Atlantic Council

SCOWCROFT CENTER
FOR STRATEGY AND SECURITY

A Framework for an Open, Trusted, and Resilient 5G Global Telecommunications Network

John T. Watts

Scowcroft Center for Strategy and Security mission statement:

The Scowcroft Center for Strategy and Security works to develop sustainable, nonpartisan strategies to address the most important security challenges facing the United States and the world. The Center honors General Brent Scowcroft's legacy of service and embodies his ethos of nonpartisan commitment to the cause of security, support for US leadership in cooperation with allies and partners, and dedication to the mentorship of the next generation of leaders.

Emergent Futures Lab mission statement:

The mission of the Atlantic Council's Emergent Futures Lab is to explore emergent issues that may seem fringe, implausible, or unpredictable today, but which have the possibility to cause significant disruption in the future. Emergent challenges can be detected but not yet fully discerned. They do not necessarily follow predictable trendlines, and therefore cannot be extrapolated solely from an analysis of plausible or likely current or near-term events. But they are likely to be disproportionately disruptive and impactful. The Emergent Futures Lab seeks to prepare for these eventualities by using a range of creative and non-traditional methodologies that explore the 'what-ifs'. While remaining anchored by practical real-world constraints, these methodologies open the aperture of possible future outcomes.

Atlantic Council

SCOWCROFT CENTER
FOR STRATEGY AND SECURITY

A Framework for an Open, Trusted, and Resilient 5G Global Telecommunications Network

John T. Watts

ISBN-13: 978-1-61977-088-1

Cover photo: 5G Sunset Cell Tower: Cellular communications tower for mobile phone and video data transmission. *Photo Credit: IStock from Getty Images, Bill Oxford (https://www.istockphoto.com/portfolio/-Oxford-?mediatype=photography)*

March 2020

Table of Contents

Acknowledgements

This report represents a wide ranging effort of review, consultation and discussion. I'd like to thank those industry experts who provided insight as well as the contributions of my Atlantic Council colleagues, Robert Manning, Claire Chan, Shaun Ee, Trey Herr and William Loomis.

Executive Summary

Recent events have seen an acceleration in the rise of reemerging great powers. This has had a profound impact on global economic, technological, and political assumptions and has created new technological realities. The potential impact and implications of artificial intelligence (AI), biotechnology innovation, and the dark sides of social media have raised new concerns for social norms. No issue is more emblematic of the competition between liberal, free-market nations and authoritarian command-economy principles than the evolution of fifth-generation (5G) telecommunications.

Generational shifts between cellular telecommunications networks have profound implications for national and global economies. As data become increasingly central to every aspect of a modern economy, the shift to the next generation of cellular networks will be of even greater significance. The Chinese government identified the importance of this transition and has, for years, been aggressively investing around the world to be the purveyor of 5G infrastructure that will carry that data in the coming decades.

Chinese-backed firms are currently better positioned to exploit the vast opportunity that 5G represents more effectively than corporations within free markets, for several reasons. The most significant is the high infrastructure cost of legacy cellular models and uncertain consumer demand in the short term. Capital costs are driven predominately by the technical requirements of 5G, which—in return for far higher speeds and ultra-low latency—require new hardware to be installed in many more locations than previous networks. Moreover, the legacy infrastructure model relied on proprietary and incompatible hardware components that are best suited to large, single-manufacture companies that can provide comprehensive end-to-end solutions.

While consumer demand is predicted to be high, businesses are cautious in deploying such large amounts of money for unproven speculative demand. The lack of a concrete user base creates an opening that vertically integrated Chinese companies, heavily backed by the state, are exploiting by deploying the 5G technology and services at a discount of about 25 percent, along with loss-leading financing terms. Given that end-to-end network solutions can cost $10–100 billion, or more, 25-percent discounts have a major impact.

While the 25-percent discount is financially enticing, the longer-term consequences are often hidden, and can include vulnerability to foreign espionage, economic leverage, and forced compliance to conditions underpinned by authoritarian principles. For the Chinese government, the financial cost is a small investment in return for potential control of the world's data backbone for the next several decades.

The reality is that questions revolving around security, as defined from the perspective of traditional "cyber" or "network security," are ancillary to the critical challenge. If a nation builds a telecommunications network with equipment supplied from Chinese tech giants such as Huawei or ZTE, those networks will inherently be subject to Chinese laws that require compliance with many principles' anathema to free-market, liberal views. Moreover, these networks, by design, must be managed and maintained by large services organizations, likely staffed by a vast workforce of Chinese citizens, who also must comply with Chinese law and can provide local human intelligence back to the Chinese state. These are terms that countries should not have to accept, and to which their citizens should not be involuntarily subjected.

An open, innovative, safe, and reliable alternative is needed, so that people have a realistic option that allows them to freely communicate and consume information.

5G is emblematic of the competition between the new authoritarianism and free-market, liberal principles. China has executed its plan well over the last five years by driving the standards discussion, developing the leading vertically integrated solution, deploying national export finance to subsidize their offerings, and building the largest and most effective services organization in the market. Free-market economies have spent far less on research and development (R&D), have only limited export finance options, rely on semiconductor dominance, deploy severely limited services organizations, and have no integrated national or international strategy. Few governments or companies were prepared for the level of sophistication of the product and export finance offering of the authoritarian-backed commercial players.

The rollout of 5G will take place over the next decade, and its future is still being written. But, the United States and its allies are behind; they must act now or face irrelevancy. This study lays out a vision for a global 5G network that satisfies the values of the United States and like-minded partners and is in the best interests of the global population. It lays out the key issues and challenges to achieving that vision and then presents an initial framework of specific actions to achieve that end state, such as supporting the deployment of more than $100 billion in 5G technology and

services; improving research and development; and reducing costs with innovative approaches, such as virtualization and the use of software to replace hardware.

After months of discussions about these issues with industry experts, global financial organizations, and government officials, a clear framework emerged for the organization of free-market nations with free-market principles. The critical point is that a competitive technical approach and a geopolitical partnership must be joined to meet an integrated authoritarian strategy. Fortunately, new cellular network models are emerging that have the potential to unlock less structured and more innovative approaches that favor free-market players.

From the outset, free-market economies across the globe need to partner to **lay out principles** that highlight the ways in which 5G can be developed to advance Western liberal values—especially freedom of expression—and provide for the consistent expression of the importance of these principles for emerging economies. Through these partnerships, free-market players should **develop export-finance vehicles** to provide for financing options that compete with authoritarian finance activity.

In conjunction with export finance, **new technical approaches should support the development of architectures and technologies** that can more easily take advantage of the iterative nature of innovation in free-market economies. The Open Radio Access Network (ORAN) is a critical step in moving toward new network models that favor Western companies, but greater support for collaboration to advance the iterative deployment of 5G telecommunications networks is needed. Small-batch silicon fabrication sites, designed to enable faster iterative testing of new silicon designs, would also support free-market development approaches. These sites could also explore and build out alternative architectures, including **virtualized or cloud-first technologies**, to reduce dependence on high-cost hardware, in the same way that Rakuten is deploying 5G in Japan.

Free-market economies must partner around a small set of ideals—namely, that the fundamental freedoms of citizens of many nations must be able rely on the safety and security of their communications. These ideals should not and cannot be impeded by discounted infrastructure. A failure to address the potential mortgaging of these freedoms, because said freedoms have heretofore been assumptions is the essential error authoritarian regimes are relying on. The reality is that there are technical means, approaches to partnering, available financing and the ability to build companies to address this strategy. First and foremost, free-market economies must recognize that 5G is just one large and strategic competition about the ideals that free-market nations must defend, both at home and in developing nations. The innovation of the free market must be unlocked, through excellent technical approaches and, most critically, through a clear mutual partnership with long-standing allies.

Recommendations

1) **Ensure laws and technical regulations align to prevent fracturing of the market.**
   - in the US context, quickly addressing spectrum issues by freeing sub-6 spectrum; and
   - establishing regular forums for dialogue and information sharing across all like-minded nations that will share market characteristics;
     - domestically through a commission of all stakeholders; and
     - internationally through a focus on 5G issues in existing partnership dialogues and potentially new technology-focused coordination forums.

2) **Encourage and accelerate innovation through supporting commercial infrastructure in free-market economies.**
   - supporting the development of innovative technologies and approaches across the value chain from ORAN to virtualized infrastructures through US government purchases and research grants;
   - developing testbed-alternative structures built on virtualized models and cloud-first technologies to reduce the dependence on high-cost hardware, such as the proposed Rakuten-backed network in Japan;
   - establishing a 5G Center of Excellence;
   - creating testbeds to drive development of new applications and use cases, while encouraging commercial investment by
     - enhancing, enlarging, and opening up existing sites (specifically the National Security Agency's (NSA) Silicon Processing Lab and BAE Systems' Manassas facility) for quicker, iterative silicon design and testing, utilizing public-private partnerships where practicable; and
     - identifying facilities—such as large military bases, large government offices, and federally funded research-and-development center (FFRDC) campuses—where startups can experiment with applications and tools that could be scaled up to wider use; and
   - establishing a National Manufacturing Innovation Initiative.

3) **Build out an integrated international export-finance capability to compete with authoritarian or planned state-driven economy initiatives.**
   - sharing the burden of competing with control-economy companies and policies in allied and developing markets;
     - developing a coordinated, synchronized strategy among select allies and partners, including the North Atlantic Treaty Organization (NATO) and the Australia, New Zealand, United States Security Treaty (ANZUS); and
   - developing export-finance vehicles, including through aid and Overseas Private Investment Corporation (OPIC) investments, to provide a practical alternative to authoritarian underpinned solutions and assist developing nations in building the foundations of digital economies with the same values and standards expected in developed ones.

5G: Risks and Opportunities

The global transition to the fifth generation of cellular technology, usually referred to as 5G, is now under way. This process is still in its infancy and will likely take a decade to fully mature. The sophistication and complexity of the technology limits the number of companies capable of participating in its development, and the commercial risks, coupled with relatively low telecommunications infrastructure margins, disincentivize many other potential players from participating. 5G's development is, therefore, being led by companies whose nation-state champions understand the broader strategic and geopolitical advantages of being a leader in the planet's telecommunications backbone. Nations that do not centrally plan communications infrastructure are unprepared to compete with industry leaders with combined economic and geo-strategic approaches to infrastructure development.

Nations that centrally plan their telecommunications infrastructure tend to be authoritarian in nature and operate closed and subsidized economies. They have become market leaders by leveraging the inherent advantages that authoritarian governance and closed markets afford them. But, technological design imbues the values of those who create it, and free-market nations should be concerned that the current technological leaders in 5G may not be compatible with their values and interests. They need to understand the stakes at play and invest in their own or allied commercial champions while coordinating with like-minded nations to ensure the global communications network of the future is open, trusted, and resilient.

The deployment of 5G is the one near-term element of the Fourth Industrial Revolution now unfolding that will drive the economic growth of the first half of the twenty-first century. Much of the technology that people rely on in their everyday lives is made possible only through previous leaps in cellular technology. In certain use cases, 5G promises up to twenty times the performance of today's cellular devices, as well as the ability for exponentially more devices to be connected simultaneously to a single network, amplifying the possibilities of communications and the Internet of Things (IoT). The full potential of this technology is currently unknowable but is likely to transform all facets of life from education to medical care to industrial production. But, with new capabilities come new risks, and new types of risks.

The transition of cellular technology toward this collection of new standards, hardware, and bandwidth—collectively, the fifth generation of mobile telecommunications—will not be linear but will occur in qualitative and quantitative bursts over the next decade. The transition of existing cellular infrastructure will require multi-billion-dollar investments and will be extraordinarily complex, and its initial impact may be overhyped. The fully transformational aspects of 5G are yet to manifest, waiting for compelling use cases—the "killer application"—of faster and more effectively distributed telecommunications technology. 5G's true value will only emerge over time, when standalone 5G is widely deployed—likely in the 2025–2035 timeframe.[1] Moreover, many of the central technologies that will enable 5G networks to reach their full potential have not yet reached maturity. This means that while the critical first stages of the 5G competition are already under way, the ultimate design of the global network is a long way from being determined.

Historical precedent suggests the nation that achieves first-mover advantage in designing and deploying at scale the core technology of a new cellular generation can reap substantial economic advantage and establish a central role in future innovation. This will likely be the case for the development and deployment of a global 5G communications network. This advantage is more than economic; the centrality of digital communications to modern society means that the values imbued within telecommunication's technological design shapes how we live and can have broad societal implications. The scope, cost, and complexity of 5G mean that those who lead the deployment of its capabilities could lock out the influence of competitors for a generation. Within this context, free and open nations that value transparent and accountable governance domestically—and the liberal, rules-based order internationally—must work together to ensure that the future global communications network reflects their shared values.

Technology is a manifest reflection of the values of those who design it. Thus, the battle for technological infrastructure is also a statement on the values of the nations and societies that lead its development. This battle, therefore, is not just for market share, but for influence over a nation's rights, values, and network design, even in neutral states. This creates

1 Value, in this instance, means not only direct revenue generated for technology developers and network providers but also the new ways of undertaking business—indeed, new businesses and industries themselves—that will be created by the capabilities that these new ways of communication enable. It also means benefits that are more important but harder to quantify. The ultra-low latency will be critical, for instance, in enabling widespread adoption of autonomous cars, which may lead to drastic reductions in road deaths. Greater connectivity may reduce the need for travel at all, again reducing road deaths and congestion. Mohanbir Sawhney, "Perspectives: Don't Hold Your Breath for 5G. Most of Us Won't Be Using It until 2025," *CNN,* December 10, 2019, https://www.cnn.com/2019/12/10/perspectives/5g-technology-t-mobile-att-verizon/index.html; Matt Kapko, "AT&T, Sprint, and Cisco Execs Throw Cold Water on 5G," SDxCentral, September 18, 2019, https://www.sdxcentral.com/articles/news/att-sprint-and-cisco-execs-throw-cold-water-on-5g/2019/09/.

a major source of risk and an opportunity for exploitation by authoritarian agents. Such influence will not only determine how countries view the global system but could shape domestic political systems and tendencies toward authoritarianism rather than democracy. It provides a toolbox for repressive leaders looking to suppress, surveil, and intimidate their populations. And, critically, as was seen numerous times in recent years, control economies can and will utilize commercial incentives to support the government's national and international policy. Moreover, a global network serviced by a vast network of high-tech workers able to gather human and signals intelligence creates global reach for revisionist powers that do not respect the rule of law and have little regard for the best interests of host nations or the global community. Coupled with the ability to exert economic leverage over resource-constrained countries dependent on the essential capabilities provided and the risks to free-minded populations around the world are stark.

This paper is not intended to advocate against any one nation or company. Rather, it is to lay out a path toward policy consensus for nations that share the values of freedom and openness or at least strive toward these values. However, as the nation that has identified and invested in the opportunity 5G represents, the Chinese state and its technology champions epitomize the risks that authoritarian governments using the advantages of a closed economy can present. The Chinese state and its technology companies, led by Huawei, have risen to a global leadership role through a combination of: astute forecasting; excellent international financial strategy and strategic decision-making; maximizing the advantages of a centrally controlled and protected manufacturing sector to achieve unbeatable economies of scale; and replicating the technology and business models of previous technology leaders.

In contrast, free and open nations—such as the United States and its like-minded partners in Europe and Asia—have fallen behind in the opening phase of this global competition. But, free-market economies also have inherent advantages, and policymakers should seek to leverage them. The move to 5G is a long-term process, not a short-term sprint, with technology, standards, and applications evolving over the 2020–2035 period. The United States and its like-minded partners have an edge in the manufacture of some of those technologies, particularly radios and related microchips, as well as the innovative capacity to define compelling use cases for 5G technologies. The competition as it has been characterized today is focused on early evolution in cellular networks and a continuing buildout of core Internet backhaul for those networks. Ongoing innovation in both the hardware and software of this wireless technology, and the wider IoT, may mean a very different technology landscape only five or ten years hence. This could leave the United States and its partners much better positioned, because free and open markets are more flexible to an evolving and dynamic market.

State of Competition and Risk

The conversation about 5G security tends to center on technical security—the resistance of telecommunications equipment to digital or physical compromise—and the relative merits of these arguments hinge on the assessed security of individual hardware or software products. But this is limiting, and two other dimensions of risk must factor into the analysis: the likelihood that some vulnerability, currently known or not, might be exploited in future at the behest of a political authority; and the accumulated social and political influence associated with use of a technology and the philosophy embedded in its design.

At present there are only four companies able to provide mature 5G capabilities to network providers, and only two of them can provide full end-to-end comprehensive solution. Huawei, a Chinese state technology champion, is the current leader in cost and, supposedly, technological maturity. Samsung, a South Korea-based global conglomerate, is the other comprehensive option available. The other two, Ericsson and Nokia, are mature companies with significant legacies. Huawei and Samsung can provide fully integrated, end-to-end 5G solutions along with the required service staffs, which has a number of inherent benefits to those seeking upgraded networks under the current network model.

The United States has raised concerns about the risks that Huawei poses to states purchasing its equipment, either through: government-directed compromise or willful neglect leading to loss of confidentiality and integrity; susceptibility to deliberate interference leading to loss of confidentiality; or potential manipulation, disruption, or other interference with governments, commercial entities, or individuals targeted by control economies. Some versions of this argument hinge on second-order logic that the initial technical vulnerabilities could shape US or allied behavior or remove intermediary states as partners, because of their use of this infrastructure.

The potential risks are significant and extend beyond the political. The potential ubiquity of 5G and its multitude of uses create new attack surfaces as data transit networks and devices unanticipated by the user, which gives intruders increased opportunities for access, monitoring, control, or compromise. These risks stem from more than just overt attacks, as poorly written code creates major vulnerabilities that could be exploited in the future. In an increasingly virtualized environment, the rise in service and cloud-based infrastructure blurs the distinction between network segments, providers, and consumers. Since the placement of these fifth-generation technologies may not map to traditional enterprise and higher-level interconnection network models, a less predictable path for data means the entire ecosystem must be trusted, rather than just individual components.

There have been numerous incidents and accusations of hacking by Chinese-based entities, including at least one incident in which intelligence sources pointed to Huawei being used to hack foreign entities.[2] More broadly, there is also plenty of evidence of the Chinese giant's shoddy software-development practices and poor product security-lifecycle management, including slow or nonexistent updates for security flaws.[3] Moreover, there is significant evidence of extralegal monitoring and of direct manipulation of infrastructure to track political dissidents, especially in countries with poor governance and rule of law.[4] This is executed with great ease by the legions of Chinese workers deployed to manage Huawei networks. China has clear laws stating its ability to coerce Chinese companies to turn over information when asked. This is important—absent any specific technical vulnerability, Huawei is still subject to an authoritarian state whose policy structures exist to propagate a model for the development and use of technology heavy on surveillance and other forms of centralized control.

The potential impact of this form of economic pressure and political leverage can be seen from multiple incidents, including in South Korea over the 2017 deployment of US Thermal High Altitude Area Defense (THAAD) ballistic-missile-defense systems and Vietnam's cancelling of the exploration of petroleum reserves within its own sovereign waters in 2018—not to mention continued harassment of Filipino fisherman

2 Colin Packham, "Exclusive: Australia Concluded China Was behind Hack on Parliament, Political Parties—Sources," Reuters, September 15, 2019, https://www.reuters.com/article/us-australia-china-cyber-exclusive/exclusive-australia-concluded-china-was-behind-hack-on-parliament-political-parties-sources-idUSKBN1W00VF; Abdi Latif Dahir, "China 'Gifted' the African Union a Headquarters Building and Then Allegedly Had It Bugged," *Quartz,* January 30, 2018, https://qz.com/africa/1192493/china-spied-on-african-union-headquarters-for-five-years/; Paul Maley and David Uren, "China Used Huawei to Hack Network, Says Secret Report," *Australian*, November 3, 2018, https://www.theaustralian.com.au/nation/china-used-huawei-to-hack-network-says-secret-report/news-story/510d3b17c2791cbcac18f047c64ab9d8.

3 "Annual Report," Huawei Cyber Security Evaluation Centre (HCSEC) Oversight Board, March 2019, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/790270/HCSEC_OversightBoardReport-2019.pdf.

4 Steven Feldstein, "The Global Expansion of AI Surveillance," Carnegie Endowment for International Peace, September 17, 2019, https://carnegieendowment.org/2019/09/17/global-expansion-of-ai-surveillance-pub-79847.

in recent years.[5] Within business and cultural spheres, this same attitude and approach can be clearly seen through the pressure applied to the National Basketball Association (NBA) by the Chinese state in reaction to comments made by a team owner.[6] It is not the only incident in recent times, and it is not hard to see how this same pressure would be exerted over the digital infrastructure that is the core of modern life and the global economy.[7] The absence of appreciable rule of law in the face of state security concerns makes this political model effectively a source of vulnerability for otherwise intact technology. And, while no specific vulnerability has yet been identified, there is an increasing awareness of the risk that "state-backed actors" could pose.[8] The United States has made recommendations to manage these risks that amount to demanding countries simply refuse to use Huawei equipment. But, this message has been carried forth with heavy-handed messaging and diplomatic pressure undermined by a ruthlessly inconsistent administration.

Beyond the Chinese government's direct actions, Chinese companies have demonstrated an unacceptable level of consideration to issues of importance to Western populations, such as TikTok's approach to privacy and censorship.[9] Even in its most benign form, the poor quality of equipment and software creates exponentially more opportunities for criminal, sub-state, terrorist, and other third-party actors to exploit and attack global communications networks.[10]

5 David Josef Volodzko, "China Wins Its War against THAAD without Firing a Shot," *South China Morning Post,* November 18, 2017, https://www.scmp.com/week-asia/geopolitics/article/2120452/china-wins-its-war-against-south-koreas-us-thaad-missile; James Pearson, "Vietnam Halts South China Sea Oil Drilling Project under Pressure from Beijing," Reuters, March 23, 2018, https://www.reuters.com/article/us-southchinasea-vietnam/vietnam-halts-south-china-sea-oil-drilling-project-under-pressure-from-beijing-idUSKBN1GZ0JN; Jason Gutierrez, "Philippines Accuses Chinese Vessel of Sinking Fishing Boat in Disputed Waters," *New York Times,* June 12, 2019, https://www.nytimes.com/2019/06/12/world/asia/philippines-china-fishing-boat.html.

6 Sopan Deb, "N.B.A. Commissioner: China Asked Us to Fire Daryl Morey," *New York Times,* October 17, 2019, https://www.nytimes.com/2019/10/17/sports/basketball/nba-china-adam-silver.html.

7 Bethany Allen-Ebrahimian, "Hollywood Is Paying an 'Abominable' Price for China Access," *Foreign Policy*, October 23, 2019, https://foreignpolicy.com/2019/10/23/abominable-china-dreamworks-propaganda-hollywood/.

8 "Annual Report," Huawei Cyber Security Evaluation Centre Oversight Board; "EU Coordinated Risk Assessment of the Cybersecurity of 5G Networks," NIS Cooperation Group, October 9, 2019, https://g8fip1kplyr33r3krz5b97d1-wpengine.netdna-ssl.com/wp-content/uploads/2019/10/Report-EU-risk-assessment-final-October-9.pdf.

9 Drew Harwell and Tony Romm, "Inside TikTok: A Culture Clash Where U.S. Views about Censorship Often Were Overridden by the Chinese Bosses," *Washington Post*, November 5, 2019, https://www.washingtonpost.com/technology/2019/11/05/inside-tiktok-culture-clash-where-us-views-about-censorship-often-were-overridden-by-chinese-bosses/.

10 Kate O'Keeffe and Dustin Volz, "Huawei Telecom Gear Much More Vulnerable to Hackers Than Rivals' Equipment, Report Says," *Wall Street Journal,* June 25, 2019, https://www.wsj.com/articles/huawei-telecom-gear-much-more-vulnerable-to-hackers-than-rivals-equipment-report-says-11561501573.

A New Way to Manage Risk

The "just say no" approach is critically flawed. It ignores the economics of telecommunications, demanding countries ignore lower-cost, and often better-integrated, Huawei equipment and service offerings, thereby requiring nations to potentially turn down the reasonable near-term economic benefit of 5G technologies while delaying the long-term benefit. This is a difficult proposition without a practical alternative. So far, no Western source has identified what that benefit might be—in large part, because no Western company has been able to offer cost-competitive solutions with the same degree of end-to-end integration and service as Huawei.

If countries are unwilling to (effectively) subsidize the cost of competing infrastructure or have waited too long to challenge the technical dominance of a handful of Chinese giants, there are two remaining pathways to action. One is to accept the insecurities listed above, avoiding suspect infrastructure where possible and mitigating it where necessary. This approach may be necessary regardless and could be effective against technical compromise, but not the broader normative influence of these telecommunications firms and their national surveillance model, or the possibility that such infrastructure could be selectively disabled. It may be possible to set out global norms or regulations that go beyond collective standards and that would govern abuses beyond intelligence collection and other acts.

The remaining option is to *reshape the market*: creating the conditions for Western firms to compete effectively against Huawei's market dominance by opening the closed, vertically integrated model. This would play to the innovative strengths of Western firms and their more diverse market for technology. The Chinese state has bet on a vertically integrated model that locks clients into a closed ecosystem, heavily dependent on services and enabled by mass manufacturing of proprietary and incompatible components, which plays to China's competitive advantage. Closed economies with heavy state backing have a competitive advantage under this model because they select champions who receive additional support and can focus on their R&D with little risk—something that the Chinese state recognized early, as it invested heavily to ensure its companies were able to dominate the market. But, this approach lacks the agility, innovation, transparency, trust, and resilience that come from a diverse supplier base.

Enabling a free-market approach allows participation by a wider array of innovative firms, playing to the free market's competitive advantages. Such an approach has multiple advantages. Software virtualization of key functions mean that hardware can be treated as interchangeable components, diversifying the supply chain, increasing competition and innovation, and allowing for new concepts for how the network is designed. Each of these has its own benefits: diverse supply chains increase resiliency; competition drives down cost while innovation generates new opportunities; and new network designs allow for radically cheaper and more flexible infrastructure. While resisted by major vendors at the time, it was the increase in interoperability between major systems during the transition from first-generation (1G) to second-generation (2G) that enabled cellular communications to become a realistic consumer product. Network providers were able to lower their prices sufficiently only because of the increase in the reliability of major components and the radically reduced costs that interoperability enabled.

While free-market economies are currently unprepared to compete effectively, an effective cooperative strategy that plays to the inherent benefits of free-market economies will win in the longer term. Like-minded nations need a vision and framework that seek to maximize free-market economies' comparative advantages, while mitigating or defending against those of a competitor.

5G in Context

Connected Life

Every generation of cellular technology is defined both by the hardware that enables it—which is usually incompatible with that of previous generations—and by a significant increase in the capability of that network. First-generation cellular networks were analog, while second-generation networks moved to digital cellular technologies, which allowed encrypted voice calls and simple data service, such as SMS text and picture messaging. Third-generation (3G) cellular allowed data speeds up to two hundred kilobits per second (kbps), triggering the rapid growth of smartphones and increasing use of mobile Internet access. The current fourth-generation (4G), long-term evolution (LTE) cellular networks ushered in true broadband capabilities to mobile phones, with speeds up to one gigabit per second (Gbit/s). Each of these generations not only bring new capabilities but use different parts of the radio spectrum and are underpinned by different underlying technologies (4G uses Internet Protocol (IP) telephony instead of circuit-switched telephony, for instance).

5G is characterized by three significant increases in capability: massive increases to network speeds, ultra-low latency, and massive simultaneous connectivity between devices. The performance of an individual 5G device will depend on a wide range of variables, including the portion of spectrum used, the configuration of the network itself, the design of the device, and the number of devices on a network.

It is envisioned that 5G networks will be able achieve twenty times the speeds of 4G networks, because of the characteristics of higher-frequency waves, as well as the use of less saturated segments of the spectrum and broader use of channel bonding to increase bandwidth (five one-hundred-megahertz (MHz) channels compared with only five twenty-MHz channels on 4G, for instance). It could reduce latency—the time taken for information to get from a device to others or the wider network—to one millisecond from the sixty milliseconds it currently takes 4G devices on average. And, its ability to connect billions of devices simultaneously enables massive machine-to-machine communications, often referred to as the "Internet of Things." While much discussion of 5G focuses on network speeds, it will likely be the other two characteristics that will be most revolutionary in developing valuable use cases, such as radical new manufacturing processes, the creation of smart cities, and enabling fleets of autonomous vehicles.[11]

New Approaches, New Opportunities

Microchips are a critical area of competitive advantage for the West, particularly the United States. US-designed chips are used at every level of the technology stack that enables 5G communications, from the user handsets to the switching within the radio access network (RAN) units. They will become even more critical as the capabilities of the 5G network become more sophisticated, particularly for AI functionality. US chips dominate the market, and most 5G manufacturers must pay for the right to produce proprietary designs—a key issue the Chinese government is seeking to break free from in its "Made in China" plan. To this end, it has recently announced a new $29-billion fund to invest in its semiconductor industry, specifically to break its dependence on US suppliers.[12]

The United States will likely retain a leadership role in the short term. To improve the depth and breadth of mobile connectivity, smartphone manufacturers, including Samsung and Apple, have turned to the all-in-one chipsets that are integrated with Qualcomm's leading modem-RF into their 5G smartphone designs. So far, Qualcomm has only commercialized one high-end chipset from its 800 series to support 5G, along with LTE, connectivity; however, it plans to extend 5G capability into its 600 and 700 series in 2020 when more 5G devices are likely to make their debuts. The expansion will help manufacturers bring down the costs for consumers.

Nonetheless, silicon manufacturing remains one of the costliest elements of the supply chain. Moreover, many US firms today focus on designing chips for subcontracted fabricators to produce, often in China. This represents a supply-chain vulnerability, which has been highlighted by the current trade war between the United States and China. Moreover, the massive cost of developing new silicon chips limits the entrance of new and innovative startups that could develop new opportunities to advance capability and compete.

11 "The 5G Ecosystem: Risks & Opportunities for DoD," Defense Innovation Board, April 2019, https://media.defense.gov/2019/Apr/04/2002109654/-1/-1/0/DIB_5G_STUDY_04.04.19.PDF.

12 "China to Funnel $29 Billion Towards Its Chip Ambitions," *Bloomberg News*, October 28, 2019, https://www.bloomberg.com/news/articles/2019-10-29/china-to-funnel-29-billion-towards-its-chip-ambitions.

In many ways, from the hegemonic nature of certain players in semiconductors to the structure of the telecommunications market, the structure of the 5G deployments misses multiple opportunities to draw Silicon Valley participants into the development of leading new technical approaches.

A key benefit of 5G will be its ability to customize to different applications and for the needs of different groups through virtualization and software-defined networking. Virtualized and software-driven functionality could lead to more modular network architecture, meaning individual groups will be better able to personalize the architecture to their needs in order to effectively monetize the capability. Software-led approaches significantly reduce the costs of deployment, open the range of potential suppliers, and enable ongoing and rapid updates to functionality through research into software and simple push-updates—as opposed to requiring the replacement of hardware.[13] Moreover, in developing nations, this approach may allow the opportunity to "leap ahead" to new capabilities that won't require the building of expensive and redundant infrastructure—just as the ubiquity of cell phones has made most landline connections unnecessary. While a sophisticated fiber-optic network is an essential element of a 5G network, the data speeds over air may reduce some need for "last-mile" fiber connectivity in some cases.

The radio access network, more commonly referred to as RAN, is the epitome of legacy approaches to cellular networks. Those legacy approaches consisted of "black-box" pieces of hardware, which are the single costliest element of the network. It fulfills a critical intermediary role between the base stations that connect individual devices and the core network and is composed of a number of subcomponents, depending on the generation of cellular network. The legacy approach is referred to as a "black-box" solution because the major components are highly proprietary, and will not work interchangeably with multiple suppliers. This is because of a legacy technology called common public radio interface (CPRI), which handles the connections between signal-processing equipment (baseband equipment, which links devices together across the network and between geographic areas) and the front-haul radios that connect to the individual devices. In existing hardware-based approaches, both these functions reside within each individual cell tower, reducing the range needed to connect to devices.[14] This means major manufacturers are able to control this function by providing complete solutions and holding off potential competitors through economies of scale and the integration of maintenance servicing.

Telecommunications Antenna *Source: Petr Kratochvil via Needpix*

The Open RAN concept creates a new network model by using a software-based solution to replicate (virtualize) the signal-processing functions. This model eliminates the need for CPRI and allows for various functions to occur in a geographically dispersed manner. In short: rather than having large, complex cell towers, 5G can reduce the size of its base stations, allowing them to be deployed more densely and in less conspicuous ways. This could help mitigate the range limitations of the millimeter-wave (mmWave) spectrum, but also opens up new and creative ways to design networks within an urban environment—such as Japan's recent approval for telecom providers to collocate them on traffic lights. This will help significantly with one of the greatest challenges to building new telecommunications infrastructure: local regulations and governance. Reducing the impact and complexity of local infrastructure requirements could significantly increase the opportunities for rollout and subsequent consumer demand.

These virtual, software-driven, and open systems will enable a smarter, more flexible, and more energy- and cost-efficient RAN, and by extension communication network. Most importantly, this more open "white-box" solution

13 Iain Morris, "Open Conflict Over Open RAN," *LightReading,* February 14, 2019, https://www.lightreading.com/mobile/fronthaul-c-ran/open-conflict-over-open-ran/d/d-id/749437.

14 Linda Hardesty, "Cisco's Early Bet on RAN Virtualization Propels Altiostar," *FierceWireless,* May 6, 2019, https://www.fiercewireless.com/tech/cisco-s-early-bet-ran-virtualization-propels-altiostar.

avoids the proprietary issues (such as vendor lock-in) of hardware-based RAN, meaning new suppliers can enter the supply chain. New and diverse applications can also be easily onboarded to existing hardware if the architecture is well designed to functionally split between centralized and distributed units. Inevitably, scalability is also made simpler by software-upgradable functions and the use of general-purpose equipment.

The benefits of virtualization can be expanded further, and entirely new network models created, such as that proposed by Rakuten in Japan. The Rakuten approach is a brand-new telecommunications network that will inherently increase the potential vendor suppliers by disaggregating the communications network model and cost orders of magnitude less than legacy approaches by reducing reliance on conventional telecommunications hardware. The proposed network will seek to utilize "4,000 edge servers and 16,000 low cost base stations to form an end-to-end fully virtualized, cloud-native mobile network."[15] Opening up the design of telecommunications networks can also improve the competitiveness of markets.

Existing telecommunications suppliers will play a role in network alongside small firms, with Nokia supplying AirScale remote radio heads and AirGile core network software, the latter of which will also be supplied by Cisco. Intel will contribute Xeon processors and field-programmable gate array (FPGA)-based accelerators. Small cells and their chipsets will likely come from Qualcomm. Fujitsu and Altiostar—both of which produce 5G antenna that can work with a virtualized RAN system, but not with proprietary "black-box" systems—are key to the Rakuten model. In the case of Fujitsu, it is already a major industrial manufacturer, but is not significant enough in the current telecom ecosystem to compete with the four major 5G component suppliers. Altiostar was spun out of research and development by Cisco specifically aimed at virtualizing RAN functions.

The Value of 5G

While 5G is extremely promising, much of its value is still theoretical. The full extent of these 5G capabilities is not yet demonstrated in real-world applications, and the use cases that could be considered of significant enough value to justify the massive investment are currently limited. The first phase of 5G rollout—which has already begun in some cities, and will unfold over the coming three to four years—will consist of 5G equipment deployed on top of existing 4G architecture known as "enhanced mobile broadband." This phase will see speeds increase by five to ten times that of current 4G. But, it will lack the ultimate speed and ultra-low latency of genuine "standalone" 5G and will be aimed at mobile phones and personal devices. The initial performance enhancement will be modest, but costly. For instance, beyond the 5G specific infrastructure needed, a Deloitte study found that $130–$150 billion of investment in fiber-optic cable would also be needed to fully deploy 5G.[16] The near-term use cases are hard to discern, and it is not clear what economic return can be expected from that large investment.

Just as modern use cases for 4G did not emerge until after the network began to mature, it is likely that true use cases for 5G will not be known for several years. However, some early possibilities hint at the importance and potential future risks. As an example, Facebook recently bought a "mind-reading wristband" made by the startup CTRL Labs. This technology can identify a user's intentions by detecting the electrical signals of their brain, allowing them to control devices such as a mobile phone. Such communications could benefit from the ultra-low latency and connectivity of 5G devices and could transform the way people interact with machines and devices. But, there are already serious questions about technology and Internet-enabled engagement, and the role that privacy and accountability play in those interactions. If this technology proliferates, it would create a global communications network that has access not only to individuals' personal data, but their very thought patterns. When considering how oppressive regimes already exploit online interactions and communications infrastructure to identify and target dissenting voices, the idea of such a government having mass access to people's thought patterns is alarming.[17] As uptake of mobile Internet use in the developing world far outpaces traditional access, this issue will be particularly pertinent in developing areas where governance, transparency, and accountability are more vulnerable to exploitation. Even if this capability is still several years from becoming a reality, today's decisions on technology adoption could determine the risk it poses when it matures.

15 Juan Pedro Tomás, "Rakuten to Deploy 4,000 Edge Servers for Virtualized Mobile Network: Report," *RCR Wireless News,* August 6, 2019, https://www.rcrwireless.com/20190806/5g/rakuten-deploy-4000-edge-servers-virtualized-mobile-network-report.

16 Dan Littmann and Jack Fritz, "Deep Fiber: The Next Internet Battleground: Deloitte US," Deloitte Consulting, August 7, 2018, https://www2.deloitte.com/us/en/pages/consulting/articles/communications-infrastructure-upgrade-deep-fiber-imperative.html.

17 Ramona Pringle, "Hong Kong Protesters Use Savvy Strategies to Dodge China's Digital Surveillance," *CBC News,* June 28, 2019, https://www.cbc.ca/news/technology/pringle-hong-kong-protests-1.5192550.

The Challenge

After missing out on the innovation wave that accompanied the transition to 4G, the Chinese government identified 5G as a "strategic emerging industry." As such, six years ago, it launched an extraordinary state-driven effort to dominate 5G. This was a key part of a larger technology strategy called "Made in China 2025."

In 2013, leading elements of the Chinese policy bureaucracy, the Chinese Ministries of Industry and Information Technology and of Science and Technology, and the National Development and Reform Commission (NDRC) began joint direction of 5G efforts by establishing a strategy to develop, test, and prove 5G technologies. At the same time, Beijing allocated mid-band spectrum and directed Huawei and the three leading state-backed mobile operators—China Mobile, China Unicom, and China Telecom—to begin R&D efforts. By 2016, they had conducted technical trials of 5G in dozens of Chinese cities. Beijing views 5G and IoT as critical technologies enabling their tech efforts to lead in autonomous vehicles and smart cities. At the same time, Chinese tech firms invested heavily in the development of AI and machine-learning algorithms that have been deployed across a mammoth web of surveillance infrastructure to monitor the Chinese population.[18]

The China Academy of Information and Communication Technology, a leading think tank, says that by 2025 the Chinese government will have invested $134–$223 billion in 5G.[19] The Chinese government has invested $180 billion in 5G over the past five years and has worked closely with Chinese tech firms to position them as market leaders in deploying a standalone 5G network. As part of this campaign for prominence, Huawei and other Chinese firms have positioned themselves to wield great influence at major technical-standards bodies, including the International Telecommunications Union (ITU) and the 3rd Generation Partnership (3GPP). Huawei alone now holds 37 percent of all 5G patents, while US firms collectively hold about 16 percent. While Chinese firms have yet to fully deploy 5G, Beijing has allocated large amounts of accessible spectrum (around the two-hundred-MHz band) to Huawei and other Chinese telecommunications carriers that plan to begin deploying 5G in 2020.

To the Chinese state, 5G is more than an economic objective. It is also an integral element of its Belt and Road Initiative (BRI)—a massive Chinese development strategy of investments and infrastructure projects meant to connect China's economy to all parts of the globe, in both physical and digital infrastructure.[20] In pursuit of those goals, Chinese firms have put in place complete 3G and 4G digital networks throughout much of Africa, Latin America, and Southeast Asia. Huawei, for example, recently extended a memorandum of understanding (MOU) for cooperation in information and communications technology (ICT) with the African Union, despite reports that Huawei-installed ICT systems were transferring confidential information to Chinese servers.[21] Chinese firms have built more than fifty 3G networks in more than thirty-six African countries.[22] They are chiefly responsible for building out 4G infrastructure in Ethiopia ($834 million), as well as in Cameroon, Zimbabwe, Guinea, and Angola—all of which received $300–$337 million in economic assistance as part of the deal. Chinese firms, with Chinese government support and subsidies (e.g., state banks, political ties), offer complete installation of ICT systems, often at 25 percent under other firms' financing proposals, and contracts include full financing, servicing, and warranties. In essence, their model is to use servicing to sell hardware.

Nations face numerous risks and trade-offs when purchasing Chinese-backed systems, and there has been increasing backlash around the world to some Chinese government-supported development programs. The concerns include limited local employment due to an imported Chinese workforce to service the equipment, the potential risk of falling into a debt trap, and the longer-term costs once initial subsidies have ceased. But, many national leaders in developing nations will find the lower outlay costs and offers of financing too tempting to resist.

18 Paul Mozur, "One Month, 500,000 Face Scans: How China Is Using A.I. to Profile a Minority," *New York Times*, April 14, 2019, https://www.nytimes.com/2019/04/14/technology/china-surveillance-artificial-intelligence-racial-profiling.html.

19 Sean Kinney, "How China Is Taking a National Approach to 5G Deployment," *RCR Wireless News*, May 29, 2019, https://www.rcrwireless.com/20190529/5g/china-national-5g-deployment.

20 Elsa B. Kania, "China's Play for Global 5G Dominance-Standards and the 'Digital Silk Road,'" Australian Strategic Policy Institute, *Strategist,* June 26, 2018, https://www.aspistrategist.org.au/chinas-play-for-global-5g-dominance-standards-and-the-digital-silk-road/.

21 Joan Tilouine and Ghalia Kadiri, "A Addis-Abeba, Le Siège De L'Union Africaine Espionné Par Pékin," *Le Monde,* January 26, 2018, https://www.lemonde.fr/afrique/article/2018/01/26/a-addis-abeba-le-siege-de-l-union-africaine-espionne-par-les-chinois_5247521_3212.html.

22 Frank Fang, "Huawei's Expansion in Africa Comes Under Scrutiny," *Epoch Times,* January 30, 2019, https://www.theepochtimes.com/huaweis-expansion-in-africa-comes-under-scrutiny_2772269.html.

The Vision

While free-market economies are at a competitive disadvantage under legacy approaches, and are already responding to their competitors' first-mover advantage, the state of competition should be kept in perspective. For instance, if Chinese firms collectively hold 37 percent of all 5G patents, then US, European, and other Asian firms hold 63 percent of the remainder. If Huawei holds 28 percent of telecom market equipment, it is on par with Ericsson (which has 27 percent) and Nokia (which has 23 percent). In the case of chipsets—one of the most vital aspects of any advanced computation-based capability—US firms like Qualcomm, Intel, and Micron are dominant, while South Korean firms like SKHynix and Samsung are also highly competitive. Combining these with the new network models mentioned above, the United States and its allies can still play a pivotal role in the future development of 5G and benefit from the subsequent innovation yields.

Careful and deliberate decisions on key issues, within and between each nation, are needed to help shape the market to a model that satisfies the needs and values of open, free-market economies. An aspirational vision for an acceptable global communications network is one that is built upon characteristics including

- a vibrant and global market for technology and services that can be trusted and is free from meddling by state or non-state actors;
- a resilient, diversified, and secure global supply-chain and communications network, supported by a diversity of secure suppliers to reduce points of failure, encourage innovation, and create technological agility;
- open and international standards that allow market access for any participant that will meet national security, trade, privacy, and other international norms; and
- a rejection of the notion that nations should be locked into a closed technology ecosystem that requires ongoing fealty and obedience to a nationalized supplier.

While a vision is a necessary and valuable starting point, it is insufficient for helping nations respond to the challenge presented. To operationalize these ideas, free-market partners need a framework of tangible, near-term actions that can progress the competitiveness of companies that reflect open, accountable, and free-market values. These include: resolving technical and governance interoperability issues; lowering barriers and increasing incentives for new free-market suppliers; evolving new approaches and network models that play to free-market economy strengths; and partnering among like-minded nations to carry the burden of investment and use creative approaches to assist take-up in developing nations.

Already, important steps are being taken. The US legislation, recently passed by the US House of Representatives, that directs the State Department to provide assistance and technical expertise to reinforce US participation in standards-setting bodies (HR 3763) and requiring the US president to create a national strategy to ensure the security of 5G infrastructure (HR 2881) are a good start.[23] Moreover, efforts such as the Prague Proposals—a set of recommendations on considerations for the design, construct, and administration of 5G infrastructure agreed to by thirty-two nations—are important forums for coordination.[24]

Below are a set of select issues and recommendations to build on these ongoing efforts. This is not an exhaustive list, nor will it solve the issues immediately or in every nation.[25] Rather, it is a framework of actions from which additional steps can be taken, and that will necessarily need to evolve as the technologies, market, and use cases for 5G mature. Each represents critical first steps that like-minded free-market nations can take to move toward a comprehensive and coordinated response to the current dominance by closed, authoritarian, state-backed companies. The end state is to establish an open, trusted, and resilient 5G global communications network. As such, the most important successes will likely be in the way this approach supports developing nations.

23 Promoting United States International Leadership in 5G Act of 2019, HR 3763, 116th Congress, 1st session (2019), https://www.congress.gov/bill/116th-congress/house-bill/3763; Secure 5G and Beyond Act of 2020, HR 2881, 116th Congress, 1st session (2019), https://www.congress.gov/bill/116th-congress/house-bill/2881.

24 "The Prague Proposals: The Chairman Statement on Cyber Security of Communication Networks in a Globally Digitalized World," Prague 5G Security Conference, May 3, 2019, https://www.vlada.cz/assets/media-centrum/aktualne/PRG_proposals_SP_1.pdf.

25 Ibid.

A Framework for Action

The technologies compromising 5G mobile telecommunications are exceptionally sophisticated in design, complicated in integration, and exquisite in potential performance. Implementation will require a challenging combination of regulatory, policy, and urban design, as well as pure technical solutions. Every nation and every state—and even some municipalities—will need a specific solution based on legacy infrastructure and policies. As such, a handful of nations will lead the way and set precedents for the rest of the world.

The Role of Governments

Cooperation and coordination of governments—within and between local and national governments; with their industry partners and champions; with research-and-development sectors; and with other like-minded partners—are vital for successfully mitigating the potential risks of 5G. This theme will come up constantly across the key issue areas below. This cooperation is particularly important to technical issues on the one hand, and the use of financial levers to incentivize third-party nations to follow a free and open approach on the other. For instance, Traficom—Finland's traffic and communications agency—coordinated the 5G Momentum project to: foster collective innovation between government, academia, and industry; conduct proof-of-concept testing; and "make Finnish 5G know-how visible."[26] Its open research and testing platforms, one of which Nokia co-leads (5G-FORCE), work to not only validate 5G use cases, but to explore and experiment with their vertical applications. In 2018, the Ministry of Transport and Communications published "Digital Infrastructure Strategy 2025," which reiterates a market-based approach throughout national communications networks, highlighting the nascent optical-fiber market, where high-speed connections will be needed to power new 5G services and applications.

Regulations within individual countries will have a massive impact on the shape of the market. As discussed below, decisions on availability of spectrum, opportunities for the placement of infrastructure, and 5G-enabled applications will have a significant impact on the development path 5G technologies take as they mature. Governments should not interfere with free-market dynamics, nor should their regulations contravene the wider public interests. Experimentation is important, and national governments should seek opportunities to encourage experiments with the applicability of 5G to drive adoption by domestic firms. The Japanese government has identified the Tokyo 2020 Olympics as a key milestone for its—and, likely, the global—next phase of 5G deployment. With plans in place to make commercial 5G go live, and to showcase Japan's latest innovations at the event, the Olympic Organizing Committee has assured that these will be "the most connected" and "most innovative Games in history."[27]

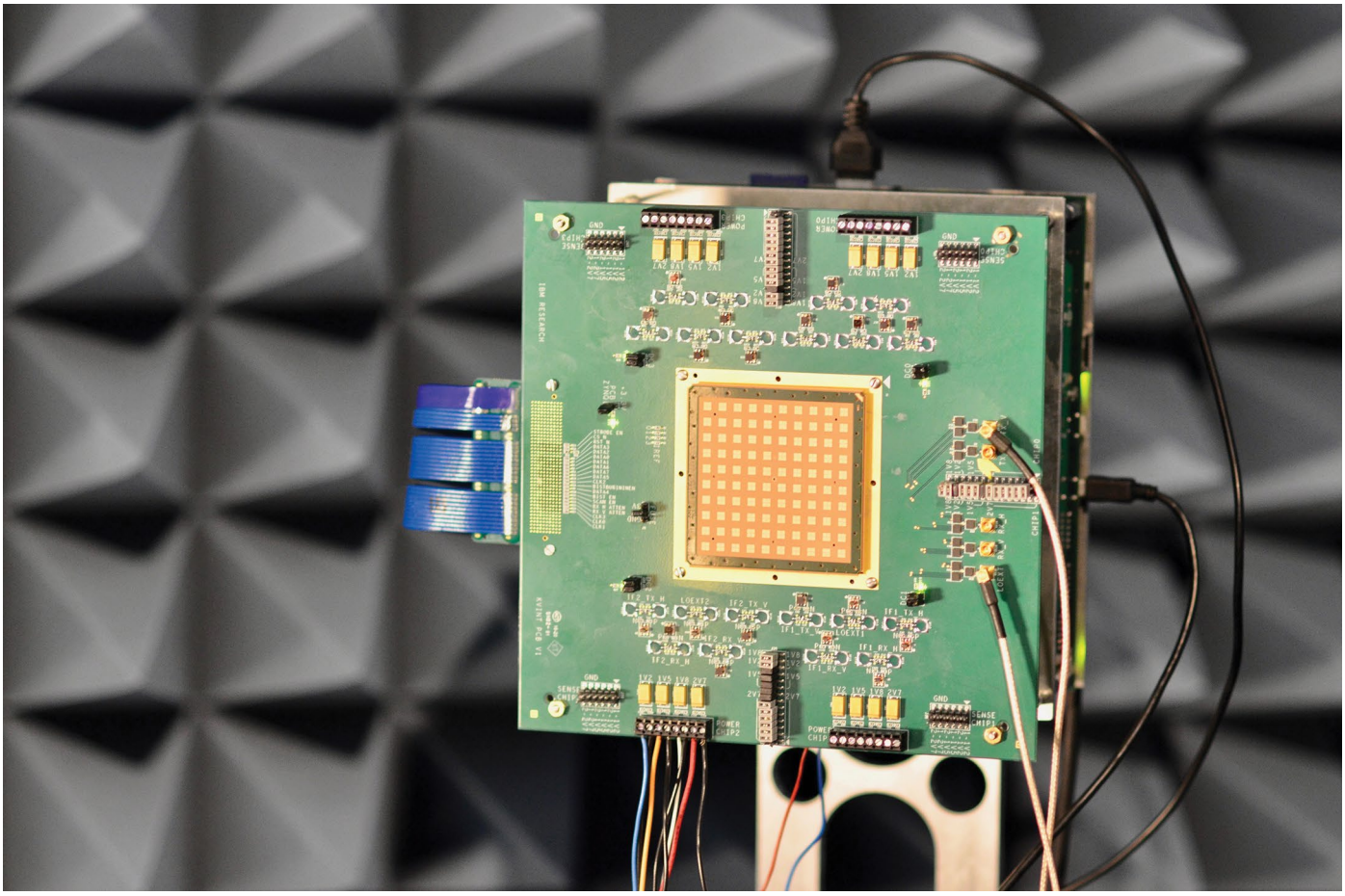
Regulations should be made with a view to the strategic importance of 5G, and with an understanding of the state's incentives. Outright bans of equipment that may be subject to external influence and control are appealingly simple in theory, but extremely challenging in most circumstances. Germany presents a model for a "middle-of-the-road" approach. In light of concerns about compromised suppliers, the German Federal Network Agency assured that no company would be selectively excluded from supplying Germany's networks.[28] But, it did release new security guidelines to demand greater transparency and to stress that all foreign equipment must be bought from trustworthy vendors, though the onus is ultimately on the operators to decide from whom to source critical components.[28] A forward-looking framework for action should also consider issues of technical access, market composition, and financial incentive.

The role of local and municipal governments should not be underestimated. While economies of scale, consumer demand, and national-level R&D will determine much of the future development of 5G, local governments will be the ultimate determinants of its implementation. Zoning boards and community-engagement agencies will play a critical role in educating the public and determining the local construction of the cellular infrastructure. Municipalities should be provided with assistance in understanding the implications and opportunities of 5G and how it can be best applied to serve their constituent populations. Increased coordination between federal, state, and local agencies to prioritize 5G and develop a cohesive strategy for its implementation could enable the United States to become a powerful and fertile

26 Marjo Uusi-Pantti, "5G Momentum: Spectrum Management, 5G Momentum Ecosystem--Vaasa Goes 5G," Traficom, May 17, 2019, https://www.univaasa.fi/fi/sites/vaasa5g/5g_momentum_marjoup_20190517.pdf.

27 "Tokyo 2020 Welcomes Cisco Systems G.K. as an Official Partner," Tokyo Organising Committee of the Olympic and Paralympic Games, June 9, 2016, https://tokyo2020.org/en/news/sponsor/20160609-01.html; Blanche Lim, "Tokyo Wants to Surpass Pyeongchang to Be the Most High-Tech Olympics," *CNBC,* March 15, 2018, https://www.cnbc.com/2018/02/26/tokyo-wants-to-surpass-pyeongchang-to-be-the-most-high-tech-olympics.html.

28 Natasha Lomas, "Germany Says It Won't Ban Huawei or Any 5G Supplier up Front," *TechCrunch,* October 15, 2019, https://techcrunch.com/2019/10/15/germany-says-it-wont-ban-huawei-or-any-5g-supplier-up-front/.



Close up of the silicon-based millimeterWave phased array antenna module, IBM Research via Flickr.

testbed for innovative companies and application developers, generating a new competitive edge.

On Technology

The most impactful action open, free-market economies can undertake is cooperation and coordination on a range of technical issues that will have an outsized impact on shaping the future of 5G. The size, expense, and complexity of 5G technologies means that producing a large enough market to share the burden of costs is critical. This cannot occur if each domestic market has its own limitations and requirements, as the global market would become fractured and reduce economies of scale.

Discussing 5G actually means discussing a group of technology issues. Of these, spectrum is the most important. Speed—or peak data rates—is one of the key attributes separating 5G from 4G. The characteristics of signal change across the RF spectrum. Current legacy cellular networks, for instance, are very low frequency and have good penetration but also relatively low bandwidth. Inversely, high-frequency spectrum has very high bandwidth, but will struggle to penetrate even plant foliage. Speed is also impacted by how much spectrum is available, with much of the lower frequencies already maxed out by current usage.

All nations are looking to find this spectrum in two places: below six gigahertz (GHz)—often referred to as "sub-6"—and between approximately 24–300 GHz—often referred to as mmWave. Radios deployed over mmWave permit more connections closer together at high bandwidth. Less an issue for applications like cell phones, this kind of network density would be useful if every lightbulb in a house, or every road sign in a city, communicated independently. While many nations are prioritizing the low-mid-band Sub-6 spectrums to accelerate rollout, US companies are putting an emphasis on the mmWave/high-band frequencies. This is because in the United States, large bands of sub-6 spectrum are reserved for use by federal agencies, particularly the US Navy and emergency services.

Limiting the development of 5G in the United States to the mmWave portion of the radio spectrum could harm interoperability with other nations, and lead to higher-cost and narrower-use "exquisite" US products. There is also a non-zero chance the mmWave technology will not penetrate

anywhere but the densest urban centers. This would stunt any growth in the broader tech sector, as many handsets—and, potentially, digital services—would be incapable of running on other nations' networks. For instance, if a new service, such as augmented reality, needs low latency and high data speeds that are only available on 38-GHz spectrum, US companies would be limited to the domestic market. Concurrently, if other nations' tech sectors are incentivized to build and innovate on the low-mid band that every other nation is using, they would have a competitive advantage: reaping the economic benefits, setting the standards, and shaping future innovation trajectories.

In the US context, this would be operationalized through quickly addressing spectrum issues by freeing sub-6 spectrum. A first step toward this objective would be for the White House to convene an all-stakeholder commission coordinated by Office of Science and Technology Policy, in order to forge a cohesive US approach. It would include: major telecom carriers; chip makers and other producers of 5G/IoT technologies; key actors in Congress; and the National Institute of Standards and Technology. Then, it should build a public-private-partnership consultative mechanism with key allies and partners in governments and the private sector. A key issue will be to identify a path ahead that respects current US spectrum allocations, but also works with allies in European and Asian markets to find a workable compromise to ensure market compatibility. Internally, the United States should work with all stakeholders to find a workable compromise that frees up sufficient sub-6 spectrum while continuing to develop capabilities in the mmWave frequencies to maximize the promise of 5G.

Recommendation: Ensure technical regulations align to prevent fracturing of the market.

This can be operationalized through

- in the US context, quickly addressing spectrum issues by freeing sub-6 spectrum; and
- establishing regular forums for dialogue and information sharing across all like-minded nations that will share market characteristics;
  - domestically through a commission of all stakeholders; and
  - internationally through a focus on 5G issues in existing partnership dialogues and, potentially, new technology-focused coordination forums.

On the Market

The second priority should be to increase the incentives for new, diverse, and innovative suppliers to shape the market to reduce costs and barriers to entry, increase incentives, build new business models, and find creative ways to use existing economic tools to assist third-party nations in building their own infrastructure. Free-market economies should seek new ways to lower the barriers of entry for new hardware, especially radio and microchip manufacturing. Public-private investment in facilities such as a small-batch silicon foundry for rapid chip testing of new designs presents an excellent example of how costs could be lowered for all, equally. In such a case, the huge investment of developing the facilities would be offset and carried by both the public and private sectors, but would be open to any company that wanted to utilize them. This would reduce costs, increasing the competitiveness of US firms, lowering the costs of network equipment, and potentially uncovering new capabilities that would enhance the use cases of 5G.

Germany provides an interesting case. Germany does not have a domestic company capable of exporting end-to-end 5G infrastructure, but has capitalized on the 5G ecosystem supply chain by positioning itself as a lead market in 5G applications and promoting serious "cooperation between telecommunications and user industries."[29] Its testbeds have attracted companies and researchers worldwide to test 5G developments under real-world conditions, with the latitude to further brainstorm, create, trial, and validate. Active testing brings faster network deployment, which brings more testing, such as for new applications on that network. It is through this virtuous feedback loop that the German government has recognized an opportunity to engage start-ups and subject-matter experts (SMEs), exploit new architecture paradigms unique to 5G, and incentivize transparency and competition in its national telecom market.

5G networks also offer new opportunities that play to free-market competitive advantage by seizing on trends in software defined networking and virtualization to permit telecommunications networks to be built on commodity computing and networking hardware, rather than specialized telecommunications gear alone. Virtualization can also allow non-traditional vendors into the telecommunications market and permit companies to compete with state-backed telecommunications giants and vertically integrated "black-box" networks.

Recommendation: Encourage and accelerate innovation through supporting commercial infrastructure in free-market economies.

29 "5G Strategy for Germany: A Scheme to Promote the Development of Germany to become a Lead Market for 5G Networks and Applications," Federal Government of Germany, July 2017, https://www.bmvi.de/SharedDocs/EN/publications/5g-strategy-for-germany.pdf?__blob=publicationFile.

This can be operationalized through

- supporting the development of innovative technologies across the value chain, from ORAN to virtualized infrastructures through US government purchases and research grants;
- developing testbed-alternative structures built on virtualized models and cloud-first technologies to reduce the dependence on high-cost hardware;
- establishing a 5G center of excellence;
- creating testbeds to drive development of new applications and use cases while encouraging commercial investment;
    - enhancing, enlarging, and opening up existing small-batch fabrication sites (specifically NSA's Silicon Processing Lab and BAE's Manassas facility) for quicker, iterative silicon design and testing;
    - identifying facilities—such as large military bases, large government offices, and FFRDC campuses—where startups can experiment with applications and tools that could be scaled up to wider use; and
- establishing a National Manufacturing Innovation Initiative.

Strategic Investment

Like-minded nations should seek creative ways to use existing financial tools to offset the subsidies that China and other closed-market economies can provide to neutral, third-party nations. Coordinating with allies and partners, both bilaterally and in key multilateral lending agencies—World Bank/International Finance Corporation (IFC), Asian Development Bank, Asia Infrastructure Investment Bank (AIIB), European Development Bank, and other EU agencies funding tech development—is a critical force multiplier. US leadership is key to coordinating priorities and direction for digital infrastructure and for standards. China flooded the zone at 3GPPP to press for international standards best suited to its 5G technologies. A coordinated approach to development technical standards and norms among free-market actors will be essential going forward.

One previously missing element in US economic strategy has been consistent, robust development/infrastructure financial mechanisms. The recent BUILD Act, consolidating development finance agencies (e.g., OPIC, US Agency for International Development) is an important first step.[30] In addition, the Export-Import Bank (EXIM Bank), which has been bordering on extinction, needs full White House and congressional support to be rehabilitated as a reliable source of financing. These agencies also need order-of-magnitude-enhanced resources.

Recommendation: Build out an integrated international and export finance capability to compete with control-economy initiatives.

Operationalized by

- sharing the burden of competing with control economy companies and policies in allied and developing markets;
- developing a coordinated, synchronized strategy among select allies and partners, including NATO and ANZUS; and
- developing export finance vehicles, including through the US Agency for International Development and OPIC investments, to provide a practical alternative to authoritarian underpinned solutions, and to assist developing nations in building the foundations of digital economies with the same values and standards expected in developed ones.

30 "Overview," US International Development Finance Corporation (DFC), accessed January 1, 2020, https://www.opic.gov/build-act/overview.

Conclusion

The global transition to fifth-generation cellular technology is a decade-long process that has already begun. While its benefits and risks may not be immediately apparent, they will eventually influence every facet of life in an ever-more-connected world. The ways in which the global 5G network is developed will not only determine the future of millions of jobs and billions in potential economic growth, but will have strategic and geopolitical implications.

One nation has developed, and is executing, an impressive strategy to lead this burgeoning economic lever. The development of any telecommunications network is, and should be, a commercial-led activity. But, the nature of the risks and opportunities 5G's development presents—as well as the strategic implications and the geopolitical realities that will occur—mean that national governments should take a proactive role in shaping the development, values, and processes, in order to ensure the nature of the network aligns with their values and interests.

The stakes of this process are enormous. 5G will not be a series of disjointed, disconnected national networks, but a global platform for information sharing and new technical innovation. Technology is a manifestation of the values of those who design it, and the cost, sophistication, and complexity of 5G equipment is a prime example. From the process through which the technology is designed and built to the way it is employed and serviced, this technology presents opportunities for exploitation by those with an interest in limiting individual freedoms and eroding privacy. This does not just present a risk to individuals, but has the potential to shape the political trajectory of nations and regions. Moreover, the legacy approach of hardware-based network functionality advantages supplier monopolization and lock-in, which reduces transparency and creates supply-chain fragility.

To date, corporations from closed economies that have authoritarian-state backing have a first-mover advantage in building this network. They have achieved this by maximizing the advantages that their closed economies and state subsidies present. But, the 5G transition has just begun, and many of the core technologies and business models are yet to reach full maturity. While open-market economies cannot compete using legacy approaches, markets can be reshaped in ways that maximize the inherent advantages through new and flexible technologies, deployment concepts, and business models.

There is time and opportunity to shape the future of 5G communications networks, but the time to take clear and decisive action is now. Open-market economies have inherent advantages that can compete with any closed-market approach, so long as they are supported in thoughtful and deliberate ways. Fundamentally, the 5G competition is not solely about developing a crucial component of the next industrial age; it is the first integrated competition between free-market and authoritarian models. The stakes are the rights and principles of billions of users, in 2025 and beyond.

About the Author

John T. Watts is a Senior Fellow at the Atlantic Council's Scowcroft Center for Strategy and Security and a partner at One Defense. Watts has spent more than 15 years working across military, government and industry, focused predominantly on the nature of future warfare and implications of complex emerging security risks. Watts has extensive experience leading high profile wargames including on Middle East and Baltic security issues; countering terrorist and irregular groups; future concepts for the U.S. Marine Corp and U.S. Army; as well as the nature of game-changing technologies in warfare. He has also led research efforts on disinformation, Indo-Pacific security and alternate futures resulting from technology adoption.

Previously, Watts was a senior consultant providing at a boutique Washington firm providing new perspectives and tangible outcomes to a diverse range of federal, local and international organizations, including US Office of the Secretary of Defense, US Marine Corps, Department of Homeland Security, National Institutes of Health, International Monetary Fund and US Environmental Protection Agency among many others. Watts has also been a staff officer at the Australian Department of Defence working in a variety of strategic planning, implementation, evaluation, and management roles. Watts also spent more than a dozen years in the Australian Army Reserves, where he held command, training, officer development, and emergency management planning and response positions.

Watts holds a Masters in International Law from the Australian National University and a BA in International Studies from the University of Adelaide.

Atlantic Council Board of Directors

The Atlantic Council is a nonpartisan organization that promotes constructive US leadership and engagement in international affairs based on the central role of the Atlantic community in meeting today's global challenges.

Atlantic Council

1030 15th Street, NW, 12th Floor, Washington, DC 20005

(202) 463-7226, www.AtlanticCouncil.org