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The Infrastructures of Global Connectivity: 5G Networks

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Executive Summary

The fifth generation of cellular networks (5G) will provide societies with much faster connection speeds than existing 3G/4G networks. 5G is also expected to enable new forms of interconnectivity such as machine-to-machine communication, which can then power the Internet of Things (IoT), or the transformation of numerous industries, amongst others.

Although the infrastructure of networks has traditionally been divided into the "core" and "RAN" (or edge) components, this distinction is increasingly blurred in 5G networks with the amalgamation of the core's functions into the RAN. The amount of supporting infrastructure required for the rollout of 5G networks will also drastically increase. Additionally, given the economic and connectivity benefits that 5G can also offer, numerous countries are keen to become early adopters and implementors of 5G technology and networks.

All of these concerns have led to a range of policy considerations that decision-makers must properly account for. Taking place against the backdrop of great power competition, such policy considerations extend beyond widely-known concerns of infrastructure integrity and network resilience to include questions revolving around global standards-setting influence and gaining strategic advantage.

What is 5G?

The term 5G refers to the fifth generation of (technology standards for) mobile/cellular networks. This new generation of networks will have greater bandwidth[1], allowing for faster download speeds than currently possible on existing 3G/4G networks. 5G networks will also be able to handle a much greater number of concurrent connections and allow even more devices to be connected. 5G is therefore poised to usher in a new age of connectivity and enable the Internet of Things (IoT), where multiple devices and appliances (e.g., smart fridges, fitness trackers, autonomous vehicles) connect to each other to communicate and exchange data—also known as machine-to-machine communication. Additionally, the low latency (delay time between user input and actual action) of 5G networks allows for critical machinery to be remotely operated with virtually zero delays, such as in telesurgery.[2]

The Infrastructure of 5G Networks

The main components of mobile networks are the **core network** ("core") and the **radio access network** ("RAN").[3]

In simple terms, the core generally functions as the physical infrastructure where most of the network data is stored, routed, and processed from a centralized location. In contrast, the RAN consists of the cell towers and other systems that connect end-user and other devices to the main core network.

For current 3G/4G mobile networks, the core and RAN are often located in different geographical locations with a few regional core networks supporting numerous RAN localities. This is done to optimize network coverage and performance.

1 Bandwidth refers to the amount of data that can be transferred per second, i.e., the size of the pipe.

2 https://www.ericsson.com/en/5g/use-cases/critical-control-of-remote-devices

3 http://www.emfexplained.info/?ID=25916

5G Infrastructure: Core vs "Edge"

5G is expected to utilize **mobile edge computing** ("MEC"). MEC refers to shifting some of the processing and storage of network data away from the core and closer to the RAN. This reduces the latency (delay time between user input and actual action) of the network.

However, one implication of this shift is the blurring of the distinction between the core and RAN. The distinction is also further compounded by the fact that most network functions no longer require physical hardware and can be done via software applications instead, a concept known as network function virtualization, or **NFV** in short.

All of the above blurs the traditional boundaries that previously existed within mobile networks. Although there still remains a distinction between the core and the RAN, the amalgamation of some core functions into the RAN mean that what was previously non-sensitive RAN equipment and infrastructure could now affect the well-being of the entire network.[4] This changes the network security outlook and has resulted in the whole "**core vs. edge**" discussion that is currently taking place.

5G Infrastructure: Small Cells

One new technology that 5G networks utilize is the ultra-high frequency radio wave, also known as millimeter wave (or "**mmWave**")—referring to the high bands (24.25GHz to 86GHz range) of the radio frequency spectrum. This was agreed upon by member states of the International Telecommunications Union (ITU) at the 2019 World Radiocommunication Conference (WRC-19).

Using mmWaves also allow for **multi-connectivity**, referring to a vast number of simultaneous user connections (up to 1 million user or device connections per square mile). However, one drawback is that high-frequency waves cannot be propagated over large distances and are prone to **blockage-induced signal attenuation** (i.e., physical objects such as trees, walls, human bodies weaken the signal).[5] The implication of this is that mobile carriers will need hundreds or thousands of "small cells" as part of their 5G network deployment.[6] The small cells are capable of handling the load requirements of areas with a high population density, such as cities or sporting arenas and are situated at the RAN, or "edge" of the network.

4 https://www.cisa.gov/sites/default/files/publications/5g_edge-core-computing_508_1.pdf
5 https://arxiv.org/pdf/1605.00105.pdf
6 https://www.pwc.com/us/en/industries/tmt/library/5g-small-cell-revolution.html

5G Infrastructure: Data Centers

Another important component of 5G networks are data centers. These refer to dedicated facilities or buildings that are dedicated to housing the necessary physical infrastructure (i.e., servers, routers) that traditionally form the "core" of the network. However, the rise of edge computing means that servers are now increasingly deployed on the "edge" of the network. Additionally, the higher download speed of 5G network also results in increased pressure onto data centers to manage the connections and process the flow of data traffic that occurs.

All of this is expected to necessitate a change in the network architecture (i.e. the way networks are designed). It is expected that the data centers of the 5G era will need to "**hyperscale**"—that is the ability to make available computing resources rapidly and seamlessly in response to user demand. 5G networks are therefore expected to be "**open-architecture**" networks that allow for easy upgrading and swapping of network components.

To-date, key telecommunications companies such as Nokia and Huawei have come up with their own open-architecture data center infrastructure solutions.

The drive to standardized data centers and make them interoperable and easily scalable has resulted in the formation of various groups. These include the O-RAN Alliance, a global group of network operators and equipment vendors that seek to promote open and fully-interoperable mobile networks, or the Open Compute Project (OCP), an organization that aims to bring together top technology companies (such as Facebook, IBM, Dell, Cisco, and Nokia) to share data center product designs and best practices.

Therefore, 5G networks require a sizeable amount of infrastructure to be constructed—which inadvertently carries with it political implications.

Key policy considerations of 5G networks for policy-makers

Given the wide-ranging economic and connectivity benefits that 5G can offer, numerous countries are thus keen to become early leaders, in either 5G technology development or implementation and adoption. These include the United States, China, the United Kingdom,[7] and Singapore,[8] to name a few. Failing to secure a "first-mover advantage" could have strategic implications for countries. For example, the United States has recognized that failing to promote a speedy rollout for the 2G and 3G generations during the 2000s had economic (and security) implications for the country—with numerous wireless technology companies ceasing operations or being acquired during this period.[9] This phenomenon was similarly replicated during the 4G era with first movers capturing virtually all of the 4G ecosystem.[10] This meant that slow movers such as Japan saw their network equipment manufacturers being supplanted in the market, despite having dominated the earlier 3G era.[11] Given the implications 5G adoption has for a country's economic and technological competitiveness, it is therefore unsurprising that countries have placed strategic importance on the speedy adoption and rollout of 5G networks.

However, the adoption of 5G may also open up a new set of vulnerabilities for states. The blurring of traditional boundaries between the "edge" and the "core" (as mentioned earlier) means that attacks on non-sensitive "edge" equipment and infrastructure could now pose a much bigger threat to the entire network.

Key security concerns regarding 5G networks involve **operational processes** (i.e., monitoring and responding to breaches), **network**

7 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_ data/file/582640/FCCG_Interim_Report.pdf

8 https://www.imda.gov.sg/-/media/Imda/Files/About/Media-Releases/2019/Annex-A---5G-Policy-and-Use-Cases.pdf

9 https://media.defense.gov/2019/Apr/03/2002109302/-1/-1/0/%20%20DIB_5G_STUDY_04.03.19.PDF

10 https://www.ericsson.com/en/blog/2020/5/5g-pushes-importance-of-first-mover-advantages-to-new-levels

11 https://www.mckinsey.com/~/media/McKinsey/Industries/Technology%20Media%20and%20Telecommunications/Telecommunications/Our%20Insights/Japan%20at%20a%20crossroads%20The%204G%20to%205G%20revolution/Japan-at-a-crossroads-The-4G-to-5G-revolution-final-web.pdf

deployment (i.e., designing secure and resilient networks), **vendor product development** (i.e., ensuring version control and secure software updates), and **standardization** (i.e., protocols, algorithms).[12] As all these components and processes are interrelated, unaddressed vulnerabilities in one component may end up compromising the integrity of the entire "supply chain". The recognition of such "supply chain risks" and the threat they pose has also led to countries like the United States launching initiatives to prevent or mitigate them.[13] In short, due to the emergence of new threat vectors and resulting vulnerabilities that accompany 5G networks, a new dimension in the security landscape for countries has also surfaced. The risks associated with 5G networks and their deployment are now also national security risks—a view echoed by both government officials and industry experts.[14]

In this regard, ongoing debate and concerns around 5G can be classified into two broad categories. The first category generally revolves around issues of infrastructure integrity and the extent to which foreign suppliers of 5G telecommunications infrastructure can be trusted. The second, and often overlooked, category revolves around themes pertaining to the adoption, deployment and regulation of 5G networks and the regulatory (or policy) regimes surrounding them.

Policy Considerations: Infrastructure Integrity

As previously discussed, 5G networks require a large amount of supporting network infrastructure. The capacity to construct and deploy such infrastructure in an efficient and cost-effective manner is largely limited to key players in the market. Some of these include Qualcomm (US), Huawei (China), Ericsson (Sweden), and Nokia (Finland).

Given the ongoing competition between the US and China, it is therefore unsurprising that Chinese technology companies have come under increasing scrutiny. Huawei, the largest vendor of telecommunications

12 https://www.ericsson.com/en/security/a-guide-to-5g-network-security
13 https://www.cisa.gov/sites/default/files/publications/cisa_5g_strategy_508.pdf
14 https://www.ericsson.com/en/blog/2020/4/5g-network-security-is-national-security

equipment in the world, has attracted the ire of both US and UK policymakers over allegations that it is linked to the Chinese Communist Party[15] and could be compelled to act on behalf of the Chinese government—allegations that Huawei actively denies. Pointing out (1) the PRC's recent enactment of the *National Intelligence Law*, which states that "*all Chinese citizens and companies have a legal obligation to support, assist, and cooperate in national intelligence work*"[16] and (2) that equipment and infrastructure produced by Huawei's have contained 'backdoors' which allow it to covertly access network data[17] which can then be transferred to the Chinese government, US policymakers have claimed that allowing Huawei to be a part of its 5G telecommunications network would be akin to placing its national security at the hands what essentially amounts to a foreign state. A notable example is that of the CryptoAG company, whose joint ownership by the America and West German intelligence services during the Cold War was kept secret until recently. The company, which specialized in manufacturing encrypted communication devices, had wittingly sold compromised devices to its customers (who included Iran and various military regimes in Latin America, amongst others). This allowed American, British, and German intelligence services to spy upon foreign governments.[18]

However, the debate over infrastructure integrity and 5G is not merely limited to Chinese telecommunications companies. The debate also reflects concerns of governments about being over-reliant on any single equipment vendor. The United Kingdom for example, found that its removal of Huawei as an equipment vendor for its 5G network resulted in the UK having greater reliance on other equipment vendors, such as Nokia or Ericsson. This is, according to the British government, "an unsatisfactory position" with regards to the overall resilience of the UK's 5G telecommunications infrastructure.[19] As stated earlier, equipment vendors play a role in delivering secure software updates and ensuring keeping their telecommunications equipment secure. Given the role that equipment vendors play in ensuring the integrity of the network, it is unsurprising to see governments taking an interest in avoiding overreliance on a single vendor—as seen in the UK's case.

15 https://www.cnbc.com/2020/10/08/huawei-accused-of-collusion-with-china-communist-party-uk-lawmakers.html

16 http://www.npc.gov.cn/npc/c30834/201806/483221713dac4f31bda7f9d951108912.shtml

17 https://www.cnet.com/news/us-finds-huawei-has-backdoor-access-to-mobile-networks-globally-report-says/

18 https://www.bbc.com/news/uk-33676028

19 https://publications.parliament.uk/pa/cm5801/cmselect/cmdfence/1091/109102.htm

Policy Considerations: Rapid 5G adoption for strategic advantage

Given the strategic benefits that being a "first-mover" in the 5G ecosystem can yield, numerous countries have already launched initiatives with regards to the adoption of 5G. For example, the US's Federal Communications Commission (FCC) has launched an extensive strategy to "Facilitate America's Superiority in 5G Technology" (known as the **5G FAST Plan**), which calls for modernizing outdated rules and regulations to streamline 5G infrastructure deployment and making funds available for provisioning 5G services in rural parts of the countries, amongst other actions.[20] The strategic importance of 5G adoption has also been seen through various directives that the Chinese government have initiated. For example, the Chinese Ministry of Industry and Information Technology (MIIT) has laid out the **5G + Industrial Internet 512 Project Promotion Plan**, signaling its intent to go beyond the rollout of 5G networks to develop a 5G-based "industrial internet". Specifically, the ministry seeks to develop at least 20 replicable industrial application scenarios as part of efforts to utilize 5G to transform its domestic industries. Amongst other things, the plan also calls for promoting alliances between industry companies, research centers, and universities to carry out joint research.[21]

20 https://www.fcc.gov/5G

21 http://www.cac.gov.cn/2019-11/24/c_1576133540276534.htm

Policy Considerations: Standards Setting in International Organizations

Standard-setting also looks to be key concern for policymakers in the 5G era. Put simply, standards serve as the basic building block for ensuring product interoperability and are the basis for the smooth introduction of new technologies and products to the market.[22] Although American and European technology firms (i.e., Qualcomm and Ericsson) have traditionally dominated standards setting in the telecommunications industry, increasing Chinese activity in that regard signals the possibility that this will be a heavily-contested era in the years to come. For example, Chinese telecommunications firms submitted the most technical documents pertaining to wired communications standards to the International Telecommunication Union (ITU) in 2019. A total of 830 documents were submitted, making China the country with the highest number of submissions. It also meant that China had submitted more than three times the number of documents submitted by the second, third and fourth-placed countries (South Korea, US, Japan) combined.

Closely related to standard-setting in international organizations such as the ITU are the assorted conferences that are attended by both country and industry representatives. For instance, the ITU World Radiocommunication Conference 2019 (WRC-19) was attended by delegates from most of the ITU's 193 member states, together with officials from other international organizations, or representatives from the industry.[23] It is at international (and regional) conferences like these that countries compete to ensure that the final consensus reflects their interests. For example, WRC-19 conference documents show that the US has actively sought to make its concerns known over the issue of 5G wireless spectrum allocation—termed the "most prominent" issue in the conference's agenda.[24] Given the importance of standards setting and the role that organizations like the ITU play, it can be expected standards setting will now increasingly reflect the wider political competition taking place in the era of 5G networks. ■

22 https://www.cencenelec.eu/research/tools/ImportanceENs/Pages/default.aspx
23 https://www.itu.int/en/newsroom/wrc-19/Pages/default.aspx
24 https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7864779

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