Berkeley
UNIVERSITY OF CALIFORNIA

BERKELEY ROUNDTABLE ON
THE INTERNATIONAL ECONOMY

BRIE / WITS
Technology Briefing #1

August 2019

5G: Revolution or Hype?

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Acknowledgements: This research was funded in part by the Ewing Marion Kauffman Foundation. The contents of this publication are solely the responsibility of the authors. Many others made significant contributions, including Alberto Sangiovanni-Vincentelli, David Lindeman, Jacob Kirkegaard, Barry Lynn, Michael Borrus, Jeff Thermond, Jane Macfarlane, Brandie Nonnecke, Phil Kaminsky, and Bruce Pickering.

5G: Revolution or Hype?

Preamble

Much of the discourse around 5G suggests that 5G networks in and of themselves will somehow unlock all sorts of value by enabling radically improved connectivity. Yet, the underlying questions not given enough attention are: *who* is likely to capture value from the vastly faster connectivity, and *how* will that value be captured?

Will the builders of 5G networks—network operators—somehow benefit from offering much faster but far costlier networks? Will 5G strengthen the already-strong position of incumbent global cloud computing providers Amazon, Alphabet, and Microsoft? Does 5G provide dramatically new opportunities for new entrants or drive a paradigm shift of the sorts we saw with the advent of the Internet, and if so, how might this play out? Is China advantaged decisively in a world of 5G, and if so, how? What are the potential roles of government?

Introduction

Is 5G revolutionary? Will the "fifth generation" of wireless technology not only update our network from 4G, but spark deep and widespread change across economies, industries, and the lives of consumers? 5G hype certainly abounds. Examine any number of industry reports on 5G, and you will find a cover design meant to evoke the wonder of technological progress: abstracted images of superhighways, circuitry, or globe-spanning networks.[1] Words like "transformation" and "revolution" are common.[2] And 5G has become a prominent feature in marketing campaigns by the wireless industry around the world, each seeking to outdo the rest in being seen as delivering innovative breakthroughs to consumers.[3]

5G hype has a solid theoretical foundation. Devices connected to the right kind of 5G signal can download data orders of magnitude faster than with 4G, enabling the beaming of high-quality video, three-dimensional, and augmented reality media to every device in a crowded area. 5G-connected devices can likewise enjoy latency reduced by an order of magnitude compared with 4G, permitting instantaneous communication among autonomous vehicles, industrial robots, and other objects moving with high levels of speed and precision. And 5G can permit millions of devices to connect to the internet within a small geographic area.

The list of potential applications for these capabilities is endless, and ranges from urban infrastructure management to manufacturing to entertainment. Mobile augmented reality could step beyond gaming, making marketing messages or walking directions appear to consumers wearing digitized eyewear.[4] Bioelectronic implants one day could send and receive mission-critical signals to and from medical professionals.[5] Patients could undergo surgery performed by robotic arms under the control of doctors far away.[6] "5G is the platform for tomorrow's economy," Meredith Attwell Baker, CEO and president of the CTIA, a trade association

representing the US wireless communications industry, recently told CNN. "It's going to transform everything from education to AI to medicine."[7] Considering the performance 5G can technically achieve, this could be an understatement. If developed and deployed, together these applications could unleash broad increases in productivity.

But the theory of 5G is difficult to put into practice. Despite the drumbeat of hype, it is not clear how quickly 5G will be deployed. Just as unclear is how transformative 5G will be when it does arrive. This paper will explore the promises and limitations of 5G through the lens of four critical issues: first, the question of how network operators will build 5G, if they do build it; second, ways that governments can use policy to make sure 5G networks get built; third, 5G's potential impact on network architectures and competition among computing infrastructure providers. Finally, this paper will explore 5G's role in the rise of China, international competition, and related debates over network security.

1) Can network operators build 5G?

5G is not a single piece of technology that network operators can simply install tomorrow on your local tower. 5G is a group of technologies that will arrive in two big steps. The first wave of deployments of 5G, which have received headline attention this year, will be built on attachments to existing 4G "macrocell" equipment, and will broadcast over relatively low frequencies. These early deployments will primarily serve growing demand for high-bandwidth broadband services like video streaming.[8]

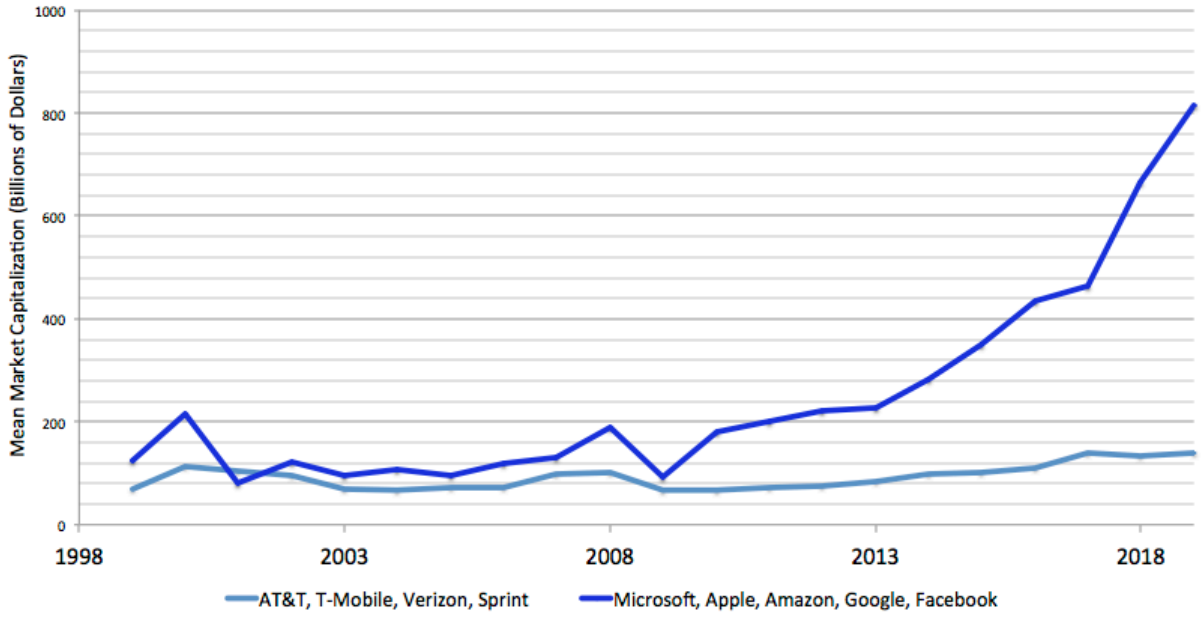
Only signals broadcasting at higher frequencies of six gigahertz and above can provide the high speed and responsiveness necessary to support the most transformative 5G applications. The challenge of building 5G stems from the fact that these above six gigahertz signals can only travel very short distances. Reports from the field suggest that they are easily obscured by interference from sources as ubiquitous as tree branches and bad weather. This means that to achieve 5G coverage in a high-density area, broadcasting "microcells" must be placed every few hundred meters from one another. Building this physical infrastructure will be extraordinarily expensive; estimates place the cost at approximately four to six times that of building 4G.[9] Moreover, wireless companies stand to see little return on building microcells, as most 5G use cases are unlikely to generate large incremental revenues for operators.[10] What returns they do see will take a long time, as most of these use cases are years away from being ready for deployment.

Recent history should not make network operators eager to take on massive upfront investments. When 4G was built, it was a commodity. Network service quality and cost were very similar regardless of who provided it, and operators competed more on price than added value. In contrast to network service offerings, the products and services that 4G enabled came in a large variety and kept customers close with rich, engaging user experiences. As these products and services evolved and offered increasing value to customers, revenues and

valuations of firms that built them skyrocketed. Meanwhile, network operators could only offer customers cheaper deals on unlimited data.

Figure 1 below shows the mean market values of the largest network operators and digital "platform" companies who built differentiated products and services during the time period when 3G and 4G networks were rolled out. Despite building the physical networks, operators and other physical infrastructure providers saw their values increase only incrementally; meanwhile, it is platforms who have seen their values soar. [11] For example, in 2007 Apple was valued at $72.9 billion, while Verizon's market capitalization was $117.5 billlion. By 2019, Apple's market capitalization was $860.88 billion; Verizon's was only $215.9 billion, despite having built the largest share of the 4G network of the four major US network operators.[12] The connectivity operators had built gave them no way to capture a slice of the massive value creation it enabled.

Figure 1: Historical Market Value of Key Platform and Infrastructure Firms



The very high initial cost, low guarantee of return, and slow pace of returns that do materialize make it unlikely that network operators will again build a pipe of connectivity for applications developers to use and capture all the value from. How, then, can operators build 5G?

To begin, network operators could use 5G to expand their existing Fixed Wireless Access (FWA) lines of business. Under FWA, homes or businesses use a wireless signal as their primary source of internet access. Up until today, FWA has primarily been useful in areas without broadband.[13] But 5G is fast enough to make wireless a viable alternative to wired broadband, especially in areas without fiber, and AT&T and Verizon are planning to expand

their FWA offerings as 5G networks are rolled out.[14] However, it is unclear whether FWA alone can provide revenue to justify the building of high-frequency 5G coverage.

In addition, network operators can share costs with each other. According to McKinsey, if three operators agree to share equipment in a densely populated area, the cost of building a small cell network can be reduced by more than 40 percent.[15] With the potential for such savings, network sharing will likely be part of the mix for any high-frequency 5G network. At the same time, this raises an important question: if operators are sharing networks, on what basis do they compete?

Another option for operators is to "de-commoditize" and begin offering differentiated services to companies building 5G applications. One of the easiest ways to do this is through network slicing, a technical capability allowing carriers to reserve segments of frequency for users.[16] While most 4G applications can endure a lapse in coverage, many applications that will use 5G are "mission critical," requiring guaranteed levels of bandwidth and latency. Such applications include remote medical device monitoring or inter-vehicle communication among autonomous cars. Operators could charge a premium to firms building and selling these applications for exclusive and/or prioritized access to a slice of the spectrum for a specific time. Operators could also build engaging product features around the provisioning of slices to add more value for network users. Beyond slicing, operators could even build other service offerings likely to be needed by 5G applications, such as potential new computing infrastructure needs explored in section 3.

If operators could be sure in advance that slicing or other service offerings would help them claw back some value from platforms, they might be more likely to make the upfront investment to build 5G networks. But revenue from new services would still be delayed until after a comprehensive 5G network is built, and it is impossible to guarantee that these revenues will be sufficient to help operators recoup their costs.

There are a variety of tools network operators could employ to make a stronger return on building 5G than past wireless transitions. But even taken together, all of the above strategies may not be enough to justify building a dense 5G network. Moreover, many strategies may not come naturally to wireless operators; sharing would demand cooperation from long standing competitors, and building new services lies outside many carriers' domains of expertise. Given these challenges, some of the people spoken to for this paper wondered what strain the need to build 5G will place on the functioning and financing of major network operators in the US and around the world.

2) What is the role of government in building 5G?

Private industry may not be able to build 5G networks on their own. Building robust 5G networks may require a more active government role than past wireless transitions. Across the world, governments are starting to play this role in three primary ways.

The first is by facilitating cost sharing and network slicing; the best example of this taking place is in China. In 2017, China's leading internet platforms Baidu, Tencent, Alibaba, Didi Chuxing, and JD.com all took equity stakes in state-controlled operator China Unicom amounting to $12 billion; this could be seen as a downpayment on 5G from the platforms that stand to gain the most from resulting innovations.[17] As of 2018, Beijing was considering merging China Telecom and China Unicom to help ease the burden of 5G deployment for the smaller two of its three dominant mobile operators.[18] In addition, China Unicom has put in place an R&D agreement with Huawei for testing network slicing for applications that may need it the most, including virtual and augmented reality, vehicle autonomy, gaming, and smart manufacturing.[19] Such early collaboration might be critical for convincing network operators that network slicing will make 5G worthwhile, and governments can help make matches between operators and developers.

The second is by becoming a major user of 5G. Such a state role in the US may be presaged by the First Responder Network Authority (FirstNet), a public-private partnership between the US government and AT&T.[20] Initially recommended by the 9/11 Commission Report, FirstNet guarantees priority access to specific slices of spectrum for first responders covering 95 percent of the US population.[21] Other use cases with an urgent public interest for which the government is a guaranteed customer could provide operators a better return on 5G investments.

Third, government could directly subsidize a 5G network, as Mexico is doing through the Red Compartida program. Under Red Compartida, the national government is providing spectrum and fiber cables to a consortium of private investors.[22] The consortium can only sell network access to firms, not consumers; buyers can include both network operators and direct users.[23] Under this wholesale model, smaller network operators can create offerings, and the total projected cost of building the network is massively reduced. If the plan is executed well and uptake is strong, Mexico could reap economic benefits from a novel strategy. And in the United States, a similar model has held appeal, both among progressives, and for a short period, within President Trump's re-election campaign.[24] However, it is too early to declare victory for wholesale; none of Mexico's three largest mobile operators have so far purchased bandwidth in the Red Compartida's 4G spectrum, and the financial soundness of the world's first wholesale 5G network remains to be seen.

Cost sharing, network slicing, government use, and government subsidies would have cascading effects in other domains, from competition policy to the nature of applications that are deployed. Cost sharing could run afoul of regulators in countries that are especially worried about protecting consumers from industry coordination; where it takes place, cost sharing could change the competitive landscape among operators, with the possibility of some carriers partnering together while excluding others. Network slicing could likewise run into regulatory trouble, as some claim it runs afoul of the principles of net neutrality. Indeed, for applications that require guaranteed service levels either for testing or to achieve scale, there is a risk that large industry players will pay a premium for all available slices, boxing out startups from these application spaces. At the same time, network slicing might be required for these applications to

be developed at all. Policymakers must balance these competing forces with desired outcomes as they plan their 5G strategies.

3) Could 5G disrupt Amazon, Microsoft, and Google's dominance of computing?

For most of the last decade, data has been managed under the cloud network model, where information is stored and processed in large, centralized facilities and delivered remotely to devices. Amazon, Microsoft, and Google have been the dominant providers of cloud computing services.[25] But in recent years, the "edge" network model, where data and processing are located in a more distributed fashion and closer to end users than traditional data centers, has risen in prominence. As the early stages of 5G deployment approach, it remains to be seen how 5G will change network architectures. Changes could either entrench the position of cloud heavyweights, or redistribute value in the computing services industry to other players.

First to consider is 5G's impact on network architectures. Will 5G push networks to evolve more towards an edge model, or solidify cloud computing as the preeminent network architecture? On one side of this debate are those who believe 5G's large bandwidth will reverse trends toward edge computing and pull more data back to the cloud.[26] This could prove true in the near future if demand for high-quality video streams continues to drive growth in mobile broadband traffic, and if operators can build and connect enough fiber optic cabling to macrocell sites to carry data back and forth from centralized cloud facilities. On the opposite side of the debate are those who argue that the need for low latency will accelerate the move to the edge, with applications that need lightning-fast responses demanding computing and storage as close to devices as possible.[27] This circumstance could be more likely if operators cannot connect sufficient fiber backhaul to base stations.

And where, in a 5G world, does the "edge" of the network lie? One or more varieties of edge computing may become preeminent depending on which 5G applications are most in demand. In some cases, the edge could be located closer to devices than under a cloud model but still in a remote facility. But this may not offer low enough latency for some 5G use cases; many Internet of Things (IoT) applications may need response times that require computing to be located at the 5G cell they are connecting to. And still other applications, especially vehicle autonomy, may need to process data so quickly that their computing machinery must be located on the device itself.

The location of computing resources within 5G networks will create winners and losers. If 5G favors the cloud model, it would most likely solidify the preeminence of Amazon, Google, and Microsoft as computing providers. In cases where computing is located on devices, whoever can manufacturer the smallest, most powerful chips will probably capture new market value. Who wins is more uncertain, however, if computing is done at the 5G base station. There is no clear favorite should a need for such a new, distributed computing platform become clear. It is possible that cloud heavyweights, who already have significant edge computing offerings, could step in to build computing and storage attached to 5G broadcast cells. It could be new market

entrants such as Cloudflare, which has relevant experience providing distributed computing services. Or it could be network operators, either working in tandem with one of the above, or perhaps less likely, building their own computing services offerings, as mentioned in section 1. Overall, it remains to be seen whether 5G will lead to the creation of new computing platforms or shore up the position of existing ones.

4) Will China be the global leader in 5G? Does it matter?

This is the question that looms over most debates about 5G's impact on geopolitics. Chinese companies have raced to the top of certain key 5G technology markets, and the Chinese government has publicized an aggressive 5G deployment timeline. It is possible that China could leverage these advantages into leadership in the next generation of information and communications technologies (ICT), up the stack from chips and devices to applications and platforms. At the same time, China's dominance of 5G is far from assured, and there is no guarantee that 5G leadership will translate into dominance of the coming era of digital technology. This section will explore China's progress in 5G from three perspectives: competition over networking equipment, the relevance of having a head start on 5G applications, and network security.

China has established leadership in networking equipment, where recent estimates give Huawei a 28 percent share of the global market. [28] In addition, according to data from the German firm IPlytics, Huawei has the most 5G standard essential patents of any company in the world at 1,529, trailed by Nokia at 1,397.[29] If China continues to set foundational technical standards for 5G, it will be in a strong position to build an ecosystem of leading manufacturers and developers throughout the 5G stack. However, Western firms maintain a slight advantage when it comes to chips and underlying technology, and China's platforms and applications have yet to achieve lasting, widespread adoption internationally.[30]

China may also have the opportunity to seize a global lead in applications that use 5G. China has indeed planned a rollout of 5G five years earlier than any country in the world.[31] However, recent reports that Huawei has not been granted a single domestic 5G contract call those plans into question.[32] Nonetheless, if China does indeed get a five-year head start, it would have more time to test and perfect applications that need 5G, and be the first to market with game-changing applications such as autonomous vehicles or social gaming platforms that use augmented reality. If these applications are exportable – and the recent history of TikTok, a Chinese app and the US' fastest-growing social media network in 2018, shows that they might be – 5G might indeed help China dislodge Western firms as the global leaders in platforms and software services.[33] But it is also possible that Chinese entrepreneurs will fail to capitalize on early access to 5G, or that the applications they develop will not be exportable due to a clash of values with their target markets, or other political, regulatory, or security reasons. The US' recent forcing of the sale of the geosocial dating application Grindr by its Chinese acquisitor shows how resistant to China certain app markets may be.[34]

Whether or not such resistance is fair is the primary question in the controversy over Huawei that forms a major part of coverage of 5G by mass media. It is through Huawei that 5G is cast as a critical determinant of the global pecking order over the coming decades.[35] Is Huawei in fact, as the US and a few of its allies claim, a security risk, willful or otherwise? It is through Huawei that the security impact of China's leadership in 5G can be explored.

There are two kinds of security vulnerabilities to which Huawei is accused of contributing. The first is the overall vulnerability to cyberattack by which all digital systems are threatened. In a series of recent tests, Huawei's networking equipment was found to have significant gaps in security that could be exploited by hackers.[36] A damning report by the UK National Cyber Security Centre found that Huawei has made "no material progress" in addressing vulnerabilities that were discovered in 2018.[37]

The second kind of vulnerability is spying by the Chinese state. This vulnerability is the subject of a more extreme suspicion, put forward by the Trump administration, that Huawei has improperly close ties to the Chinese military and Communist Party, and has intentionally built "backdoors" that would allow the Chinese government to access communications and devices that use networks built with Huawei equipment.[38] Supporters of this theory further note that Chinese law requires all Chinese companies to assist the state in intelligence activities if asked.[39] This would seem to represent a significant security risk to countries that are already using Huawei as a backbone for nascent 5G networks, such as Mexico and Germany. It is based on this claim that President Trump recently issued an executive order prohibiting US firms from doing business with Huawei. While the President recently issued comments that cast the future of this order in doubt, for now Commerce Department rules prohibiting US firms from selling to Huawei remain in force, reflecting the US government's ongoing concern about the integrity of Huawei's equipment.[40]

But as some experts have pointed out, installing backdoors in equipment used by foreign powers is squarely against Huawei's business interest.[41] The first confirmed discovery of a backdoor could destroy Huawei's international reputation and threaten its market leadership. China's leaders could see a trusted brand with a dominant global market position as more in line with national interest than intelligence gathering. Furthermore, the mere existence of vulnerabilities in network equipment is not unique to Huawei.[42] With small cells every few hundred meters and massive deployments of connected devices, a fully deployed 5G network will turn every populated area into a forest of access points, any one of which a pirate might attempt to use for eavesdropping, theft, or remote device control.[43] How to respond to this expansion of the "attack surface" – whether by installing an internet "off switch," or something less heavy-handed – should be of primary concern to policymakers in countries that are pushing hard for 5G leadership.[44]

Indeed, Western nations on guard against Huawei may simply be acting on protectionist impulses. And while some of this reaction may be seeking to prevent what they see as a threat to their dominance of the digital economy beyond their borders, it is also understandable. To be dependent on a rival power for critical infrastructure would be an undesirable weakness. As

Huawei presses its advantage, it would make sense for Western governments to consider steps to ensure they have access to multiple suppliers for networking equipment. Among these steps could be to bolster friendly suppliers, such as Nokia and Ericsson.

But paradoxically, protections against Huawei could catalyze the rise of Chinese platforms and applications to global prominence. Soon after the executive order was issued, Google announced that it was cutting off access to Android updates and several Google services on Huawei phones.[45] In response, Huawei will likely build and deploy its own smartphone operating system, creating a new Android competitor in the global market. This new OS could prioritize other search engines and services beyond what Google offers; as Huawei is one of the fastest-growing smartphone shippers in Europe, this could potentially damage American dominance of global internet services. The most extreme scenarios may not unfold, but policymakers must consider a range of potential outcomes as competition over 5G technology heats up.

Conclusion

Will 5G be like the transition from 3G to 4G – enabling new uses of mobile technology, but failing to transform the economic landscape? Or will it be like the transition from pre-internet to post-internet? It is too early to say. Certainly, it will be at least several years before a full-fledged, high-frequency 5G network is built; who builds it, and how, is unclear. Once it does arrive, its impact on industrial and international competition remains to be seen. But in asking the right questions, stakeholders can understand 5G's possibilities and limitations, and begin to shape a positive future.

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