chile completing its first 5G auction. Listed below are the countries in the region that have already launched 5G or are preparing 5G deployment.

According to the information in table 3.1 below, only Chile in Latin America has completed its first spectrum auction, which means that Chile has officially entered the commercial phase of 5G. Other countries are only launching 5G pilots, and spectrum auctions of Mexico and Brazil have been pushed back. One of the main reasons holding back 5G development is the region's current low 4G coverage which poses a significant challenge for deployment of 5G. Despite an increase in smartphone and network usage during COVID-19, for the average Latin American subscriber, 4G will continue to dominate the Latin American telecom market for years to come. As shown below, 5G connections in the region are expected to reach nearly 10% in 2025, while 4G will still account for 67% of total connections.¹⁵³

¹⁵² GSMA, "The Mobile Economy Latin America 2020," GSM Association, Accessed March 2, 2021, 3. https://www.gsma.com/mobileeconomy/wp-content/uploads/2020/12/GSMA_MobileEconomy2020_LATAM_Eng.pdf.

¹⁵³ GSMA, "The Mobile Economy Latin America 2020," 7.

Table 3.1. 5G Rollout In Latin America ¹⁵⁴

Country	5G Deployment Status
Argentina	<ul style="list-style-type: none"> ● 10 antennas are operational. ● No tentative schedule has been announced for the allocation of frequencies for 5G.
Brazil	<ul style="list-style-type: none"> ● Not yet deployed, the auction is expected to take place in August 2021. ● “Airwaves in the 700 MHz, 2.3 GHz and 3.5 GHz bands are set for sale alongside 26 GHz mmWave spectrum.”¹⁵⁵
Chile	<ul style="list-style-type: none"> ● Completed first 5G auction with 3 operators in competition (Movistar, Entel, WOM).
Colombia	<ul style="list-style-type: none"> ● Focused on implementing 4G networks nationwide, with 5G only being pilot tested in the capital and a few regions.
Mexico	<ul style="list-style-type: none"> ● Spectrum in the 600 MHz and 3.3 GHz bands is available for potential use in 5G technology. ● Has not yet been publicly deployed. ● Auction expected to be held this year.
Peru	<ul style="list-style-type: none"> ● Not deployed yet. Bidding is expected to take place in the first quarter of 2021. ● Will implement 5G on fixed wireless Internet in the 3.5 GHz band.
Uruguay	<ul style="list-style-type: none"> ● Launched the first 5G network in Latin America in April 2019. ● 5G deployment is pre-commercial, with limited coverage currently still in the testing phase.

¹⁵⁴ Tim Fisher, “5G Availability Around the World,” Lifewire, Updated on September 11, 2021. <https://www.lifewire.com/5g-availability-world-4156244>.

¹⁵⁵ Juan Pedro Tomás, “Brazilian Government Confirms 5G Auction for August: Report,” RCR Wireless News, July 1, 2021. <https://www.rcrwireless.com/20210701/5g/brazilian-government-confirms-5g-auction-august-report>.

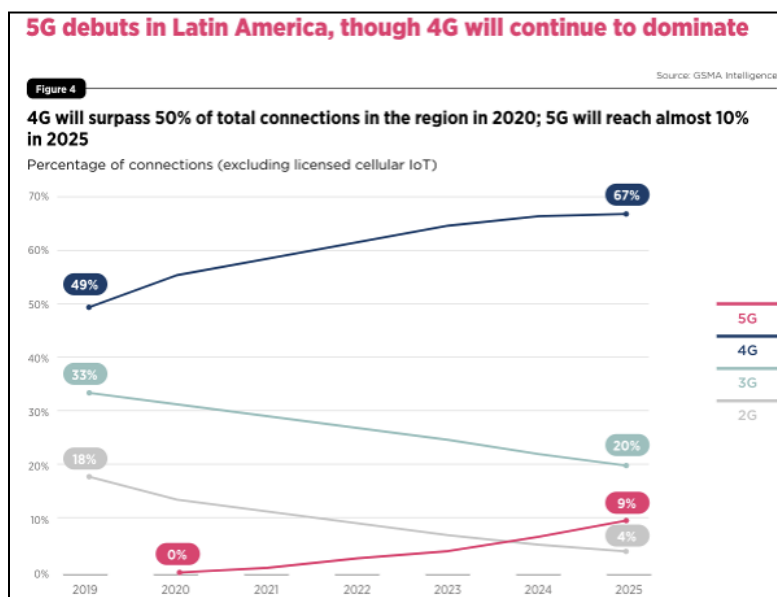


Figure 3.1. 4G of Latin America will continue to dominate in 2025¹⁵⁶

Geopolitical Challenges: The choice between the U.S. and China

Since 2001, China's engagement with the Latin American region has increased significantly, especially in terms of diplomatic and economic relations. To date, nine of the 21 countries in Latin America have joined the Belt and Road Initiative (BRI).¹⁵⁷ Although some regional heavyweights such as Argentina, Brazil, Colombia, and Mexico have yet to formally embrace the BRI, they have nonetheless deepened their economic ties with China in recent years. China has become the largest trading partner of Brazil, Chile, Peru, and Uruguay while maintaining strong free trade agreements with Chile, Costa Rica, and Peru.¹⁵⁸

The United States has cited security concerns to discourage countries seeking continued security cooperation with the United States from using Chinese equipment in their 5G network

¹⁵⁶ GSMA, "The Mobile Economy Latin America 2020," 13.

¹⁵⁷ "Countries of the Belt and Road Initiative (BRI)," Green Belt and Road Initiative Center, Accessed August 2, 2021. <https://green-bri.org/countries-of-the-belt-and-road-initiative-bri/>.

¹⁵⁸ Thomas Lum, "China's Engagement with Latin America and the Caribbean," Congressional Research Service, July 1, 2021, 1. <https://crsreports.congress.gov/product/pdf/IF/IF10982>.

and asked these countries to join the U.S Clean Network initiative.¹⁵⁹ Latin America is caught in a difficult position as a result of this situation. On the one hand, because much of Latin America lags in 4G access and has low coverage, it will take significant human and financial resources to implement 5G deployments while retrofitting existing infrastructure. Furthermore, many countries in the region are finding Chinese equipment to be less expensive in which the U.S. cannot offer a comparable alternative. On the other hand, the U.S. has been the security guarantor of the Western Hemisphere since the early 20th century and despite having differences with Washington, many countries in the region prefer to maintain this arrangement. They currently benefit from the backed security initiatives of the U.S and do not want to face American hostility in the region, particularly because China offers little direct support in this regard.¹⁶⁰ Some countries like Mexico and Chile have always tried to neutralize their positions; however, as these countries have had to identify their own 5G providers one after another, their positions cannot remain neutral anymore.

“Some countries like Mexico and Chile have always tried to neutralize their positions; however, as these countries have had to identify their own 5G providers one after another, their positions cannot remain neutral anymore.”

¹⁵⁹ “Latin America’s 5G Dilemma” Geopolitical Futures, March 5, 2021.

<https://geopoliticalfutures.com/latin-americas-5g-dilemma/>.

¹⁶⁰ Geopolitical Futures ,“Latin America’s 5G Dilemma”.

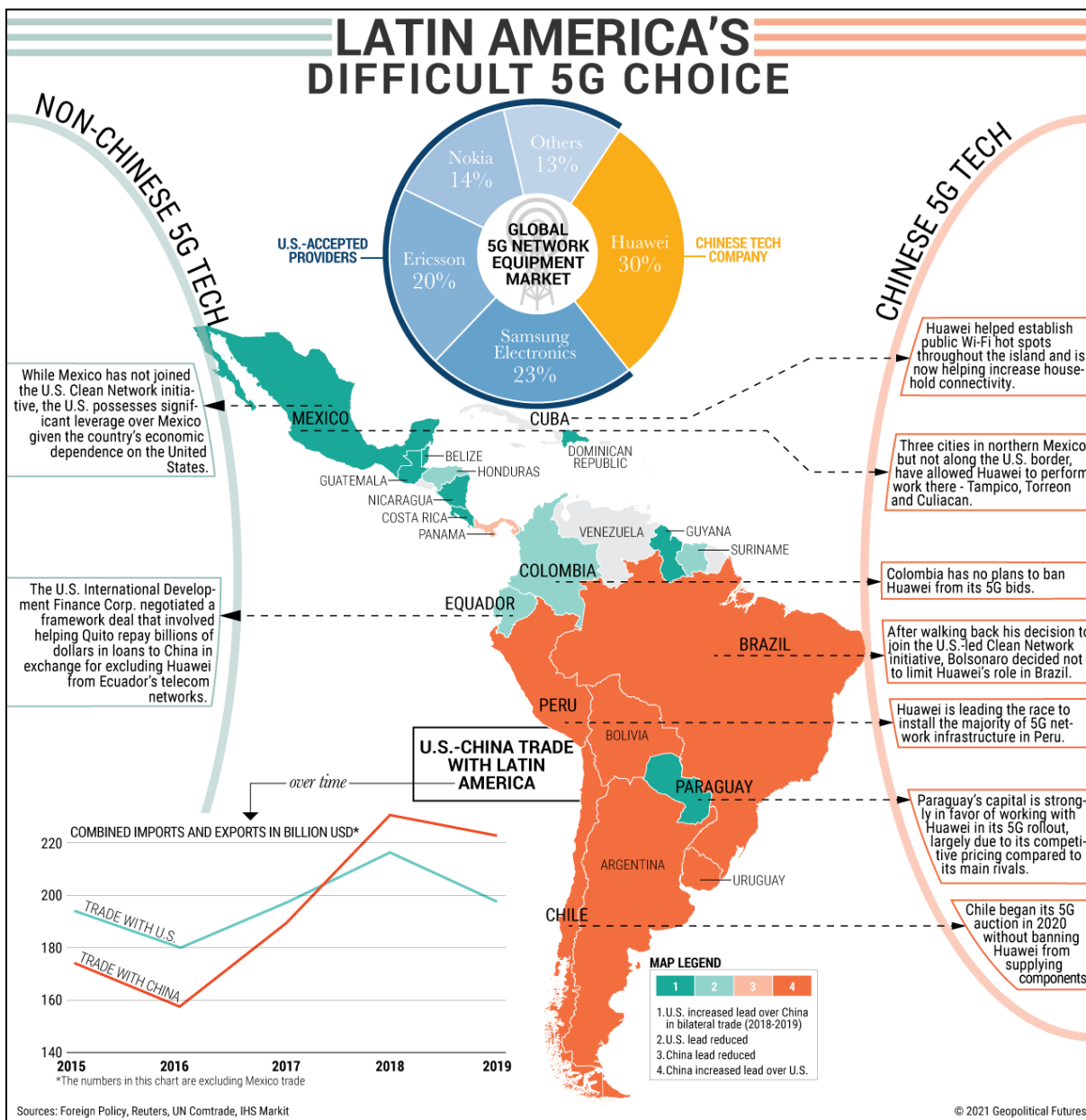


Figure 3.2 shows the difficult 5G conundrum that many countries in Latin America face.¹⁶¹

¹⁶¹ Geopolitical Futures, "Latin America's 5G Dilemma".

Colombia and Chile do not plan to ban Huawei from bidding on and supplying components for 5G. Brazil's Bolsonaro decided not to limit Huawei's role in the country after withdrawing from its decision to join the U.S. Clean Networks Initiative. Cuba and Paraguay have maintained a positive attitude toward Huawei because the company helped Cuba in establishing public Wi-Fi and household connectivity, while Paraguay found Huawei's pricing more competitive. Although Mexico has not yet joined the U.S. Clean Networks Initiative, it has a strong economic dependence on the United States which makes it unlikely to deal with Huawei. Finally, Ecuador accepted the framework agreement of the U.S. International Development Finance Corp to negotiate to exclude Huawei within its telecom network.

Digital transformation Challenges: significant investment and rural-urban disparities

Currently, 5G appears to be a reality in Latin America as countries are rolling out 5G and starting spectrum auctions. However, poor 4G coverage and lack of infrastructure have resulted in many countries in the region needing to invest more money to build 5G. 5G service deployment will require an overhaul of the existing network architecture, which means significant capital investments in new infrastructure, systems, additional site deployments, and technologies will need to be made under the context of uncertain future use cases and revenue streams.¹⁶² In addition to the large upfront investment, countries in the region need to be aware that the cost of operating and maintaining equipment in rural areas will be much higher than in urban areas after 5G is deployed. Brazil is a typical example in this regard. The remoteness of its rural areas and its unstable road infrastructure and power supply will make the operation of equipment maintenance more difficult and have a substantial impact on the network site as a whole.¹⁶³

¹⁶² “Submission to House of Representatives Standing Committee on Communications and the Arts,” OPTU5G. November 2019, 5.

<https://www.aph.gov.au/DocumentStore.ashx?id=1cd1d847-7de1-4634-9545-9f547f76d3c7&subId=673756>.

¹⁶³ Cavalcante, Andre Mendes, Maria Valeria Marquezini, Luciano Mendes, and Carlos Salle Moreno. “5G for Remote Areas: Challenges, Opportunities and Business Modeling for Brazil.” *IEEE Access* 9 (2021): 10831-10832. <https://doi.org/10.1109/access.2021.3050742>.

The urban-rural divide has also emerged in Chile, where productivity has been declining despite the country's ongoing digital transformation with one of the challenges being low fixed broadband penetration. According to the 2019 data from OECD, Chile lags far behind the OECD average in terms of fixed broadband penetration and high-speed connectivity (as shown in figure 3.3). Whereas the deployment of high-speed fixed networks is important for upgrading next-generation mobile networks, 5G networks also rely heavily on fiber backbones. Another challenge is the large differences in quality broadband coverage between urban and rural areas, especially in fixed connections. The data in figure 3.3 shows that Chilean rural areas have 21% of homes covered, while urban areas have more than 60%.¹⁶⁴

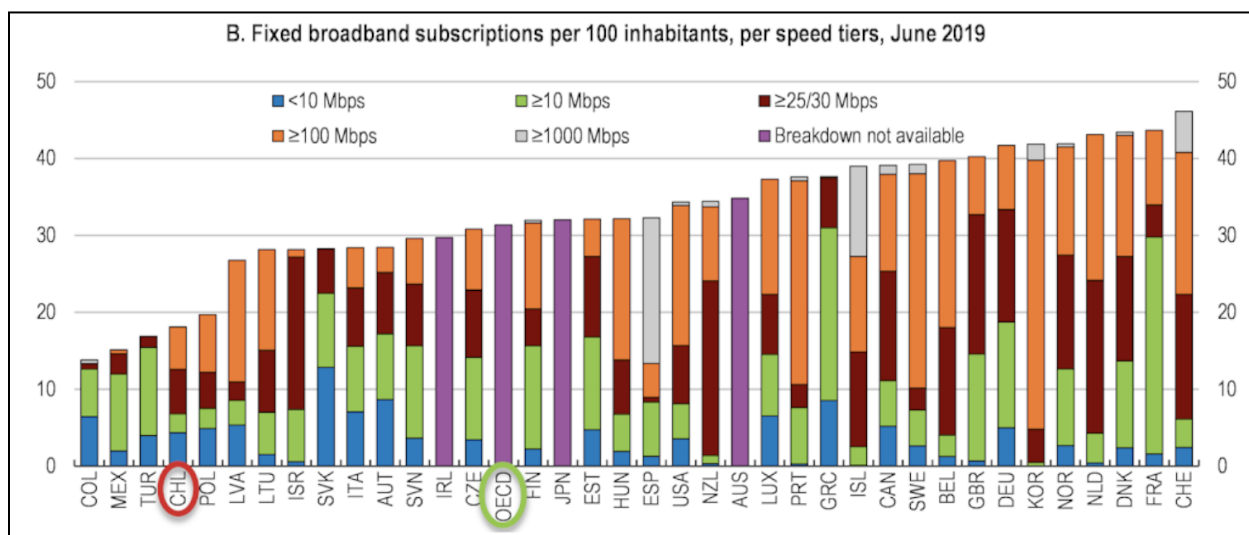


Figure 3.3. Chile Fixed Broadband Subscriptions¹⁶⁵

For private operators who are deploying networks with an emphasis on revenue, one cannot expect them to address the digital divide unless government regulators require them or give them incentives to provide rural coverage. One report notes that Brazil has seen limited

¹⁶⁴ OECD, “OECD Economic Surveys: Chile 2021- 2. Making Digital Transformation Work for All in Chile,” OECD iLibrary, Accessed June 7, 2021.

<https://www.oecd-ilibrary.org/sites/4c7db951-en/index.html?itemId=/content/component/4c7db951-en>.

¹⁶⁵ Ibid.

success in penetrating rural areas with telecommunications infrastructure, despite receiving private sector investments of about US\$80 billion in the telecommunications sector from 1999 to 2011.¹⁶⁶ In addition, there are many countries in the region like Chile that have small markets in which many of their industries, including telecommunications, are dominated by a few large companies, often to the detriment of consumers. Existing telecom users, especially those with 4G services, may find that 5G does not offer enough additional benefits to justify higher service costs or the cost of new equipment.¹⁶⁷

Therefore, for Latin American countries with a low overall fixed broadband connection, large differences in rural and urban infrastructure, and small market size, it is not advisable to place the whole burden of digital transformation on 5G deployment led by private operators. Without a long-term plan, specific digital transformation goals, well-defined use cases, thorough laws and regulations, and incentives, 5G will hardly help the region achieve its desired digital transformation.

¹⁶⁶ Mike Jensen. *Brazil-Broadband in Brazil: a multipronged public sector approach to digital inclusion*. No. 69173. The World Bank, 2011, 7.

<https://ddtoolkits.worldbankgroup.org/sites/default/files/2018-10/Broadband%20in%20Brazil.pdf>

¹⁶⁷ Oxford Analytica Daily Brief, “5G Rollout May Not Reduce the Digital Divide in Chile,” November 26, 2020. <https://dailybrief.oxan.com/Analysis/DB257803>.

SOUTH-EAST ASIA

Like Latin America, developing countries in South-East Asia are caught in a geopolitical battle between the U.S. and China for technological dominance. Since the U.S. pivot to Asia in 2012, many South-East Asian countries rely on the military capabilities of the U.S. to cooperate on security issues such as humanitarian assistance, piracy, disaster response and freedom of navigation.¹⁶⁸ On the other hand, maintaining relations with China is also paramount given its importance as a trading partner and its geographical proximity to the region. 5G technology will grant South East Asia enormous economic benefits. It is predicted that 5G will add 6% to 9% to consumer revenues and 18% to 22% to enterprise revenues for ASEAN states by 2025.¹⁶⁹ Therefore, developing economies in South East Asia such as the Philippines, Thailand, Vietnam, and Malaysia must make financial decisions that fit within their preferred timelines to achieve digital transformation while maintaining cordial relations with the U.S. and China.

ASEAN countries, excluding Vietnam, are open to working with Chinese telecommunications suppliers like Huawei. For countries that are a part of the territorial disputes in the South China Sea such as the Philippines, Vietnam, Indonesia, and Malaysia, it is surprising that only Vietnam decided to partner with vendors other than Huawei. Furthermore, Malaysia and Indonesia's anti-Chinese sentiment seems to have not affected the attractiveness of Huawei as a 5G supplier. One possible explanation for this trend is that developing countries in the region have aspirations to rapidly develop their industrial capacities and to digitize their economies and see Huawei, with its impressive technological portfolio and pricing advantage, as the best supplier to achieve these goals. It is therefore not surprising that the most economically developed country in the region, Singapore, felt comfortable partnering with

¹⁶⁸ Janine Davidson, "The U.S. 'Pivot to Asia,'" *American Journal of Chinese Studies* 21 (2014): 77.

<https://www.jstor.org/stable/44289339>.

¹⁶⁹ Hari Venkataramani and Nikolai Dobberstein, "5G in ASEAN: Reigniting Growth in Enterprise and Consumer Markets," 2019, Accessed 26 May 2021.

<https://www.southeast-asia.kearney.com/article/?/a/5g-in-asean-reigniting-growth-in-enterprise-and-consumer-markets>.

Nokia and Ericsson. Another explanation for Huawei’s success in the region is that many ASEAN states are BRI participants, and existing working relationships within BRI infrastructure projects have given Chinese companies like Huawei an advantage over Nokia and Ericsson.

Table 3.2. 5G Vendor Selection and Approaches to Huawei in Selected in ASEAN Countries.¹⁷⁰

Country	5G Climate
Malaysia	Has started its digital masterplan - Jalinan Digital Negara - to achieve 5G coverage. Telecommunications providers are generally open to collaborating with Huawei despite public resistance to other Chinese investments. In 2018, Malaysia’s Prime Minister halted Chinese BRI Projects and criticized Chinese-backed projects. However, his resistance to Chinese investments did not affect his stance on Huawei. In fact, the Prime Minister firmly welcomes Huawei’s expansion in Malaysia, citing Huawei’s unmatched technological capability. Huawei has a strong presence in 4G with some telecom providers, and is currently developing 5G networks for Malaysian telecommunications provider Maxis.
Indonesia	Chinese telecommunications companies are achieving significant market growth in Indonesia. Chinese mobile phone sales grew by more than a third - significantly higher than for any other mobile brand. Although Indonesia’s stance on Chinese investment in general is increasingly unstable due to a series of anti-China protests with regards to its treatment of the Uyгур population, its stance on Huawei appears unaffected. Indonesia’s Agency for the Assessment and Application of Technology signed an MOU with Huawei to develop its 5G network. Huawei has also partnered with approximately 200 companies in Indonesia.
Singapore	Singapore is on pace to achieve nation-wide 5G by 2025. Singapore’s largest provider, SingTel, selected Ericsson while other providers M1 and Starhub partnered with Nokia. Singapore’s Prime Minister stated that it did not specifically exclude any vendor and that the selection process was rigorous and competitive.

¹⁷⁰ Melinda Martinus, “The Intricacies of 5G Development in Southeast Asia,” *ISEAS Yusof Ishak Institute* 2020, no. 130 (2020): 3-6.
https://think-asia.org/bitstream/handle/11540/12821/ISEAS_Perspective_2020_130.pdf?sequence=1.

Cambodia	Cambodian Telecommunications Provider Smart Axiata partnered with Huawei to build its 5G network
Philippines	Huawei partnered with the City of Davao and Manila to develop a US\$ 400 million video surveillance system - "Safe Philippines". Globe, the largest telecom provider in the Philippines partnered with Huawei but is also seeking to diversify its vendor selection. Globe currently plans to have Huawei supply 80% of its equipment, with other vendors such as Ericsson and Nokia providing the remaining 20%.
Thailand	As part of its aspirations to achieve 'Industry 4.0' and a push for a 'Digital Economy', Thailand has relied heavily on Huawei since 2019. The company has invested US\$15 million to establish a 5G research center in Thailand and has supported programs to support talent development in digital skill. ¹⁷¹
Vietnam	Of all ASEAN states, anti-Huawei sentiment is most prevalent in Vietnam largely due to territorial disputes over the South China Sea. Vietnam's largest telecommunications provider, Viettel diverged from Huawei and now uses equipment mostly from Ericsson and Nokia while sourcing 5G chipsets from Qualcomm. Viettel's CEO insisted that its decision to avoid Huawei was because of security concerns and not U.S. pressure.

¹⁷¹ Suchit Leesa-Nguansuk, "Huawei to Ramp up Tech Investment in Support of Thailand 4.0," *Bangkok Post*. August 11, 2021. <https://www.bangkokpost.com/business/2163343/huawei-to-ramp-up-tech-investment-in-support-of-thailand-4-0>.

SUB-SAHARAN AFRICA

5G will eventually become a reality in Sub-Saharan Africa as it is a natural development from earlier generations of mobile technology. However, reaching 5G standards is not possible in the short term because present technologies cannot support current use cases and mobile internet access demands.¹⁷² Additionally, the majority of the population in Sub-Saharan Africa keep their mobile devices for about 4 years or more¹⁷³ making it difficult to drive demand for new technologies. Therefore, for all countries in the region, market readiness is necessary to determine the timing of the transition to 5G. This will help realize the maximum value of 5G services for consumers, operators, and the broader community.

According to table 3.3 below, it is easy to see that most of the countries in the region are currently very slow in rolling out 5G. Senegal has even chosen to upgrade its existing network first instead of rushing to roll out 5G which is not necessarily a bad choice. For regions with poor network infrastructure, taking more time to upgrade existing networks and facilities will provide a strong stepping stone for the follow-up 5G deployment.

Although 5G deployment has been slow in most Sub-Saharan African countries, Huawei has been a critical partner for the region's economic and technological growth in the last two decades and is strongly positioned to become the leading 5G vendor in the continent once its technical infrastructure is ready for it. Many African countries such as Sierra Leone, Senegal, Guinea, Mali, and Nigeria have benefited from loans sent by China's EXIM bank to support several Huawei led projects to build 3G and 4G networks, connect fiber optic cables, and provide expertise to help further develop information and communication technologies in the

¹⁷² Kenechi Okeleke, David George, and Emeka Obiodu, "5G in Sub-Saharan Africa: Laying the Foundations," GSMA, 2019, 15-17.
<https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=45121572&file=2796-160719-5G-Africa.pdf>.

¹⁷³ Jiang Chenglong, "Huawei Likely to Benefit from 5G Rollout in Africa," *China Daily*, February 2, 2020.
<https://www.chinadaily.com.cn/a/202002/25/WS5e553ef1a31012821727a424.html>.

region. The African region is also especially positioned to partner with Huawei due to its heavy participation in the BRI.

Table 3.3. 5G Rollout In Africa. ¹⁷⁴

Country	5G Deployment Status
South Africa	<ul style="list-style-type: none"> ● South African operators Vodacom and Rain launched what is claimed to be Africa's first commercial 5G network in May 2020. ● Currently, only 3 cities (Johannesburg, Pretoria and Cape Town) in South Africa have 5G Vodacom coverage.
Nigeria	<ul style="list-style-type: none"> ● In 2019, MTN Nigeria successfully conducted 5G trials in several locations. ● Has not set a definitive date for 5G roll out.
Kenya	<ul style="list-style-type: none"> ● Operator Safaricom suspended their 5G deployment in late 2020 to focus on 4G. ● However, Safaricom launched 5G services in Nairobi, Kisumu, Kisii, and Kakamega in late March 2021.
Lesotho	<ul style="list-style-type: none"> ● Operator Vodacom has launched Africa's standards-based commercial 5G network in Lesotho in the 3.5 GHz spectrum. ● 5G in the region is currently serving two major customers in the local banking and mining industries.
Senegal	<ul style="list-style-type: none"> ● The region does not appear to have plans to roll out 5G at this time. ● Operators Free (formerly Tigo Senegal) and Ericsson are working together to upgrade their networks to roll out LTE across 1,000 sites.

Huawei’s pre-existing dominance in Africa will likely continue, and due to the low level of economic development and under-developed telecommunications industry in the region, switching to a new supplier is not a viable option for many. Amidst U.S. pressure on Huawei, South African President Cyril Ramaphosa defended the company and called it a victim of the U.S. trade war with China and that South Africa “cannot afford to have (its) economy held back

¹⁷⁴ Tim Fisher, “5G Availability Around the World.”

because of this fight.¹⁷⁵ Many countries in the region like Kenya, Mozambique and Namibia have followed Ramaphosa’s example and have already agreed to partner with Huawei to build future 5G networks.

CONSIDERATIONS FOR DEVELOPING ECONOMIES

Many developing and emerging countries see 5G as a means to rapidly industrialize, catalyze economic growth, and boost global competitiveness. However, for developing and emerging economies in regions like Latin America, South East Asia, and Sub-Saharan Africa, the factors that influence their decision making process for 5G deployment differ from that of developed economies in North America, Western Europe.

As a general trend, low to middle income countries face unique challenges as it pertains to 5G deployment that are a result of:¹⁷⁶

- Weaker institutions
- Weaker technical infrastructures
- Scattered national broadband connectivity
- Lower skilled workforces
- Lower capital availability
- Higher unemployment
- Low household disposable income
- Reliance on primary sectors with weaker service and industrial sectors

¹⁷⁵ Loni Prinsloo, “Huawei Strengthens Its Hold on Africa despite U.S.-Led Boycott,” *Bloomberg*. August 19, 2020. <https://www.bloomberg.com/news/articles/2020-08-19/china-s-huawei-prospers-in-africa-even-as-europe-asia-join-t-rump-s-ban#:~:text=Even%20as%20Europeans%20and%20Asians>.

¹⁷⁶ Simon Forge and Khuong Vu. “Forming a 5G Strategy for Developing Countries: A Note for Policy Makers.” *Telecommunications Policy* 44, no. 7 (2020): 101975. <https://www.sciencedirect.com/science/article/abs/pii/S0308596120300677>.

Given these characteristics, it is not surprising that many countries in South East Asia and Sub-Saharan Africa are more receptive to Huawei as a telecommunications vendor than developed countries in North America and Europe. Although Latin America is attempting to stay as neutral as possible, its lack of network coverage and increasing reliance on China as a trading partner means that it will likely follow the trend of other developing economies. Given the novelty of the 5G ecosystem, the absence of proven business models, and confusion over spectrum reallocation, developing countries likely see Huawei as the most attractive option because of its cheaper prices, strong technological portfolio, talent and development training and ability to tailor a package that fits specific country infrastructure needs. In this sense, the geopolitical implications of not siding with the U.S. as well as the alleged security concerns aimed at Huawei technology are not as important for developing countries as it is for developed ones.

CONCLUSIONS

This paper takes a holistic view of 5G through the lens of technology and geopolitics. On the technical side, it explains that 5G provides higher speed, lower latency, higher reliability, and greater connectivity for machine to machine communications. The technical side also outlines the key elements needed for 5G networks, how 5G standards are set, related use cases, and the key 5G vendors. On the geopolitical side, this paper discusses the potential impacts of 5G leadership on the global economy, the standard setting process, internet governance, and world order.

Commercially, before 5G, countries that led or seized the development of wireless technology achieved huge commercial benefits. U.S. leadership in the 4G era helped turn American technology companies like Apple, Google, Facebook, Amazon, and Microsoft into global powerhouses, allowing the U.S. to shape the global ecosystem of mobile technologies. In turn, U.S. leadership allowed its economy to capitalize on the windfall of the mobile internet explosion in the 4G era, bringing immense levels of economic growth and creating high-end job opportunities. From IoT and Industry 4.0 to E-health and AI, 5G will bring revolutionary change to various industries. Given the success of China and telecommunications companies like Huawei, the U.S. is concerned that it will lose its position as a leader in the telecommunications industry to China and will be excluded from taking part in the standard setting process of emerging mobile technologies.

Commerce shades into geopolitics. In an effort to slow China's technological rise, the U.S, with the support of some of its allies, particularly the Five Eyes, has continued to allege that Huawei will be used by the CCP as a backdoor to commit espionage. While there is no direct evidence that Huawei poses a security threat so far, some countries have started to exclude

Huawei from their 5G networks because they also believe that Huawei poses a security threat or view maintaining friendly relations with the U.S. as too strategically important.

On the other hand, many countries are trying to neutralize their approaches to 5G vendor selection to avoid conflicts with both the United States and China. However, as countries begin to conduct 5G spectrum auctions and unveil 5G deployment plans, remaining neutral will become progressively more difficult. While, this paper argues that 5G networks built by Huawei do not pose a security any more than 5G networks built by other vendors, it will be up to country governments and service providers to discern whether security concerns around Huawei are legitimate.

The U.S. has also characterized 5G as a battle of political values, theorizing that China and Huawei will integrate authoritarian values into the fabric of internet governance. The argument is plausible given that the U.S. and Europe were highly successful in perpetuating western values within internet governance in previous mobile network generations. Therefore, countries all over the globe face not only a choice of who to source 5G technology from, but also a choice of which great power to side with and what type of internet governance they prefer. China's 5G ambitions share similarities to its own initiatives in other domains such as in the World Bank, IMF, WHO, and BRI, in which China is increasing its participation to increase its sphere of influence and to champion its own model of a nationalist state. Even if Huawei's 5G networks do not pose a security threat per se, China's rising influence in the telecommunications sector, led by Huawei, may have residual effects that impact security standards and the larger context of world order in the long-term through the promotion of Chinese norms which includes a greater deference to national sovereignty; the expansion of institutions that align with Chinese economic interests; and a global technological ecosystem composed of values and policies that are increasingly authoritarian in nature.

China's presence is likely to be different in the different telecommunications markets around the world. Its 5G presence will diminish in developed countries, particularly in liberal democracies that are closely allied with the U.S. and its values. However, countries that have confidence in their own internal security measures, particularly in the EU, will seek to diversify their vendor selection to maximize the advantages of each supplier while maintaining strict security standards. In the end, China will set its sights on developing countries that have a relatively low level of network connectivity and have aspirations to digitize their economics quickly because Huawei is better positioned than its competitors to help these countries achieve their technological goals. This might create a dichotomy, in which 5G networks built by vendors like Nokia and Ericsson will pervade in developed countries, while networks built by Huawei will dominate in developing countries.

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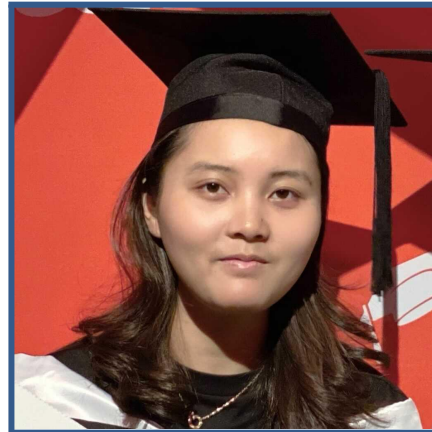
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