Securing America's Future Energy

Issue Brief

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The Race to 5G: Advancing the Safety and Efficiency Benefits of Enhanced Mobile Connectivity

Summary

- The integration of high-speed fifth-generation (5G) wireless networks in transportation will be transformative for everyday Americans—generating billions of dollars in economic benefits, reducing congestion, and saving lives. 5G is the latest iteration of enhanced mobile broadband that delivers internet speeds that are 10- to 100-times faster than current fourth-generation technology.
- The United States lags behind China in deploying 5G. Since 2015, China has deployed 12 connected sites for every one site in the United States. The Chinese government's $400 billion investment in 5G and the growing international influence of its state-supported telecommunications giant Huawei Technologies Co. mean the United States risks ceding global leadership to a strategic adversary on crucial technology that will help shape the global economy.
- U.S. 5G deployment requires as much as $275 billion in cumulative telecommunications industry investment through 2024. In contrast to China's government-directed approach, the expansion of 5G in the United States will be commercially-driven. The Federal Communications Commission's (FCC) 5G FAST Plan identifies spectrum access, private investment, and infrastructure as the key challenges to 5G deployment in the United States.
- Carriers in the United States will need more access to mid-band portions of the electromagnetic spectrum to achieve expansive 5G coverage, especially if 5G's transportation benefits are to be fully realized. The FCC should prioritize wireless broadband in these frequencies to get more spectrum in the hands of mobile carriers. In addition, the United States needs a robust, differentiated, and competitive wireless communications market that has the capacity to make scalable investments in 5G. FCC approval of the Sprint-T-Mobile merger would be a positive development to achieve this outcome.

Background

In recent years, fifth-generation (5G) wireless networks have moved from being a theoretical concept to a deployable technology. An evolution over current fourth-generation (4G) wireless networks, 5G promises Internet connectivity that is 10- to 100-times faster than current network speeds, lower

latency (processing times), and more efficient use of the electromagnetic spectrum.[1] These advances in mobile broadband will enable greater levels of machine learning and cloud-based computing, which in turn will deliver significant benefits to the U.S. economy.[2]

5G is a form of enhanced mobile broadband that receives and transmits data from cell sites attached to a wide variety of infrastructure, including towers, street lamps and building rooftops. In contrast to the current 4G Long-Term Evolution (LTE) network, which uses low- and mid-range spectrum bands to cover geographically expansive areas, initial 5G deployments in the United States have used low-coverage millimeter wave spectrum bands (above 24 GHz). For 5G to be truly transformative for transportation, connectivity must be ubiquitous in every location where individuals and machines travel, which makes it essential that 5G is not deployed on millimeter wave spectrum alone. Carriers in the United States will need access to mid-band portions of the spectrum to achieve expansive coverage if 5G's transportation benefits are to be fully realized.

For 5G to be truly transformative for transportation, connectivity must be ubiquitous in every location where individuals and machines travel, which makes it essential that 5G is not deployed on millimeter wave spectrum alone.

Interest in manufacturing and expanding 5G infrastructure is global in nature and increasingly pits the United States in a technological race against China. Chinese telecommunications giant Huawei Technologies Co., whose leadership have links to China's state security apparatus,[3] has signed contracts with governments and businesses around the world and plans to supply 5G equipment, software, and services to its many international trading partners.[4] China's strategy of integrating military and civilian surveillance into a complex and interwoven global network of telecommunications equipment presents a serious threat to the national security of the United States and its allies.[5]

Expanding 5G networks domestically will require a comprehensive and streamlined federal policy. Policymakers and regulators should work together to eliminate barriers that currently inhibit commercial deployment by expanding mid-band spectrum access, simplifying regulations, and ensuring a robust, competitive, and differentiated mobile carrier market exists to expand 5G.[6] Failure to expeditiously deploy next-generation wireless telecommunication networks risks ceding global leadership to China and delaying the rollout of lifesaving connected and autonomous vehicle (CAV) technologies.

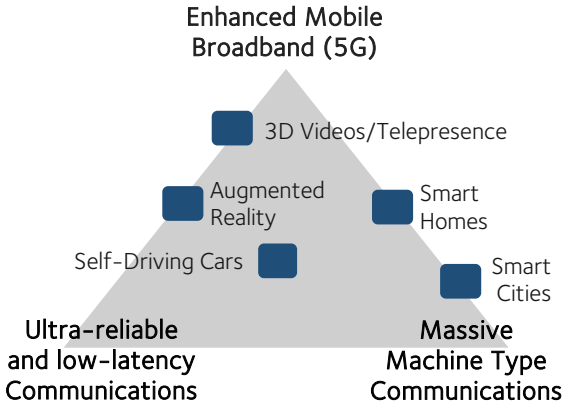
[1] Ericsson Inc., *Ericsson Mobility Report,* November 2018; and Gopal Ratnam, "5G Technologies Could Challenge US Spy Agencies," Roll Call, February 26, 2019.
[2] Deloitte LLP, *5G: The Chance to Lead for a Decade,* August 2018.
[3] See, e.g., Arjun Kharpal, "Huawei says it would never hand data to China's government. Experts say it wouldn't have a choice," CNBC, March 9, 2019; and Kanishka Singh, "U.S. intelligence says Huawei funded by Chinese state security: report," Reuters, April 20, 2019.
[4] See, e.g., The Heritage Foundation, "China, Huawei and the Challenge of 5G," March 21, 2019.
[5] Klon Kitchen, "The U.S. Must Treat China as a National Security Threat to 5G Networks," The Heritage Foundation, April 16, 2019.
[6] Note: The Federal Communications Commission identified these as barriers to 5G deployment in Chairman Ajit Pai and the Commission's 5G FAST Plan.

5G's Transportation Benefits

The current transportation system is vastly inefficient and could be considerably safer. On average, only 4 percent of household vehicles are in use at any given time, and peak utilization is about 11 percent.[7] Dense urban areas with growing populations lead to system congestion and wasted time and fuel. Motorists consume more fuel and space searching for parking, which also contributes significantly to urban congestion and lost opportunity cost for valuable urban land areas.[8] More vehicle miles traveled also leads to a higher risk of crashes with motor vehicles serving as a major cause of death or serious injury.[9] For the last two years, annual U.S. roadway fatalities topped 37,000—the highest in a decade.[10]

On its own, 5G-enhanced mobile broadband will not improve transportation sector efficiency or roadway safety. Instead, 5G provides a technological pathway to introduce data-intensive technologies, like CAVs. Alongside smart technologies and the broader Internet of Things (IoT), improvements in vehicle sensors, augmented reality, and intelligent transportation networks will create the next generation of network architectures that benefit from synchronous growth (see, Figure 1).[11] Enhanced mobile broadband will support the growing data needs of CAVs, which are estimated to consume up to 10 terabytes of data per day.[12] CAV reliance on 5G-enhanced connectivity will be especially important as a more substantial number of automated vehicles come onto U.S. roads.

Figure 1: 5G's Technological Ecosystem



Source: SAFE rendering based on a concept diagram from the International Telecommunication Union.

The cumulative effect of these transformative technologies will improve the operational efficiency of the modern American transportation system and its safety, preventing accidents and saving lives. Some of the specific applications of 5G-enhanced mobile broadband include:

A Cellular Pathway to Vehicle Connectivity. Connectivity plays a key role in integrating individual vehicles into the broader transportation system and enables a shift to "mobility as a service."[13] Connected vehicle technologies also allow for real-time traffic updates, collision avoidance, and more efficient routing and fuel use.

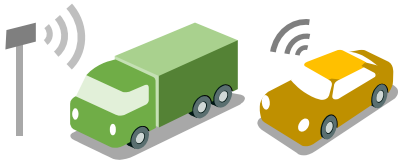
[7] Lawrence Burns et al., "Transforming Personal Mobility," The Earth Institute, January 27, 2013.
[8] Ibid.
[9] Note: The problem is much more significant than vehicle crashes alone: for every person killed in a motor vehicle crash in the United States, eight are hospitalized. See, Centers for Disease Control and Prevention, *Motor Vehicle Safety*, n.d.
[10] U.S. Department of Transportation, NHTSA, *Early Estimate of Motor Vehicle Traffic Fatalities for the First 9 Months (Jan-Sep) of 2018,* April 2019.
[11] See, e.g., Eryk Dutkiewicz, Xavier Costa-Perez, Istvan Z. Kovacs, and Markus Mueck, "Massive Machine-Type Communications," IEEE Communications Society, 3 (6), November/December 2017.
[12] Accenture Inc., *Autonomous Vehicles: The Race is On,* 2018, at 5.
[13] Sampo Heitanen, "Mobility as a Service – the new transport model?" Eurotransport, Volume 12, Issue 2, 2014.

Three prominent connected vehicle technology platforms are vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-pedestrian, collectively called V2X. V2X uses transponders installed in vehicles and key infrastructure to permit communication between elements of the transportation system, preventing crashes and allowing for more efficient traffic flow. Thus far, the development of these technologies has primarily focused on safety applications, such as alerting a driver to the presence of other cars at a blind intersection. Existing V2X pilots use Dedicated Short-Range Communications (DSRC), a wireless communications technology.[14]

V2X is based on short-range communication in the 5.9 GHz band (DSRC) and differs from other connected vehicle technologies due to its low "latency" or ability to exchange messages with very short lag time (several milliseconds). This feature positions V2X technology for important uses, such as preventing crashes, particularly those resulting from vehicles that are not in each other's direct line of sight, and vehicle platooning, which will improve fuel efficiency.

Figure 2: DSRC and C-V2X

Dedicated Short-Range Communications (DSRC): A wireless communication channel for vehicle safety that uses the 5.9 GHz spectrum to allow vehicles in intelligent transportation systems to communicate with other vehicles and roadside infrastructure.



Cellular Vehicle-to-Everything (C-V2X): A platform that provides connectivity through direct communications between vehicles, infrastructure, and pedestrians as well as mobile cellular networks.

In 1999, Congress set aside the 5.9 GHz spectrum band for DSRC. Developers have not yet deployed DSRC-capable vehicles at scale. Some automakers are urging Trump administration officials to support a 2016 National Highway Traffic Safety Administration proposal to equip passenger cars with onboard DSRC.[15] However, as mobile technology has advanced, other automakers and telecommunications companies have started looking at cellular vehicle-to-everything (C-V2X) networks as another avenue to facilitate vehicle communication.[16] DSRC opponents say mobile cellular connections give drivers a fuller picture of the overall highway environment and provide more direct communication over longer distances.[17] Supporters say DSRC networks are more reliable, proven, and mature – demonstrably important requirements to ensure automotive safety.[18]

The choice between DSRC and C-V2X can be an either/or proposition, although both can coexist and may be best suited for particular use cases. Regardless of whether automakers incorporate DSRC into new vehicles, mobile wireless broadband will ultimately become a major part of the connected and shared mobility revolution. Federal policy should be nimble as the market chooses between these two emerging and potentially complementary technologies.

[14] See, Department of Transportation, Intelligent Transportation Systems Joint Program Office, Connected Vehicle Pilot Deployment Program, New York City (NYC) DOT Pilot, Wyoming DOT Pilot, and Tampa (THEA) Pilot.
[15] See, e.g., Chester Dawson, "5G Race Pits Ford, BMW Against GM, Toyota," The Wall Street Journal, May 6, 2018.
[16] Paul Lewis, "Point/Counterpoint: 5G or DSRC for Connected Vehicle Technology," Eno Transportation Weekly, September 10, 2018.
[17] Jessica Nigro, "Cellular Vehicle-to-Everything ("C-V2X") Technology Will Deliver on the Promise of Safer Streets," Eno Transportation Weekly, September 10, 2018.
[18] Hilary Cain, "DSRC is Best Suited for Collision Avoidance and Other Safety Applications," Eno Transportation Weekly, September 10, 2018.

The Federal Communications Commission (FCC) continues to study whether the 5.9 GHz band can be safety shared between cellular, unlicensed WiFi, and vehicle safety applications. In 2016, the FCC released the results of a three-phase test that found unlicensed devices can safely share the 5.9 GHz spectrum.[19] However, in 2018, the FCC's Office of Engineering and Technology acknowledged: "We recognize there have been a number of developments since the three-phase test plan was announced in 2016—such as the introduction of new technologies for autonomous vehicles, the evolution of the Wi-Fi standards, the development of C-V2X technology, and the limited deployment of DSRC in discrete circumstances."[20] SAFE believes that as long as use of the 5.9 GHz spectrum continues to be developed for automotive applications, it should be preserved for its exclusive use unless there is conclusive evidence that it can be shared safely.

Improved Vehicle Data Processing. 5G-enhanced connectivity will help improve data processing capabilities for vehicles. With higher degrees of autonomy, the reduced latency of 5G can increase the viability of remote vehicle operation, which allows, for example, fleets to better control the real-time movements of medium- and heavy-duty trucks.[21] Automotive original equipment manufacturers (OEMs) are developing augmented reality displays, which can project real-time information like weather and mobile phone notifications onto a vehicle's windshield,[22] helping reduce distracted driving incidents. In place of time-consuming dealer visits, the widespread integration of over-the-air firmware updates can let OEMs tweak software the instant updates are released.[23]

Intelligent Transportation Systems. Intelligent Transportation Systems (ITS) integrate tremendous amounts of real time traffic information received from installed infrastructure. This enables vehicles to reroute and reduce travel times, moving vehicles efficiently through the transportation system rather than through the same bottlenecks.

5G can be a powerful tool to help cities manage existing urban transportation infrastructure more efficiently by providing real-time traffic management tools, like dynamic tolling and signal control.[24] Virtualization, or the segmentation of networks into private channels, can, for example, give cities and transportation officials high-definition and multi-perspective video access of virtually every traffic corridor—providing on-demand access to current and historical patterns. Well-informed policy responses that use this information may even help reduce the amount of fuel motorists use sitting in traffic, estimated to be more than 3 billion gallons every year.[25] In a related development for the transportation sector, 5G can support virtual reality applications, lowering the number of workers commuting to work by permitting telepresence and new video teleconferencing solutions.[26]

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[19] FCC, Office of Engineering and Technology—Laboratory Division, *U-NII-4-to-DSRC EMC Test and Measurement Plan: Phase I FCC Laboratory Results,* October 7, 2016.
[20] FCC, "FCC Requests Comment on 5.9 GHz Phase I Testing Data," October 29, 2018 at 2.
[21] Sriganesh Rao and Ramjee Prasad, "Impact of 5G Technologies on Smart City Implementation," Wireless Press Commons, 100, 2018, at 172.
[22] See, Hyundai Motor Company, Press Releases, "Hyundai & WayRay Unveil Next-generation Visual Technology at CES 2019," January 8, 2019.
[23] Bertel Schmitt, "Why Haven't Over-The-Air Updates Taken Over The Auto Industry?," The Drive, February 27, 2019.
[24] SAFE, *Congestion in America: A Growing Challenge to U.S. Energy Security,* January 2012.
[25] SAFE, *America's Workforce and the Self-Driving Future: Realizing Productivity Gains and Spurring Economic Growth,* June 2018 at 9; and Department of Energy, Vehicle Technologies Office, "Fuel Wasted in Traffic Congestion," November 5, 2015.
[26] See, e.g., Research and Markets, Press Releases, "Global Telepresence Robot Market Analysis and Forecast, 2018-2023: Ongoing Advancements in Hardware and Software Technologies & Advent of 5G Communication Services," March 20, 2019.

Enhanced Mapping and Wayfinding. Automakers are increasingly using onboard vehicle cameras and sensors to generate high-definition 3D maps of the built environment and monitor real-time road conditions. Compared to LTE, 5G will send a more substantial amount of data to cloud-based applications that can create finer distinctions in mapping and navigation services.[27] In combination with an extensive network of sensors on many vehicles on the road, these advances can improve the precision of geolocation services, helping lower operating costs for shared fleets and other transportation network companies like Uber and Lyft. Verizon has said its high-bandwidth network will, for example, improve the critical intelligence-gathering functions of first responders.[28]

5G Deployment Challenges in the United States

All four of the nation's facilities-based mobile operators—AT&T, Verizon, T-Mobile, and Sprint—have announced plans to expand 5G coverage to a nationwide network in the 2019- to 2024-timeframe.[29] In 2018, AT&T deployed 5G pilot demonstrations in 12 U.S. cities.[30] Verizon introduced 5G in Minneapolis and Chicago this year.[31] In each case, carriers have limited initial tests to a few commercial districts in mostly urban areas and, so far, connections are only available on a few enabled devices.[32] Early reviews of network speeds and coverage, however, have been less than enthusiastic. CNET's April 2019 test of Verizon's 5G network in Chicago, for example, found connections to be slow and patchy.[33] Verizon's network currently averages test speeds that are only a fraction of the 20 gigabytes per second industry standard with one millisecond of latency.[34]

Carriers will need to scale and densify networks to realize 5G's full potential. In recent proposed rulemakings, the FCC has recognized issues related to 5G network expansion and is now considering rules to alleviate impediments to deployment.[35] Challenges remain and include:

Level of Capital Investment. Small cells are cheaper to purchase and install on a per-unit basis than cellular towers,[36] but 5G networks require many more cells, which cumulatively represent a significant upfront cost. Accenture Strategy estimates telecom operators will spend as much as $275 billion deploying 5G networks through 2024.[37] This figure includes the costs of densification and higher-capacity backhaul—returning collected data from cells to the network. In addition to wireless solutions, fixed fiber optic networks will support increased system capacity at nationwide costs estimated by

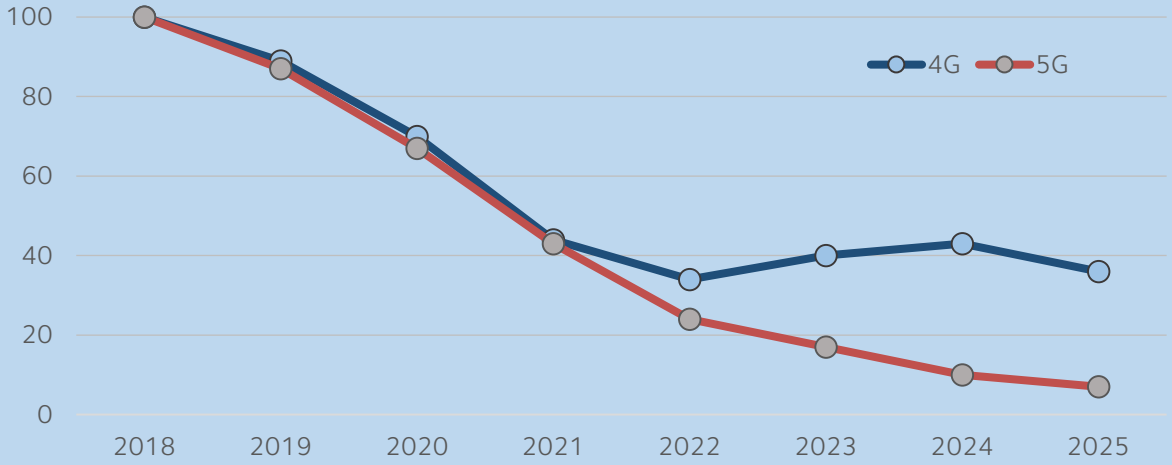
[27] See, e.g., CB Insights, "What Is 5G? Understanding the Next-Gen Wireless System Set to Enable Our Connected Future," January 23, 2019.
[28] Verizon Communications Inc., "How 5G will help first responders answer the call," May 6, 2018.
[29] See, e.g., Ericsson Inc., *Ericsson Mobility Report,* November 2018.
[30] AT&T Inc., Press Releases, "AT&T First to Make Mobile 5G Service Live in the U.S. on Dec. 21," December 18, 2018.
[31] Verizon Communications Inc., Press Releases, "Customers in Chicago and Minneapolis are first in the world to get 5G-enabled smartphones connected to a 5G network," April 3, 2019.
[32] See, e.g., Scott Moritz, "Verizon's First 5G Mobile Service Goes Live in Two U.S. Cities," Bloomberg, April 3, 2019; Scott Moritz and John J Edwards III, "Sprint Sets 5G Launch in Nine Cities as Competition Heats Up," Bloomberg, February 25, 2019; and Scott Moritz, "AT&T Adds Three More U.S. Cities to 5G Plans as It Races Verizon," Bloomberg, July 20, 2018.
[33] Jessica Dolcourt, "Testing Verizon's new 5G speeds exposed three major issues with the next-gen data network," CNET, April 6, 2019.
[34] Ron Amadeo, "Watch a Verizon 5G phone hit speeds faster than your home Internet," ArsTechnica, April 3, 2019; and Verizon Communications Inc., Press Releases, "Customers in Chicago and Minneapolis are First in the World to get 5G-Enabled Smartphones Connected to a 5G Network," April 3, 2019.
[35] FCC, "The FCC's 5G FAST Plan," n.d.
[36] See, e.g., 5G Americas/Small Cell Forum, *Small Cell Siting Challenges and Recommendations,* August 2018.
[37] Accenture Strategy, "Tackling the cost of a 5G build," August 3, 2018.

Estimating 5G's Economic Benefits

Smart technologies, IoT, and high-speed interconnectedness will unlock systemwide economies of scale and network efficiencies that far exceed these initial, high upfront costs. According to McKinsey, the economic value created by IoT will grow from $3.9 trillion to $11.1 trillion by 2025.[1] For mobile carriers, 5G will speed up data transfers and increase network capacity—freeing up available spectrum and increasing the revenue generated per user on a cost per megabyte basis.[2] In urban areas, small cell clustering will also let carriers densify coverage and virtualize—replacing expensive hardware with lower-cost software solutions.[3] As Figure 3 shows, by 2022, Boston Consulting Group estimates data delivered on 5G networks will cost half as much as 4G.[4]

For the United States, some studies have shown profound economic benefits: By 2030, Accenture estimates 5G and the Internet of Things (IoT) to add 3 million new jobs and generate an additional $500 billion in annual GDP.[5]

Figure 3: Indexed Cost per Gigabyte of Traffic on 4G and 5G Networks



Note: Chart shows 3-year moving average of network spending on 4G and 5G.

Source: Reconstruction based on Bloomberg visual and Boston Consulting Group data.

[1] McKinsey and Company, *The Internet of Things: Mapping the Value Beyond the Hype,* June 2015.
[2] Alex Webb, "Why 5G Will Arrive With a Whimper, Not a Bang," Bloomberg, March 1, 2019.
[3] Note: This is the definition of virtualization; see, e.g., William Lehr, *Future of Broadband Competition in a 5G World, August* 2018.
[4] Ibid.
[5] Accenture Inc., *Winning with the Industrial Internet of Things: How to Accelerate the Journey to Productivity and Growth,* 2015.

Deloitte to range from $130 to $150 billion through 2026.[38] Some estimates suggest the global expansion of 5G will cost more than $1 trillion by the end of 2020.[39]

New small cell installations account for the most substantial capital investment cost. Carriers will need to add three to 10 times the number of cells and base stations to make efficient use of the spectrum and accommodate new demand growth for 5G.[40] According to projections provided to SAFE from industry trade association 5G Americas, the average densification project in 2020 will involve approximately 100 to 350 cells per square kilometer in urban areas.[41] For comparison, 4G networks rely on the approximately 0.02 cellular towers per square kilometer in the contiguous United States—200,000 towers in total.[42] McKinsey estimates a smaller number of small sites for high-band spectrum, approximately 15 to 20 sites per square kilometer.[43] Although the deployment costs for expanding infrastructure are likely to be initially high, it is important to note that high costs will come down, especially as cities and states streamline approval processes.

In public comments, FCC Chairman Ajit Pai has said the market will primarily shoulder the costs of expanding 5G: "Although success will require a government-wide effort, we are pursuing a *market-based strategy* to promote 5G development and deployment. As the President said, "In the United States, our approach is private-sector driven and private-sector led."[44]

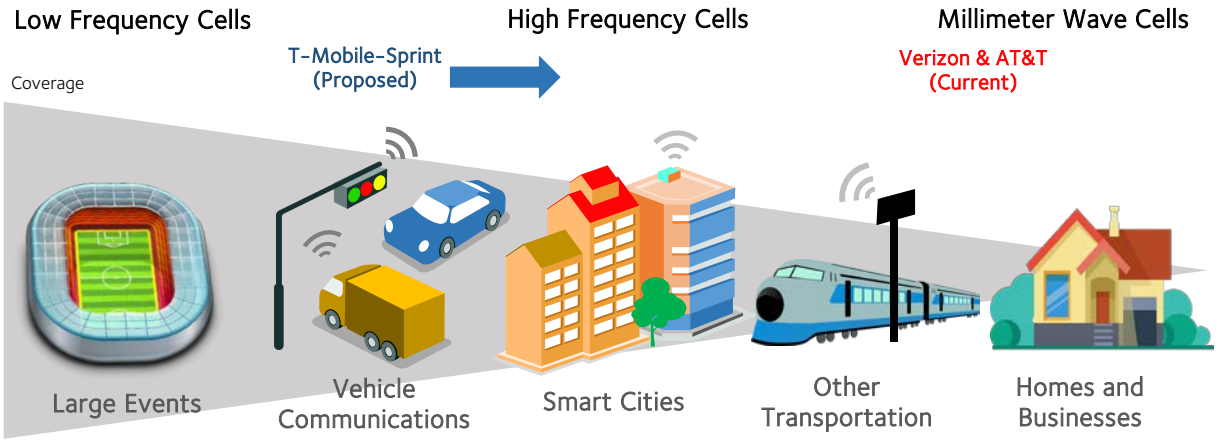
Spectrum Access. 5G requires reliable and consistent connections to be used in transportation applications. Physical structures in the built environment, however, can create barriers that obstruct signals from reaching enabled devices. Verizon and AT&T have deployed 5G in urban "hotspots" that send and receive signals within a small radius of a single cell. [45] These networks use millimeter wave spectrum bands to propagate ultra-fast connectivity, but the range is more limited. Verizon says its network can cover up to 800 feet around one location. Tests suggest the range may be as low as 300 feet.[46]

T-Mobile alternatively plans to expand its network using mostly mid-band spectrum, which would carry signals further and require less densification. Unlike millimeter band-based networks, mid-band networks can propagate coverage within a much wider radius of a single small cell, making it easier for moving vehicles to transmit and receive cellular signals. As shown in Figure 4, mid-band-based networks are best suited to transportation use cases and require less infrastructure while millimeter wave networks work best for homes and businesses.

The FCC is reviewing a proposed merger between T-Mobile and Sprint, which, if approved, would combine Sprint's 2.5 GHz spectrum with T-Mobile's existing 600 MHz band and financial assets.[47] A

[38] Deloitte LLP, *Deep Deployment of Fiber Optics is a National Imperative: The Success of 5G Wireless Will Hinge on Deep Fiber,* July 23, 2018.
[39] Greensill, *Financing the Future of 5G,* February 25, 2019.
[40] See, e.g., 5G Americas/Small Cell Forum, *Small Cell Siting Challenges and Recommendations, August* 2018.
[41] Ibid.
[42] Remarks of FCC Chairman Tom Wheeler as Prepared for Delivery, Competitive Carriers Association, September 20, 2016.
[43] McKinsey and Company, Inc., "Are you ready for 5G?," February 2018.
[44] Remarks of FCC Chairman Ajit Pai as Prepared for Delivery, National Spectrum Consortium, April 30, 2019.
[45] Verizon Communications Inc., "What is millimeter wave technology?," June 21, 2018.
[46] Sascha Segan, "Here's the Real Truth About Verizon's 5G Network," PC Magazine, April 8, 2019; and Walter Piecyk, "Is Millimeter Wave Spectrum The Key To Winning The Race To 5G? We Flew To Chicago To Find Out," BTIG, April 12, 2019.
[47] GSMA, *5G Spectrum: GSMA Public Policy Position,* November 2018 at 4.

Figure 4: Small Cell Use Cases and Current U.S. Deployments



Note: In addition to millimeter wave spectrum, the future transportation use cases of 5G require access to mid- and high-band spectrum in the U.S., like the networks proposed by T-Mobile and Sprint.

Source: SAFE analysis.

merged T-Mobile and Sprint could offer a scalable alternative to AT&T and Verizon's millimeter wave-based network that would differentiate the types of coverage available to consumers across mobile network operators. By extension, offering coverage at mid-band frequencies would provide a pathway for CAVs to connect to 5G networks across large geographic areas.

In November, the FCC auctioned 1.55 GHz of spectrum to be used by wireless providers for 5G connectivity.[48] The FCC is also planning a historic sale of 3.4 GHz for December 2019—the largest in American history.[49] While these auctions signal the FCC's commitment to incentivizing market participants to expand 5G connectivity, the announced plan is not bold enough to cover large segments of the nation.[50] The United States needs the full range of spectrum to enable a wider variety of use cases.

Infrastructure Policy. Regulatory requirements and long approval processes can slow the introduction of new wireless technology and erode the business case for installing small cells. Mobile carriers must gain site and equipment approvals, negotiate fees with cities and landlords, ensure cells have adequate backhaul and power, and conform to municipal aesthetic and environmental regulations.[51] Permitting approval processes for these tasks can take up to two years.[52]

Federal and state efforts aim to scale the application process to the growing number of proposed small cell sites. So far, over 20 states have passed laws streamlining site approval processes. In 2018, the FCC issued rules limiting per site fees and narrowing city approval times to 60 days for existing site upgrades and 90 days for new sites.[53] The FCC also issued a "one-touch, make-ready" rule requiring

[48] Michael Farrell, "FCC Readies Third 5G Spectrum Auction," April 16, 2019.
[49] FCC, "The FCC's 5G FAST Plan," n.d.
[50] See, e.g., Tom McKay, "Report: The FCC's Big Millimeter-Wave Auction Won't Help Speed Up 5G Rollout All That Much," Gizmodo, April 15, 2019.
[51] 5G Americas/Small Cell Forum, *Small Cell Siting Challenges and Recommendations,* August 2018.
[52] Ibid.
[53] FCC, *Declaratory Ruling and Third Report and Order, Accelerating Wireless Broadband Deployment by Removing Barriers to Infrastructure Investment,* September 27, 2018.

broadband providers to efficiently and safely prepare utility poles for 5G access.[54] Accenture reports that reforms like this will help reduce over $1.6 billion in regulatory costs, free up capital for up to 55,000 new cell sites and create 17,000 new jobs.[55]

Challenges to U.S. Leadership

China's government and telecommunications firms are aggressively pursuing the economic gains associated with 5G. In 2015, the government's Five-Year Plan identified 5G network development as a national priority.[56] Unlike in the United States, where mobile phone carriers competitively invest in new technological capabilities according to market signals and scale, China's approach is top-down: the government's plan pledges over $400 billion in 5G research and development through 2020.[57] In 2018, China completed the first phase of its trials and is now working toward commercialization.[58] The scale of China's investment puts it far ahead of the United States; according to Deloitte, since 2015, China has deployed nearly 12 5G-connected sites for every one deployed in the United States.[59] In total, China installed 350,000 small cell and base station sites, compared to fewer than 30,000 in the United States.[60] China is also planning a large-scale expansion of its fiber-optic network, to which it hopes will eventually connect up to 80 percent of homes in the country.[61]

Through its telecommunications giant Huawei Technologies Co., China is taking a leading role in issuing patents, identifying industrial use cases, and informing global equipment standards (see, Figure 5). Huawei is on pace to gain a substantial portion of the worldwide 5G market, having won at least 40 international contracts for its software, equipment, and services.[62] In the United States, regulators have banned Huawei's technology from being used domestically, citing intelligence community concerns that it is susceptible to cyber-espionage.[63] The threat of Chinese spyware infiltrating a tightly woven and global network telecommunications equipment is so serious that in February, Secretary of State Mike Pompeo threatened to cut military and diplomatic ties with countries that purchase its equipment.[64] Huawei's patents have also concerned U.S. federal prosecutors, who in January opened a criminal investigation for intellectual property theft.[65]

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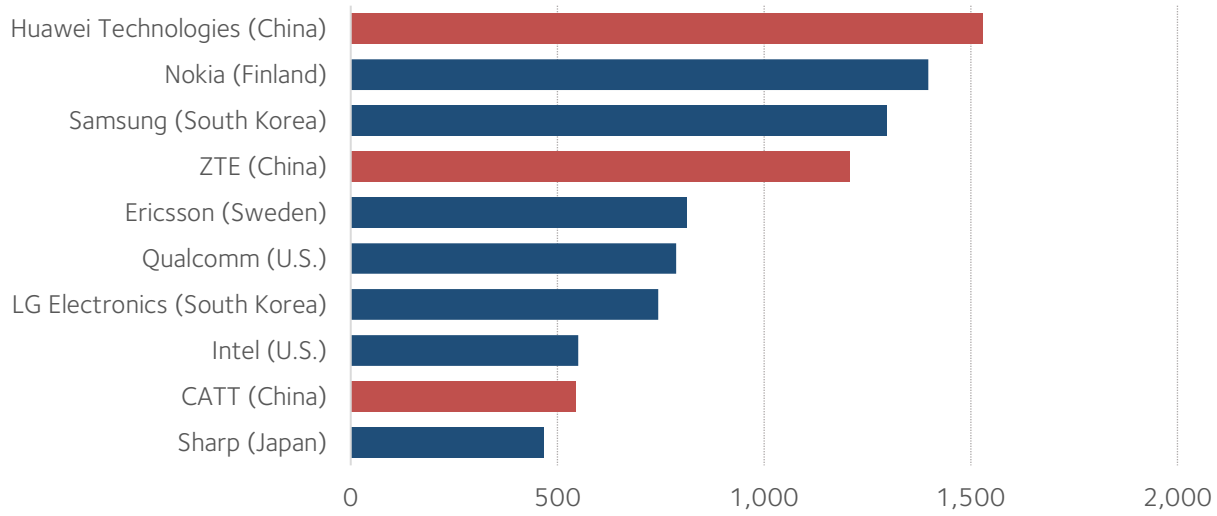
[54] FCC, Press Releases, "FCC Speeds Access to Utility Poles to Promote Broadband, 5G Deployment," August 2, 2018.
[55] Accenture Inc., *Impact of Federal Regulatory Reviews on Small Cell Deployment,* March 12, 2018.
[56] Central Committee of the Communist Party of China, *The 13th Five-Year Plan for Economic and Social Development of the Peoples' Republic of China 2016-2020,* 2015.
[57] See, e.g., Deloitte LLP, *5G: The Chance to Lead for a Decade,* August 2018; and Susan Crawford, "China Will Likely Corner the 5G Market – and the U.S. Has No Plan," Wired, February 2, 2019.
[58] Huawei Technologies Co. Ltd., Press Releases, "Huawei Takes the Lead in Completing China 5G Technology R&D Trial using 2.6GHz Spectrum," January 17, 2019; and Juan Pedro Tomas, "Huawei completes third phase of China's national 5G trial," RCR Wireless News, January 21, 2019.
[59] Note: Deloitte's estimates are based on company financials for wireless communication infrastructure related to 5G. Deloitte's August 2018 report estimates fewer than 30,000 sites in the United States. In March 2018, Accenture estimated there to be a 138,000 small cell sites at the end of 2018—a much higher number than Deloitte. See, Deloitte LLP, *5G: The Chance to Lead for a Decade,* August 2018; and Accenture Inc., *Impact of Federal Regulatory Reviews on Small Cell Deployment,* March 12, 2018.
[60] Ibid.
[61] Note: Citing Rethink Technology Research with an unclear time horizon. Susan Crawford, "China will Likely Corner the 5G Market—And the U.S. Has No Plan," Wired, February 20, 2019.
[62] Sija Jiang, "Huawei says not discussed 5G chipsets with Apple, wins more telco gear contracts," Reuters, April 15, 2019.
[63] Stu Woo and Kate O'Keeffe, "Washington Asks Allies to Drop Huawei," The Wall Street Journal, November 23, 2018.
[64] Alex Scroxton, "US may cut off countries that use Huawei in 5G networks," ComputerWorld, February 22, 2019.
[65] Katie Benner, Paul Mozur and Raymond Zhong, "Huawei Said to Be Under U.S. Investigation in Trade-Secrets Case," The New York Times, January 16, 2019.

Figure 5: Number of 5G Standards Proposed as of December 12



Source: Dan Strumpf, "Where China Dominates in 5G Technology," The Wall Street Journal, Feb 26, 2019.

Concerns over Huawei fit into the intelligence community's broader alarm about China's emergence as a leading information and telecommunications superpower. Nine of the world's 20 largest technology companies are from China,[66] including Huawei, the world's largest producer of telecommunications equipment. By 2020, Huawei is expected to outpace Apple Inc. in smartphone production and become the world's leading manufacturer.[67] As the Center for Strategic and International Studies' James Lewis testified to the U.S. Trade Representative in 2017, the fundamental issue for the United States is how to respond to a managed economy with a well-financed strategy to create an industry intent on displacing foreign suppliers.[68]

Ensuring American Competitiveness

> *"The race to 5G is a race that America must win. It's a race that we will win,"*
> *– President Donald J. Trump, April 12, 2019.*

The only way to ensure American leadership in the global 5G race is to ensure there is a competitive mobile carrier market at home. Access to the spectrum is of paramount importance. In February, the President warned, "American companies must step up their efforts, or get left behind."[69] Two months later, in April, the FCC and the White House announced the government would auction high-frequency spectrum bands for 5G deployment.[70] The administration plans a $20.4 billion Rural Digital Opportunity Fund to connect more than four million U.S. households over the next decade—a particularly important investment that will help ensure the United States has reliable and consistent nationwide coverage.

These announcements signal the seriousness with which the U.S. government considers 5G deployment. Streamlining approvals and getting more spectrum in the hands of carriers are undoubtedly important steps forward. Yet, ensuring global leadership will require a continued,

[66] Sally French, "China Has 9 of the World's 20 Biggest Tech Companies," MarketWatch, May 31, 2018.
[67] Arjun Kharpal, "After overtaking Apple in smartphones, Huawei is aiming for No. 1 by 2020," CNBC, November 15, 2018.
[68] James Lewis, *Section 301 Hearing 6,* September 27, 2017.
[69] Twitter.com, Post by @realDonaldTrump, February 21, 2019.
[70] Todd Shields, "5G Airwaves Coming to Market in Broadest Sale Yet, FCC Says," Bloomberg, April 12, 2019.

comprehensive approach. Already the administration plans to develop a national spectrum strategy that would serve the national interest.[71] Such a spectrum strategy should consider how to capably expand 5G beyond urban centers by evaluating the issues of spectrum access and competition.

Spectrum Access. 5G in sub-1 GHz and mid-bands will be needed to extend mobile broadband coverage across larger geographic areas—important requirements to ensure connected vehicles have a C-V2X pathway. As noted, early 5G deployments in the United States, however, have used the millimeter wave spectrum. In a positive development, the FCC has proposed flexible use of the 3.7 to 4.2 GHz mid-band.[72] Thirty-five countries plan to use mid-band spectrum for 5G, including China and the European Union, which each plan to use the 3.3 to 3.6 GHz and 3.4 to 3.8 GHz bands for 5G, respectively.[73] The United States should continue to evaluate current spectrum allocations to ensure they are in line with current commercial interest.

Competition. The expansion of 5G networks in the United States requires market players who can capably invest resources in deployment activities. In cities and urban environments, concentrations of millimeter wave spectrum like those being deployed by Verizon will help consumers gain access to ultra-high-speed, ultra-low latency mobile broadband for home or business needs. While these networks serve some important use cases, the millimeter wave spectrum band's inferior propagation characteristics make it cost-prohibitive to deploy a truly ubiquitous 5G network. Verizon has acknowledged millimeter wave coverage will not reach rural areas.[74]

Notably, neither Sprint nor T-Mobile have the means to quickly move on 5G. A combined Sprint and T-Mobile that has the resources to expeditiously deploy a nationwide 5G network will force the other carriers to transition their own 4G networks to 5G—creating better outcomes for consumers and the state of technology in the U.S. In short, a market with three mobile carriers that possess the capacity to advance 5G instead of just two will hasten the development and deployment of next-generation mobile networks.

The U.S. telecommunication and transportation sectors are in a period of remarkable technological transition. 5G's enhanced mobile broadband will not only deliver ultra-fast connectivity, but also increased reliability—filling in the holes of current cellular networks with profound interconnectedness. It is imperative that policymakers at every level of government maximize the economic value of this opportunity and ensure access to 5G is available in urban, suburban and rural areas. 5G will enable the U.S. transportation sector to move people and freight with greater efficiency—but only if it is deployed widely. It is therefore crucial that the United States not only develop this technology to keep pace with its international rivals, but also to improve safety and boost economic productivity. Through accelerated deployment of 5G networks, the United States can prove once again that proactive public policy and innovative private investment can develop a transportation system that works in the national interest.

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[71] The White House, Press Releases, "Presidential Memorandum on Developing a Sustainable Spectrum Strategy for America's Future," October 25, 2018.
[72] FCC, *FCC Expands Flexible Use of Mid-band Spectrum,* July 13, 2018.
[73][73] Gary Lerude, "GSA Tallies Worldwide 5G Spectrum," GSA, January 23, 2018; and Qualcomm Technologies Inc. "Spectrum for 4G and 5G," December 2017.
[74] See, e.g., Jon Brodkin, "Millimeter-wave 5G will never scale beyond dense urban areas, T-Mobile," ArsTechnica, April 22, 2019.