

CHINA'S S&T CATCH-UP AND SINO-U.S. TECHNOLOGICAL DECOUPLING: THE CASE FOR 5G

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Underlying the trade war, technological competition has moved to the center of the U.S.-China relationship. The U.S. leadership in world innovation, research and technology development since World War II has allowed it to win the Cold War, and to gain economic and military advantages over potential rivals. But that leadership is now at risk. On one side, there is a widespread belief in the U.S. that the post-war world order no longer benefits the country as much as it used to, and that the best way to regain its freedom and competition is to move away from multilateralism in favor of an international order based on bilateral relations¹. U.S. leadership on S&T is now mainly based on private sector investment and multinational corporations, while there is a decade-long stagnation in federal support and funding for R&D, directed at national economic, strategic and social concerns². On the other side, the rise of Chinese power and influence felt on the five continents and the U.N., since the 2008 global crisis and the ascent of Xi Jinping in 2013, is coupled with an unprecedented national support in S&T, R&D, at a time where the next wave of breakthrough innovation will generate economic and military advantages for the countries that develop and deploy these technologies first³. This explains the actual technological decoupling, of which best example is the rivalry over 5G.

After an evaluation of China's R&D catching up in frontier technologies relative to the USA and Europe, this paper will focus on the 5G implementation, its geopolitical dimensions and its consequences in terms of technological decoupling.

I. CHINA'S R&D CATCHING UP

To “catch up and surpass” (赶超) the USA has been in the gene of the Chinese communist leadership of Mao Zedong in the 1950s, who took over this slogan from the Soviet grand brother, to Xi Jinping⁴. But, in 2018 for the first time, a majority of European firms responding to a survey, report that Chinese firms were equally or more innovative than them despite Internet restrictions which cast doubt on China's ambitions to become a global R&D center⁵. This new perception shows that innovation has become a key resort of the competition between Chinese and foreign MNCs. This is the result of a long-term

¹ Francois Delattre, France's Ambassador to the U.N., *New York Times*, June 13, 2019. In a few years time, China has taken the lead of four U.N. Agencies: UNIDO, ITU, ICAO and FAO (*Le Monde*, 15-16/09/2019).

² James Manyika, William H Mac Raven, Adam Segal, *Innovation and National Security: Keeping our Edge*, Council of Foreign Relations, September 2019.

³ *Ibidem*, p.75.

⁴ Julian Baird Gewirtz, “China's Long March to Technological Supremacy: The Roots of Xi Jinping's ambition to catch up and surpass”, *The New York Times*, August 27, 2019.

⁵ *European Business: European Confidence Survey*, China-European Chamber of Commerce, 2019.

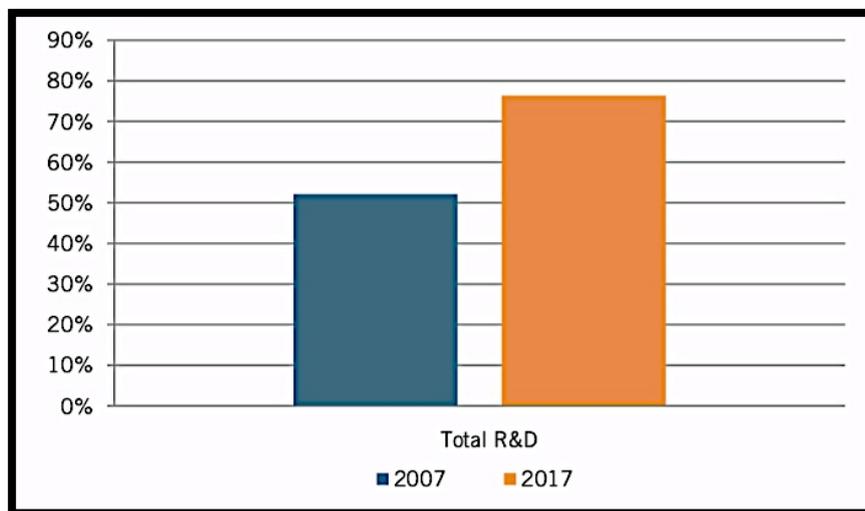
policy on S&T⁶, which tends to catch up the country's backwardness relative to the U.S. in frontier technologies. China has made progress on all indicators and in some areas it is now in front of the United States⁷. China's R&D spending surpassed the EU in 2014 and is rapidly catching up with the U.S. (Fig. 0 & 1).

Figure 0. Research and Development spending



China's 2007 investment in R&D was 33 % less than the U.S. By 2017 it represents 76 % of U.S. levels and 2.13 % of its GDP.

Figure 1. Chinese Expenditures on R&D as a Share of GDP, Relative to the United States 2007-2017

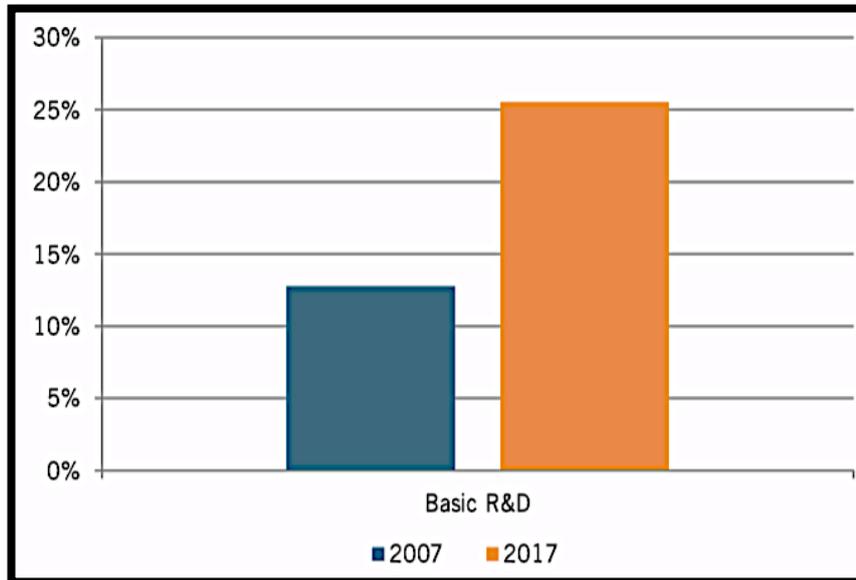


⁶ Cf. Guilhem Fabre & Stephane Grumbach, "The World upside down: China's R&D strategy", FMSH Working Paper, 2012: <https://halshs.archives-ouvertes.fr/FMSH-WP/halshs-00686389>; Guilhem Fabre, "China's digital transformation: Why is artificial intelligence a priority for Chinese R&D", FMSH Working Paper, 2018: <https://wpfms.hypotheses.org/994>

⁷ Robert D. Atkinson & Caleb Foot, "Is China catching up to the United States in innovation?", *Information Technology and Innovation Foundation*, April 2019.

In basic research, which has the greatest potential to create fundamental innovation, China lags behind the U.S. but during the same period, it has closed its gap from 13 to 26 % of the U.S. level (Figure 2).

Figure 2. Chinese Expenditures on Basic R&D as a Share of GDP, Relative to the United States 2007-2017



In terms of institution Chinese Business R&D (BERD) went up to 80 percent of the US level, Higher Education R&D (HERD) rose to 40 percent of US level, and Government R&D (GovERD) surpassed the US by 19 % (Figure3), as the US R&D is mainly focused on private investment and federal support for R&D tend to decline in their share of the GDP (Figure 4).

Figure 3. Performers of Chinese Expenditures on R&D as a Share of GDP, Relative to the United States 2007-2017

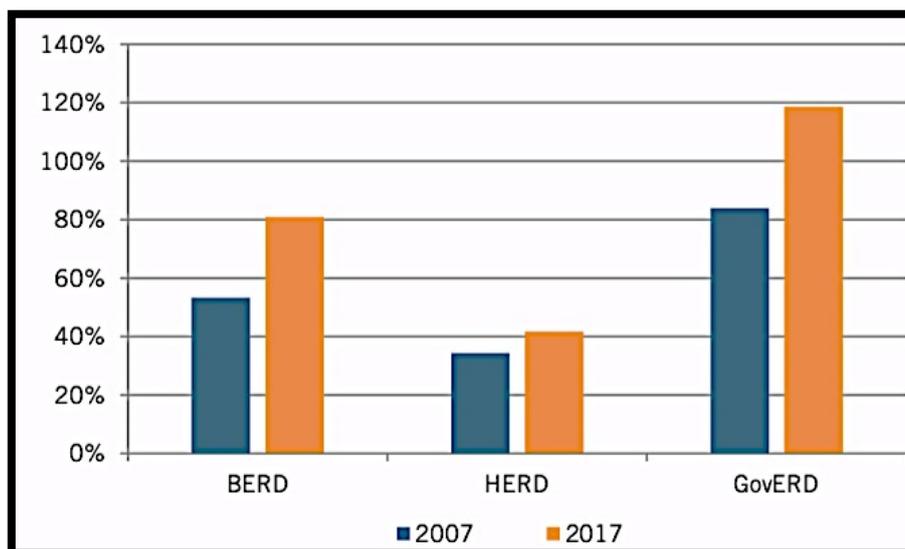
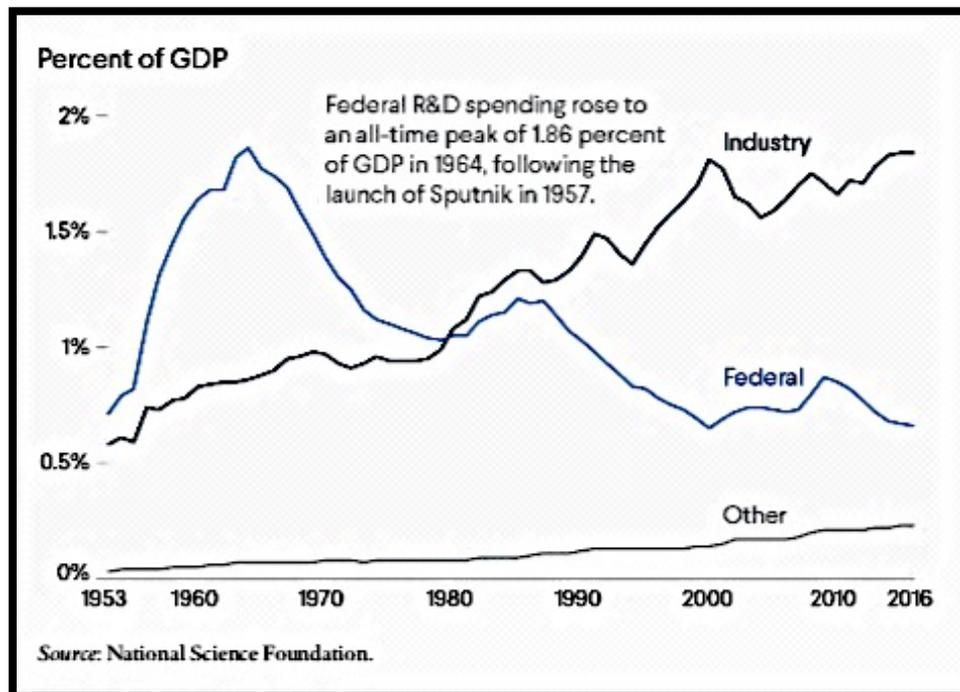
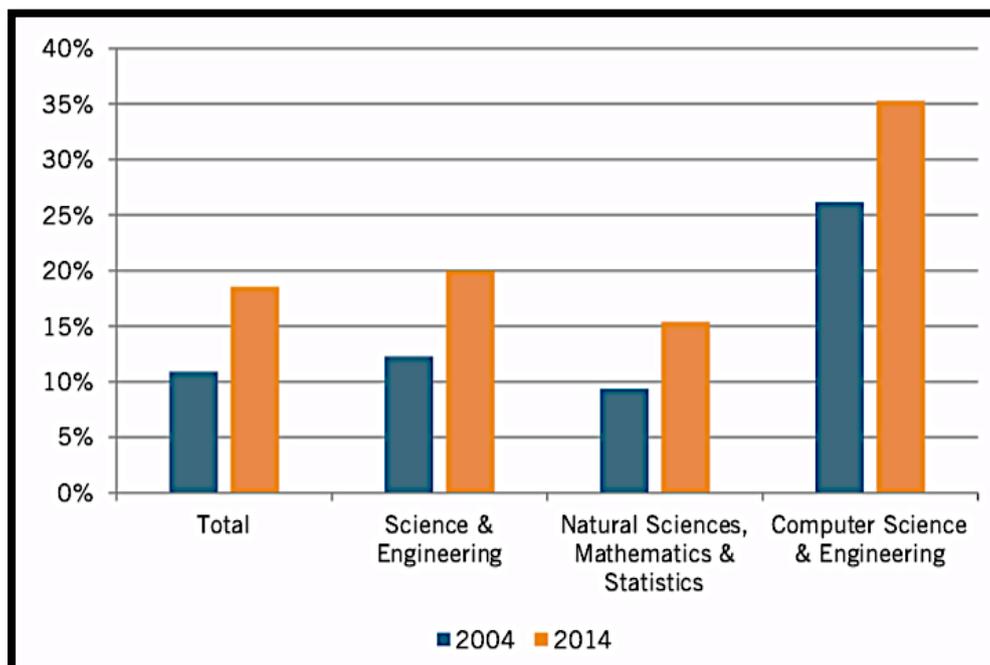


Figure 4. U.S. R&D Funding by Sector as a Share of GDP



In terms of talents, China performs much worse for doctoral degrees per capita, relative to the U.S., but computer science and engineering doctorates reached 35 % of the per capita U.S. level. (Figure 5) Thus, in absolute terms, the number of Chinese doctoral degrees is catching up very quickly and even surpasses the U.S. in computer science and engineering.

Figure 5. Chinese per capita Doctoral Degrees as % of the U.S, 2004-2014



In terms of University ranking, Chinese research universities rose from 9.5 percent of the U.S. score in 2009, to 28 percent of the U.S. score in 2018 (Figure 6). The quality of research has also improved, as the relative citation of Chinese scientific and engineering

articles reached 68 percent of the U.S. level and more than half are as likely as U.S. articles to be among the top 1 percent most cited articles in their field, surpassing the global average (Figure 7). As for Intellectual Property Rights, the Chinese patents filed under the International Cooperation Treaty rose from 10 to 80 percent of the U.S level (Figure 8). China has become the largest producer and exporter of ICT goods, exporting over eight times the number of American ICT exports, and ICT value-added went from about half of US levels in 2006 to around 50 percent more ten years later (Figure 9).

Two sectors may illustrate China’s catching up the U.S. in advanced fields: Artificial Intelligence and aerospace. In AI, apart from Tsinghua, three other Chinese universities and research centers have risen in terms of publication in top AI conferences between 2014 and 2018, Beijing University, the Academy of Sciences and Nanjing University (Figure 10). The impact of Chinese scientists publications on AI has been growing compared to European and U.S. ones (Figure 11). But that is only one part of the story. If we refer to the attendees to the 2018 Conference of the Neural Information Processing System (NIPS) as the top AI researchers, 60 percent (or 68 scientists) are currently working in American institutions (Figure 12). But more than half (38 out of 68) of the AI talent pool in America, is composed of foreign nationals who chose to work in the U.S. (Figure 13) and the largest supply (10) comes from China, just before India (Figure 14).

Figure 6. Chinese Universities among the top 500 relative to the United States, weighted by ranking

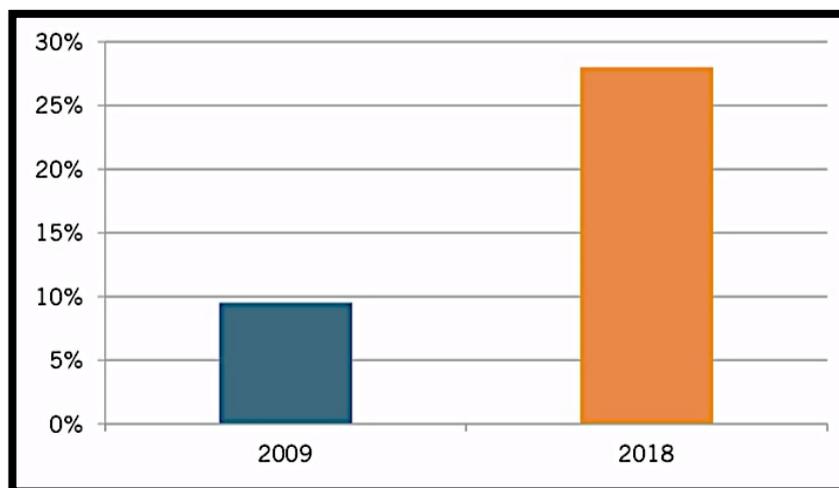


Figure 7. Relative Citations of Chinese Sciences & Engineering Articles as a Percentage of the United States 2004-2014

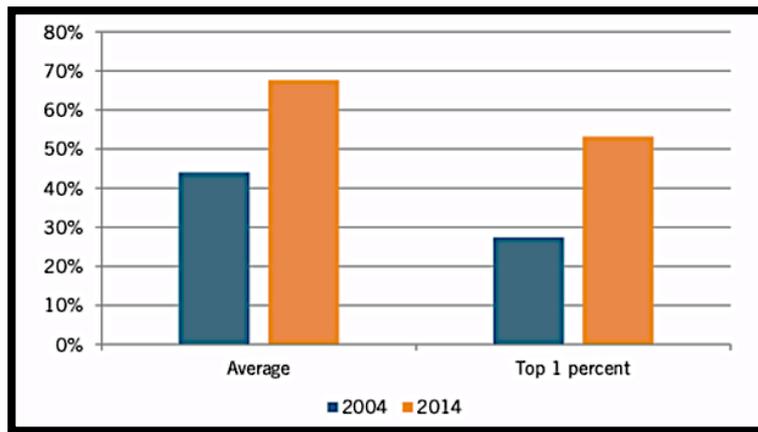


Figure 8. Chinese Patents Filed Under the International Patent Cooperation Treaty as Percentage of the United States, 2008-2018

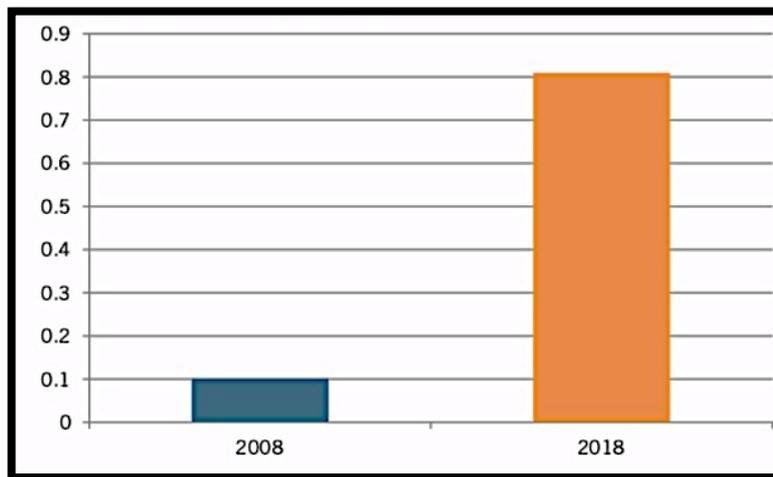


Figure 9. Chinese ICT Goods Trade and Production as Percentage of the United States, 2006-2016

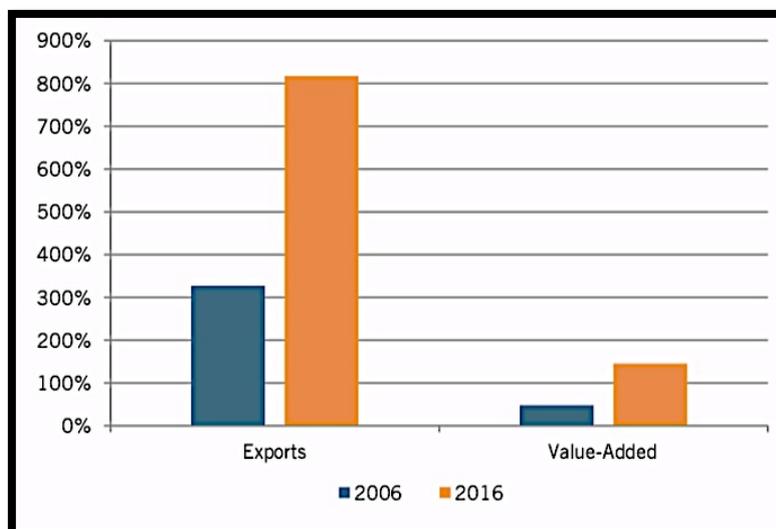


Figure 10. Chinese Universities Rising in Artificial Intelligence Field



Figure 11. Field-Weighted Citation Impact of AI authors by region (1998-2016)

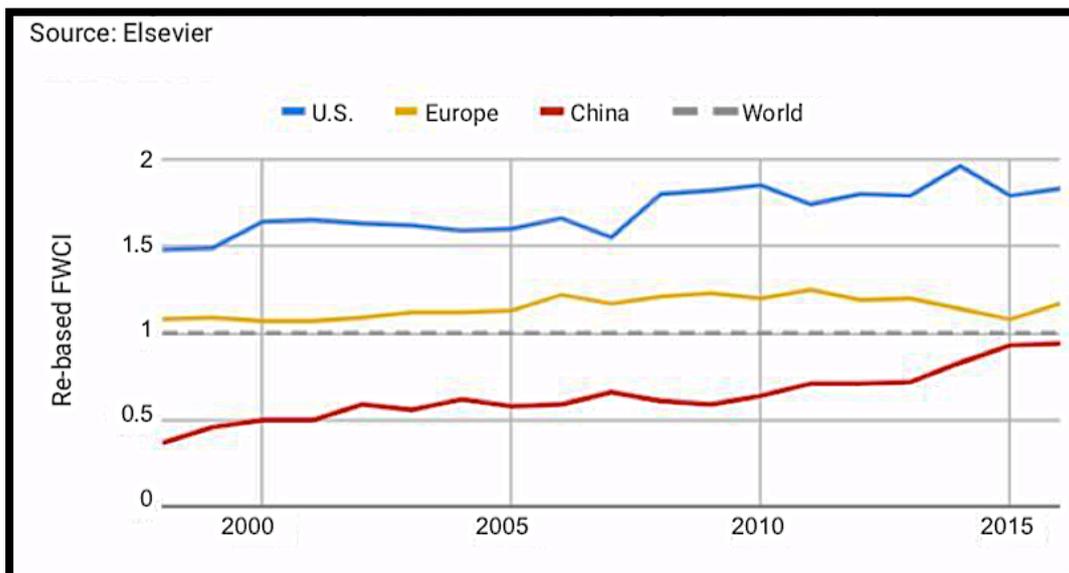


Figure 12. NIPS Oral Presentation Author Current Location

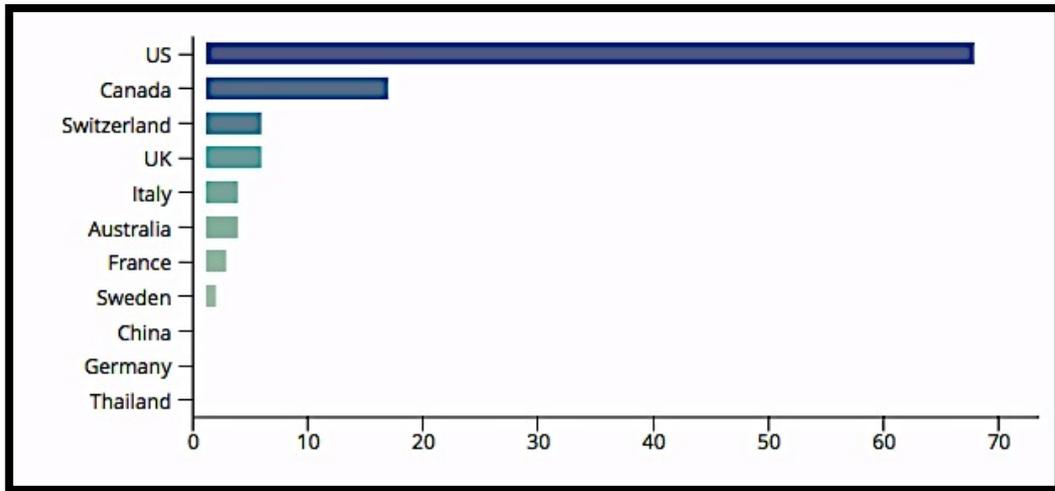


Figure 13. NIPS Oral Presentation Author Undergraduate Location

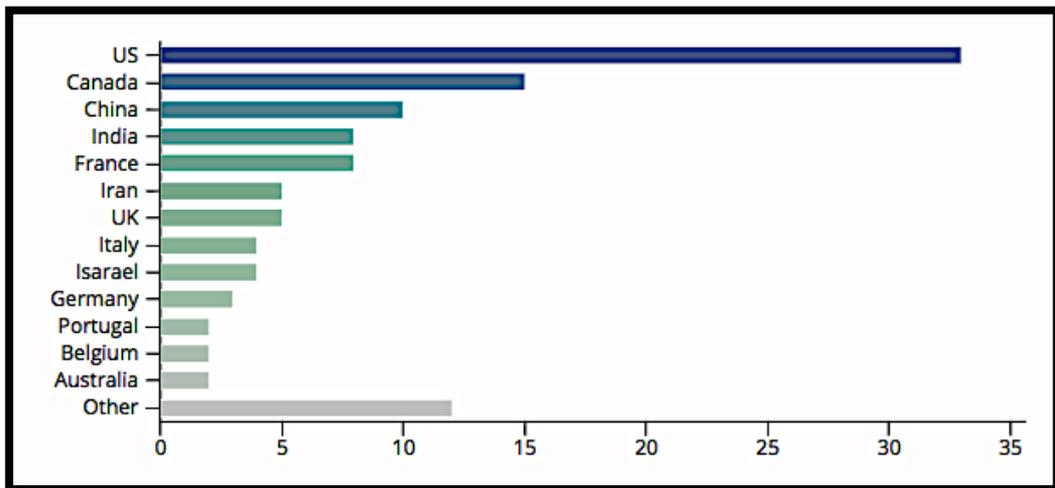
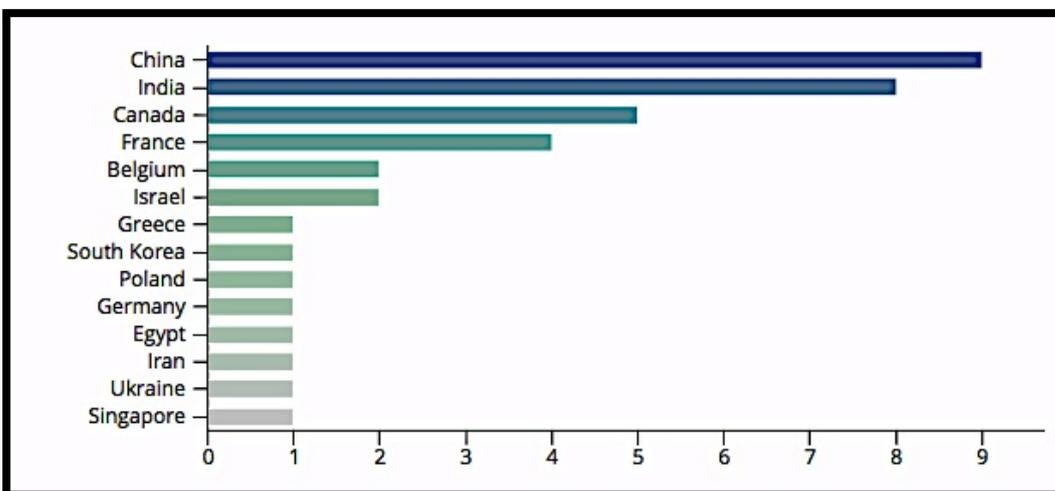


Figure 14. Coming to, Staying in, America



Thus the attractiveness of U.S campuses for foreign scholars is the main asset for the quality of AI research⁸. The current administration's executive order on establishing AI leadership and anti-immigration policies could be self-defeating, as it would allow Beijing to catch up by building a strong talent pool, according to a top Chinese technology investor⁹. New visa limitations only aid Beijing's ambitions¹⁰. And besides, Chinese scientists may also go to Canada...

China's catch-up in the aerospace industry is also particularly impressive. It has surpassed Russia and the U.S in 2018 for the number of successful space launches (Figure 15). According to a 2019 US China Economic and Security Commission report, China's space program is more connected to the "levers of power", meaning its goals more often draw support from top leaders and are connected to the country's priorities in industrial and foreign policies. This is particularly the case for the China's Beidou satellite navigation system, which is a vital component of the Belt and Road digital Silk Road. It promotes the use of Beidou and other satellites among BRI participants, including for military use, in the case of Pakistan¹¹ (Figures 16, 17, 18, 19). China aims to have 35 Beidou satellites in orbit by 2020¹². Apart from its dual dimension, the growth of China's satellite data positioning has profound implications. Chinese smartphones and car navigation systems are Beidou compatible by default. For companies with global ambitions, making Beidou compatible products is a necessity, because products and services that use Beidou are available in many countries. More than 30 countries in the Middle East, Africa and elsewhere use Beidou. If it becomes the standard in these countries, China will have an advantage in introducing technologies and products. US chipmaker Qualcomm was the first to supply chips for Beidou-capable smartphones. Leading American smartphone makers other than Apple use the chips in their devices.¹³.

⁸ Daniel Castro *et al.*, "Who is winning the A.I race: China, the E.U or the United States?", Center for Data Innovation, August 2019; Joy Dantong Ma, "The AI race is wide open if America remains open", *Macro Polo*, April 15, 2019 : <https://macropolo.org/us-china-ai-race-talent/>

⁹ Catherine Wong, "Tough U.S immigration policy could be the key to China winning technology race, says top China technology investor", *South China Morning Post*, Hong Kong, October 30, 2019.

¹⁰ Yangyang Cheng, "Don't close the door on Chinese scientists like me", *Foreign Policy*, June 4, 2018.

¹¹ U.S.-China Economic and Security Commission: China's Pursuit of Space Power Status and Implications for the United-States, April 2019: <https://www.uscc.gov/research/chinas-pursuit-space-power-status-and-implications-united-states>

¹² BBC, Technology, September 20, 2018: <https://www.bbc.com/news/technology-45471959>

¹³ Kazuhiro Kida *et al.*, "China's version of GPS now has more satellites than U.S original", *Nikkei Asian Review*, August 19, 2019. The European Global Navigation Global Satellite Systems Agency estimate the market for devices and location data services to reach US \$ 190 billion by 2020, with 8 billion receivers in operation.

Figure 15. Commencing countdown, engines on

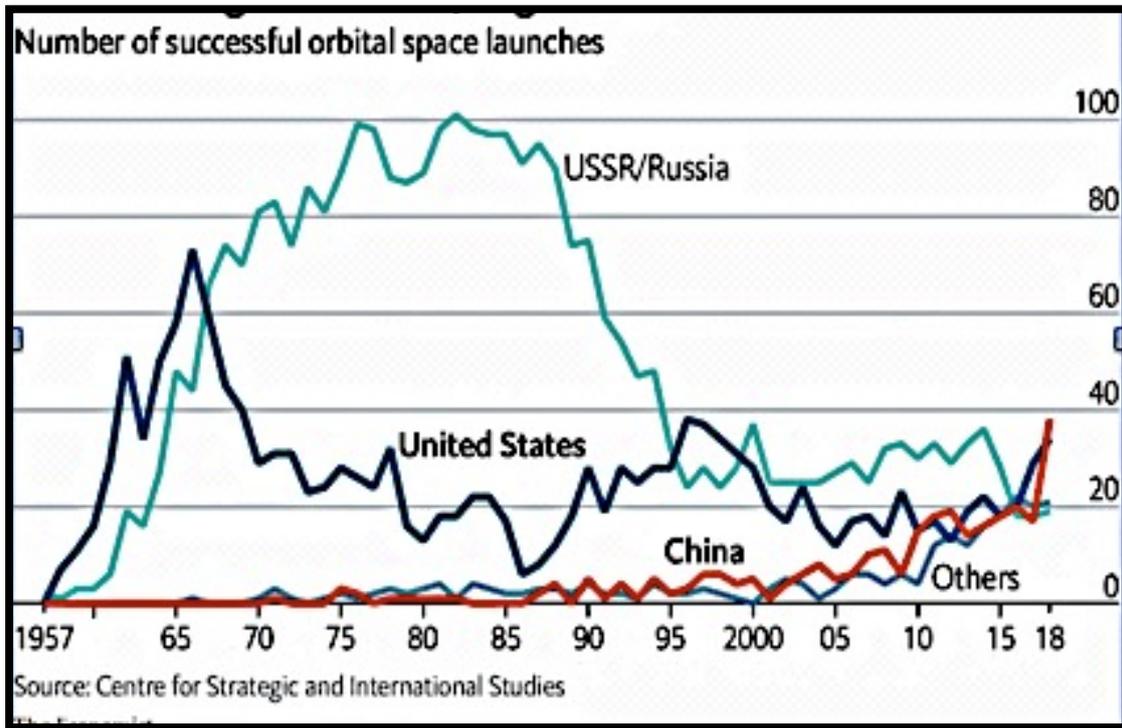


Figure 16. Beidou Satellite Navigation System

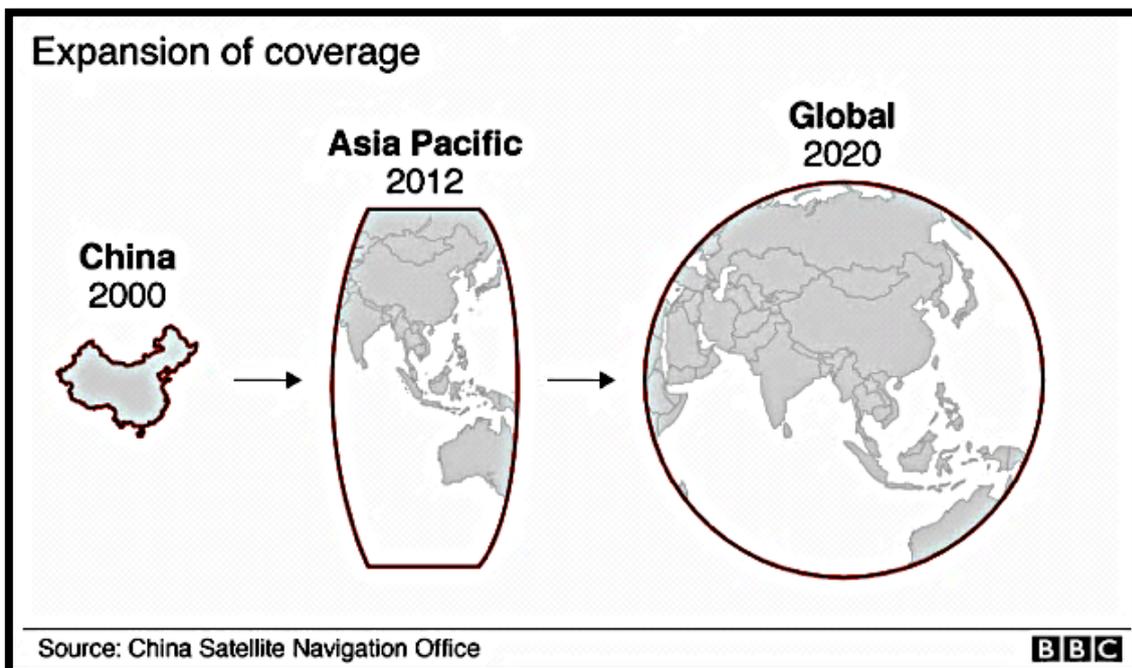


Figure 17. Global Navigation Satellite Systems

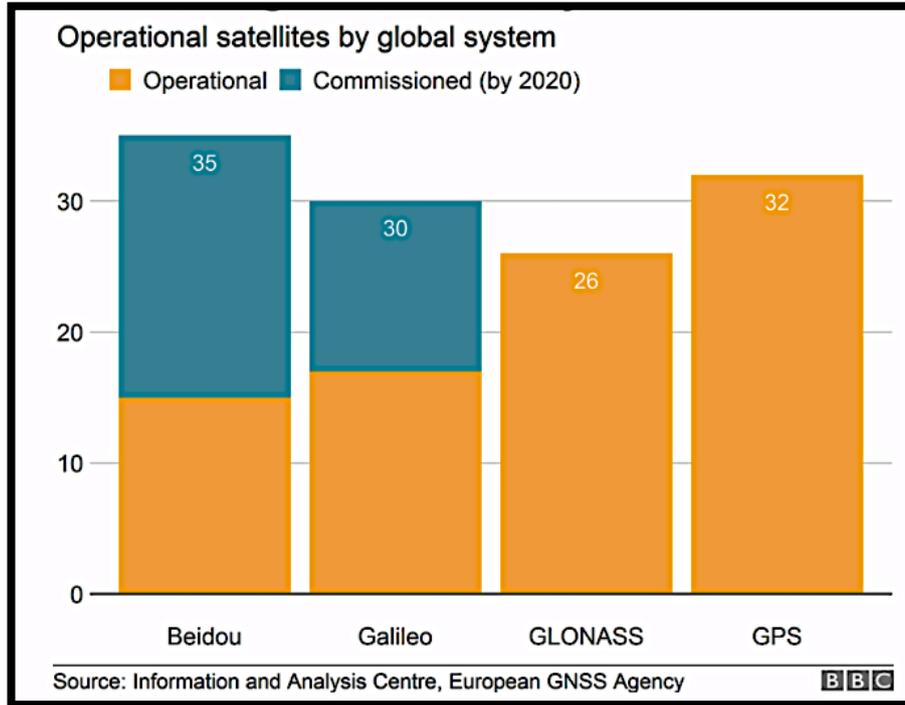


Figure 18. Chinese version of U.S. GPS, Beidou expands influence in Asia and Africa

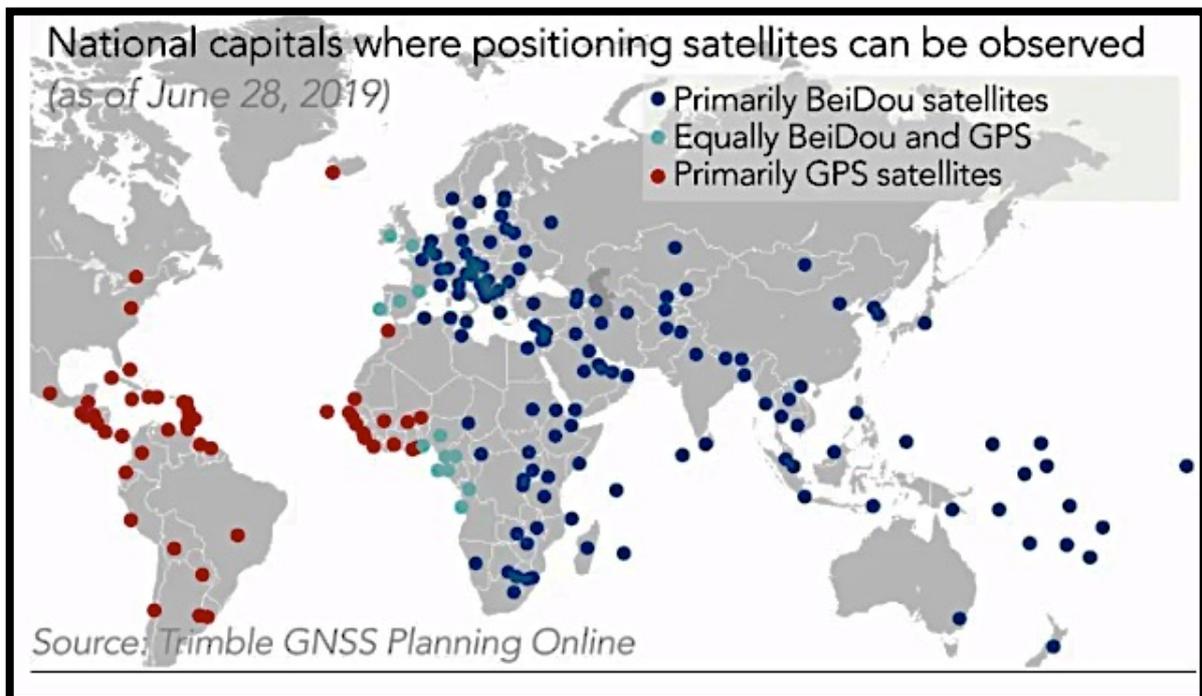
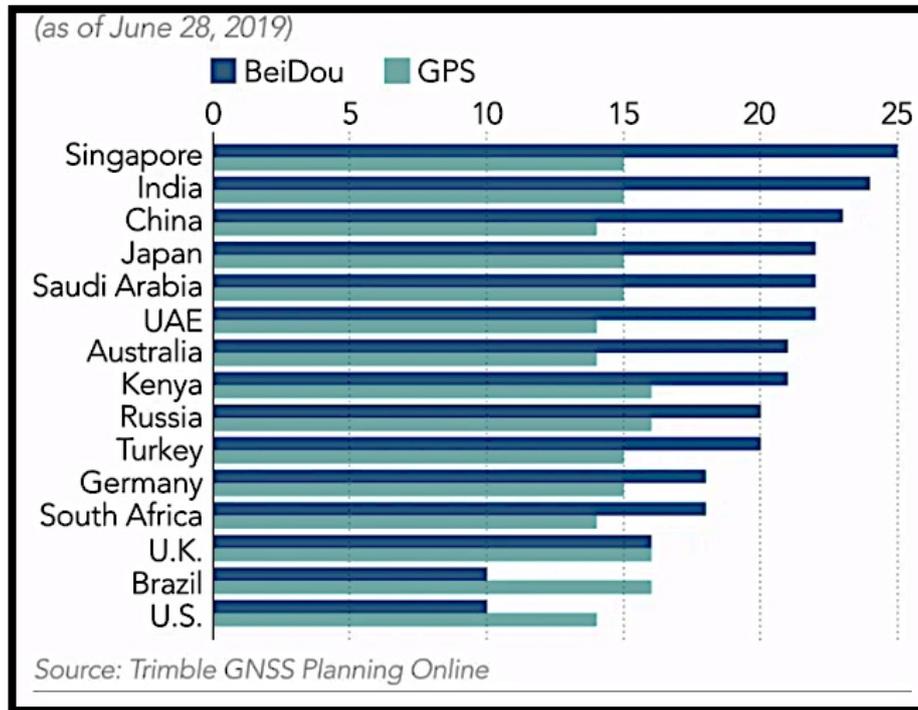


Figure 19. Number of positioning satellites in major cities



II. THE STAKES OF 5 G

China's new satellites infrastructure is particularly important in the context of the new 5th Generation of mobile, (5G), which is a breakthrough innovation compared with the previous ones, because its intention is to serve both consumers and machines through the Internet of Things (IoT) (Figure 20). Although 5G remains in a fairly nascent stage and will fully develop between 2020 and 2030, it will deeply disrupt transport, with driverless vehicles, energy, manufacturing with the 4th industrial revolution, healthcare, smart cities, smart homes, and entertainment with virtual reality etc. (Figure 21).

Figure 20. The Internet of Things (IoT)

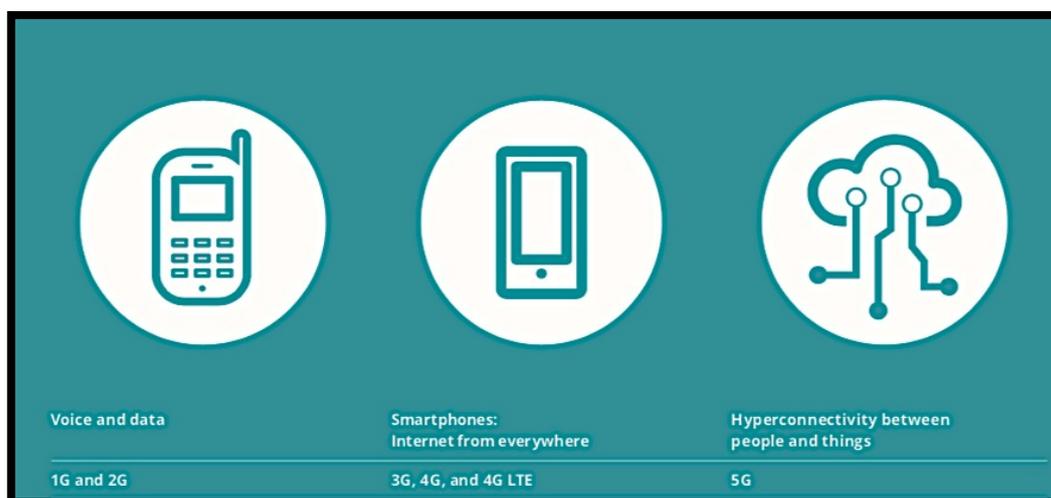
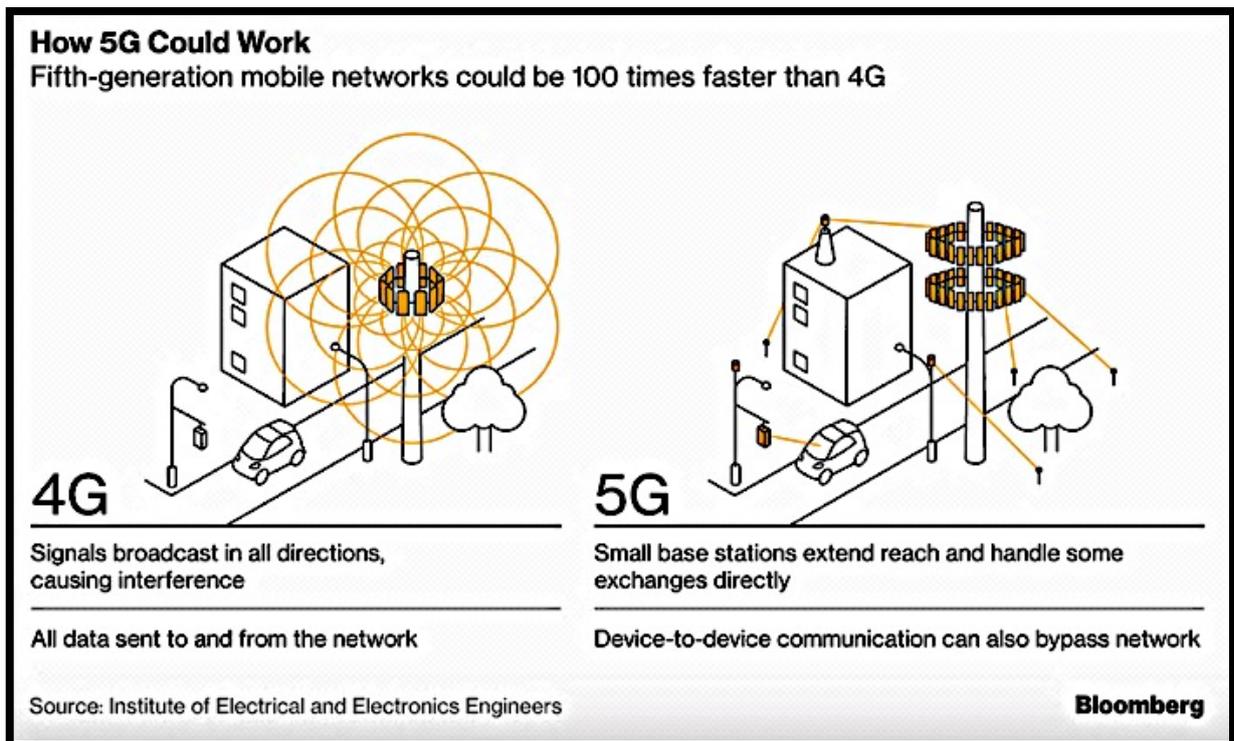


Figure 21. What 5G is about



Figure 22. How 5G Could Work



With 5 G, wireless connectivity is transforming from a traditional macro network based on large towers with broad coverage, to a network of at least hundreds of thousand of small cells strung closely together, which, because of spectral re-use, produces significantly higher bandwidth (up to a million connections versus 4000 connections that 4G base stations can cope with) at a much higher download speed (600 megabits per second and faster in the future, compared with 28 megabits per second for 4G) and at a

much lower latency (the time it takes for a signal to travel across the network is just a single millisecond compared with 50 milliseconds or more for 4G)¹⁴ (Figure 22).

Concrete examples of 5G’s IoT applications range from the commercial to the military field, with integrated missile defense systems or 360 degrees battlefield awareness (Figure 23).

Figure 23. Commercial and Military Applications of the IoT

Sector	Examples of IoT Applications
Consumer	<ul style="list-style-type: none"> • Augmented reality and virtual reality entertainment • Smart appliances • Wearable devices (e.g., fitness trackers)
Buildings	<ul style="list-style-type: none"> • Smart thermostats • Energy and water management • Automated networked surveillance
Retail	<ul style="list-style-type: none"> • Delivery drones • Supply chain management • Targeted advertisements • In-store customer behavior monitoring
Transportation	<ul style="list-style-type: none"> • Self-driving cars • Traffic management • Remote vehicle performance monitoring
Healthcare	<ul style="list-style-type: none"> • Telemedicine • Robot-assisted surgery • Remote medical device and physiological monitoring
Military	<ul style="list-style-type: none"> • Unmanned systems (e.g., drone swarms) • Integrated missile defense systems • 360-degree battlefield awareness • Logistics and inventory management

Source: Various.¹⁶

Source: *U.S.-China Economic and Security Commission*, U.S. Congress, 2018.

Thus 5G, with its potential in terms of innovation, its dual character as well as its implications in terms of Cloud data management and competition, a US \$ 200 billion industry dominated by Amazon Web Services, Google, Microsoft Azure and Alibaba Cloud¹⁵, marks a return of geopolitics to international relations, and is now at the forefront of the U.S-China technological rivalry and decoupling. For some analysts, “China has made its decision: China is building a separate system of Chinese technology: its own standards, infrastructure and supply chains to compete with the West”¹⁶. But in terms of communication, things are not so simple, as the standards need to be global. If we take the example of 5G, the most promising and influential technology for the next decade, technical standards that will enable interoperability and facilitate widespread commercialization are taking shape through the 3 Generation Partnership Project (3GPP), a consortium of telecom firms and associations under the United Nations International Telecommunications Union (UITU), which holds the World Radio Conference every

¹⁴ *MIT Technological Review*, April 19, 2019

¹⁵ Scott Malcomson, “The Real Fight for the Future of 5 G”, *Foreign Affairs*, November 14, 2019.

¹⁶Cf. “The End of the American Order”, Ian Bremmer speech at 2019 GZERO Summit, Tokyo, Eurasia Group, November 18, 2019: <https://www.eurasiagroup.net/live-post/end-of-american-order-ian-bremmer-2019-gzero-summit-speech>

three or four years. As China did not have a say in 2G, developed an internal standard for 3G, had a relatively small participation in the conception of 4G, 5G, as a new global standard, gives it a brand new opportunity to be a significant player. Thus China has sought leadership position in the technical standards forums to raise its influence, which has irritated the U.S and other incumbents. The secretary general of ITU is now a Chinese, Houlin ZHAO, and three Chinese firms, Huawei, CATT and China Mobile have representatives in the three technical groups of 3GPP (Figure 24).

Figure 24. 3GPP Plenary Leadership 2019-2021

Group	Position	Name	Company	Country
CT	Chairmanship	Lionel Morand	Orange	FR
	Vice Chairmanship	Behrouz Aghili	InterDigital	US
		Ming Ai	CATT	CN
		Johannes Achter	Deutsche Telekom	DE
RAN	Chairmanship	Balazs Bertenyi	Nokia	FI
	Vice Chairmanship	Satoshi Nagata	NTT DOCOMO	JP
		Xiaodong Xu	China Mobile	CN
		Stephen Hayes	Ericsson	SE
SA	Chairmanship	Gerog Mayer	Huawei	CN
	Vice Chairmanship	Yusuke Nakano	KDDI	JP
		LaeYoung Kim	LG Electronics	KR
		Gregory Schumacher	Sprint	US

Table source: CGS 2019 based on data from 3GPP.

CT = Core Network and Terminal; RAN = Radio Access Network; SA = Service and Systems Aspects.

The core technology of a mobile network is Radio Access (RAN). It is about how signals (voice or data) are transmitted between a base station and the terminal (i.e. a mobile phone or a wearable device). Another key consideration is the amount of spectrum and frequency level that can be made available for 5G. This has an impact on the performance of the mobile technology. Finally, to simplify a complex technological topic, the amount of Standard Essential Patent (SEP) owned by different firms determines the share of IPR revenues, in an ecosystem where no single company controls the technology¹⁷.

China has clearly taken the lead in RAN through its public policy, it has outspent the U.S by around 24 billion in wireless infrastructure, and 400 billion \$US in 5G-related investment in its 5-year economic plan. China Tower added approximately 460 sites per day, implying US tower companies and carriers added fewer sites from 2015 to 2018, due to statutory constraints, that China Tower added in three months. The RAN is dominated by Huawei and the Scandinavians Ericsson and Nokia, who share almost 80 percent of the market's revenue (Figure 25)¹⁸.

¹⁷ For an excellent presentation: Jefferies Franchise Note, *Telecom Services: The Geopolitics of 5G and IoT*, September 14, 2017: <https://www.jefferies.com/CMSFiles/Jefferies.com/files/Insights/TelecomServ.pdf>

¹⁸ Xuewu Gu et al., *Geopolitics and the Global Race for 5G*, CGS Global Focus, May 2019.

Figure 25. Main Players on the RAN-Market

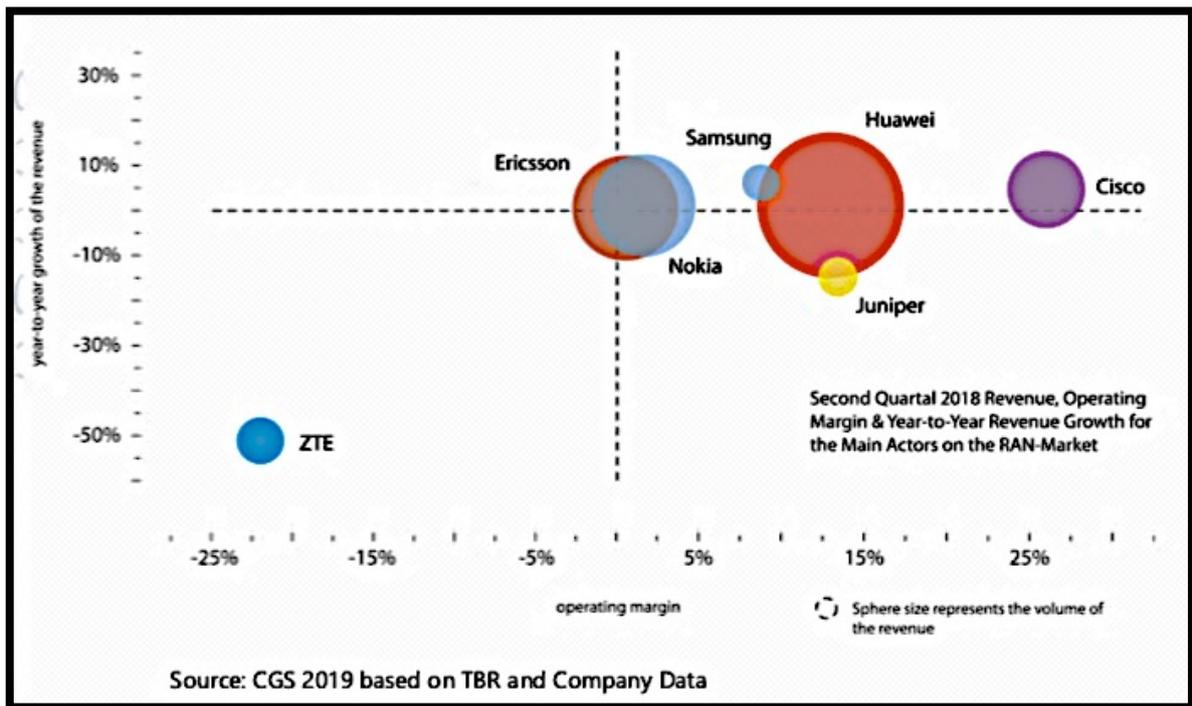
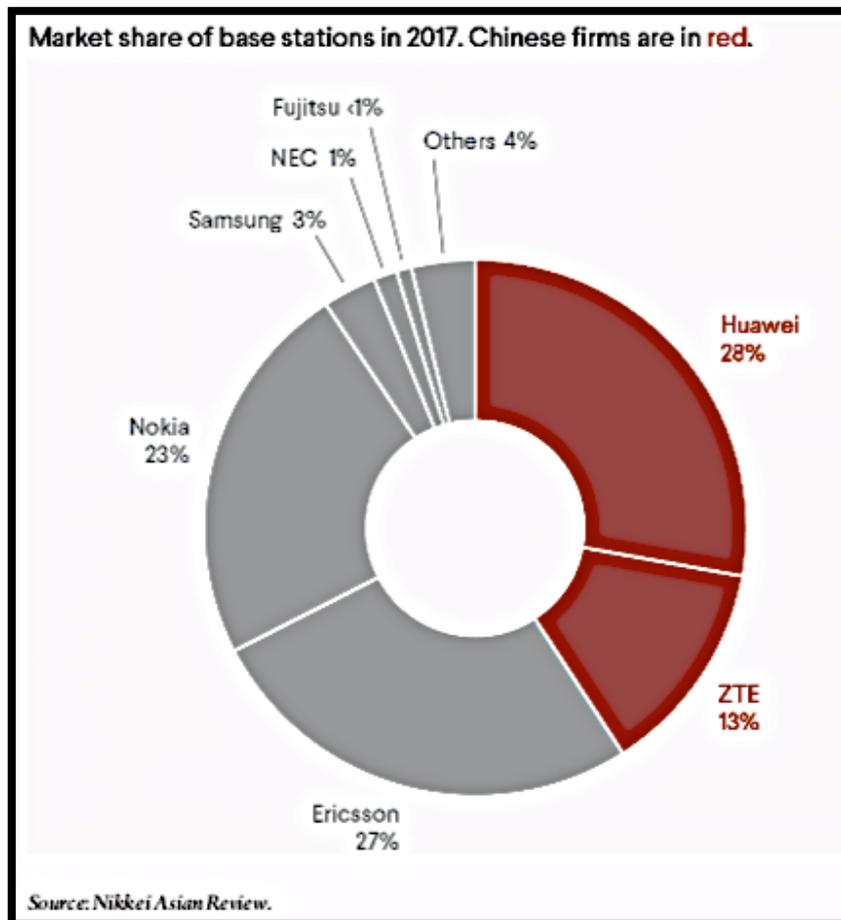


Figure 26. Chinese Firms dominate 5G Rollout

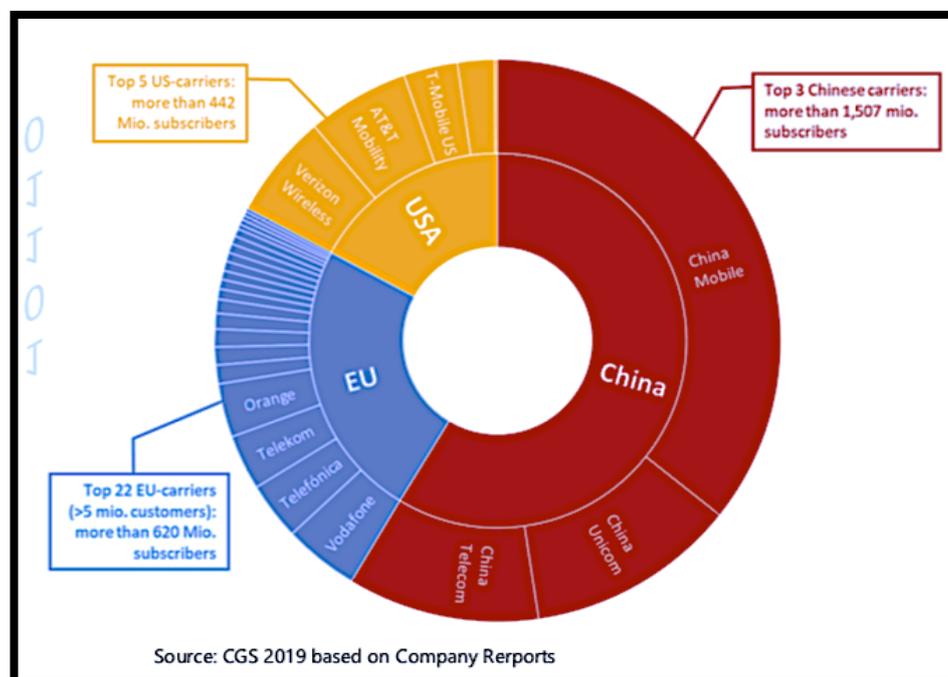


Huawei is building on its established presence in 4G networks, which already amounts to nearly a third of the global telecom market (Figure 26). It is one of the few players that can provide mature and cost-effective equipment for 5G. It has shipped 150,000 base stations as of June 2019, and signed 50 commercial 5G contracts with 30 countries, including Russia and a significant proportion in Europe¹⁹.

One of the key points to winning and exercising a 5G leadership is the spectrum and frequencies used, a scarce public resource. Mid-band and low frequencies (under 6 GHz) are congested but provide much better area coverage at less cost, because they do not require as many sites or towers. High frequencies (over 24 GHz), also called mmWave, can offer much wider, cleaner bandwidth but has tech challenges, such as rain fade, tree blockage and short transmission distance. China has clearly preferred mid-band and low frequencies for coverage, which is supported by Europe, but it has also allocated spectrum on high frequencies. The U.S has chosen high frequencies, but is now constrained to adopt options for mid-band frequencies, despite their actual usage by satellite companies and the military. According to a US Defense Innovation Board Report, “as 5G is now deployed around the globe in similar bands of spectrum, China’s handset and internet applications are likely to become dominant, even if they are excluded from the U.S. China is on a track to repeat in 5G what happened in the United States with 4G”²⁰.

Apart from its leadership in RAN, and its facility of spectrum allocation by government’s decisions, instead of a longer process of auctions to operators made elsewhere, China has a clear advantage in terms of scale, since the numbers of mobile subscribers in its market surpass the U.S and Europe altogether (Figure 27).

Figure 27. Largest mobile network operators by subscribers

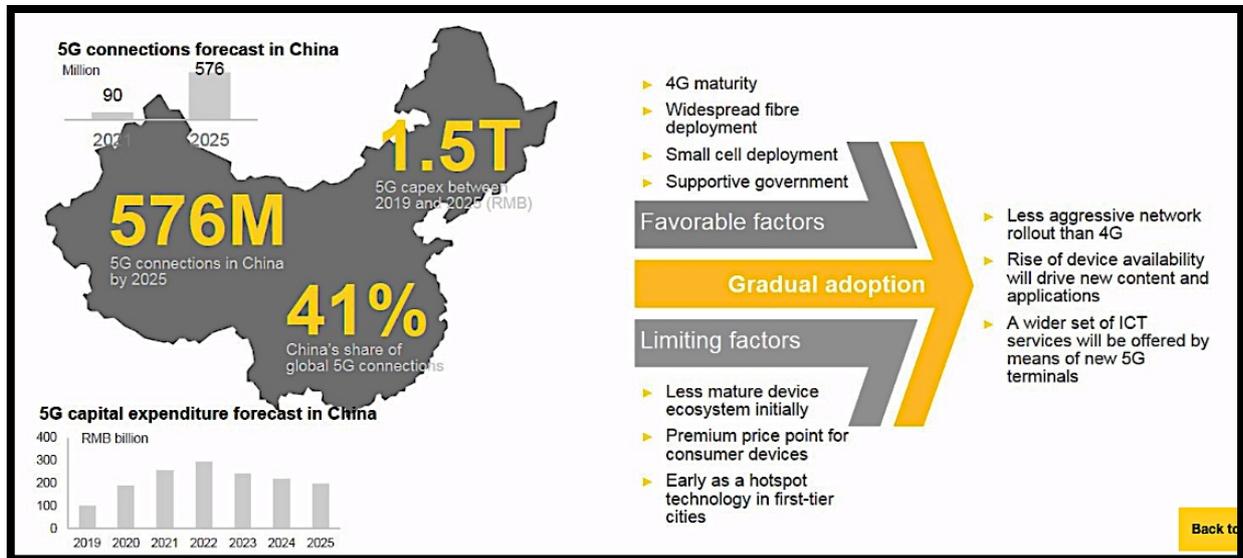


¹⁹ Elsa B. Kania, *Securing our 5 G Future: The Competitive Challenge and Considerations for U.S. Policy*, Center for a New American Security, November 2019: <https://www.cnas.org/securing-our-5g-future>

²⁰ Milo Medin & Gilman Louie, *The 5 G Ecosystem: Risks and Opportunities for DoD*, Defense Innovation Board, April 3, 2019.

With a forward-looking industrial policy and huge enthusiasm among local governments, the forecasts for 5G capital expenditures and connections in China are impressive, they vary from 428 to 576 million in 2025 (Figure 28).

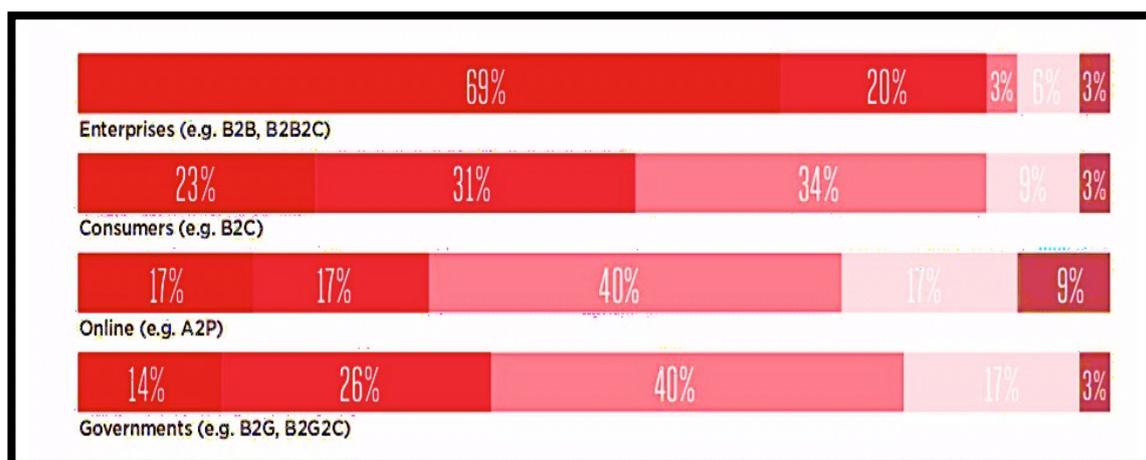
Figure 28. 5G connections and capital expenditure forecast in China



Source: EY

The advantages of first mover status are twofold: success across large networks in China can demonstrate to carriers in other big markets that low frequencies can deliver on performance. Second, since 5G will enable widespread use of IoT applications and upgrade to advanced manufacturing, China's technology giants will capitalize on these new technologies and then will more easily export 5G systems along the Belt and Road Initiative, as a part of the Digital Silk Road.)²¹. In this context, firms are expected to be the main source of revenues for the operators (Figure 29).

Figure 29. Sources of new operator revenues for 5G

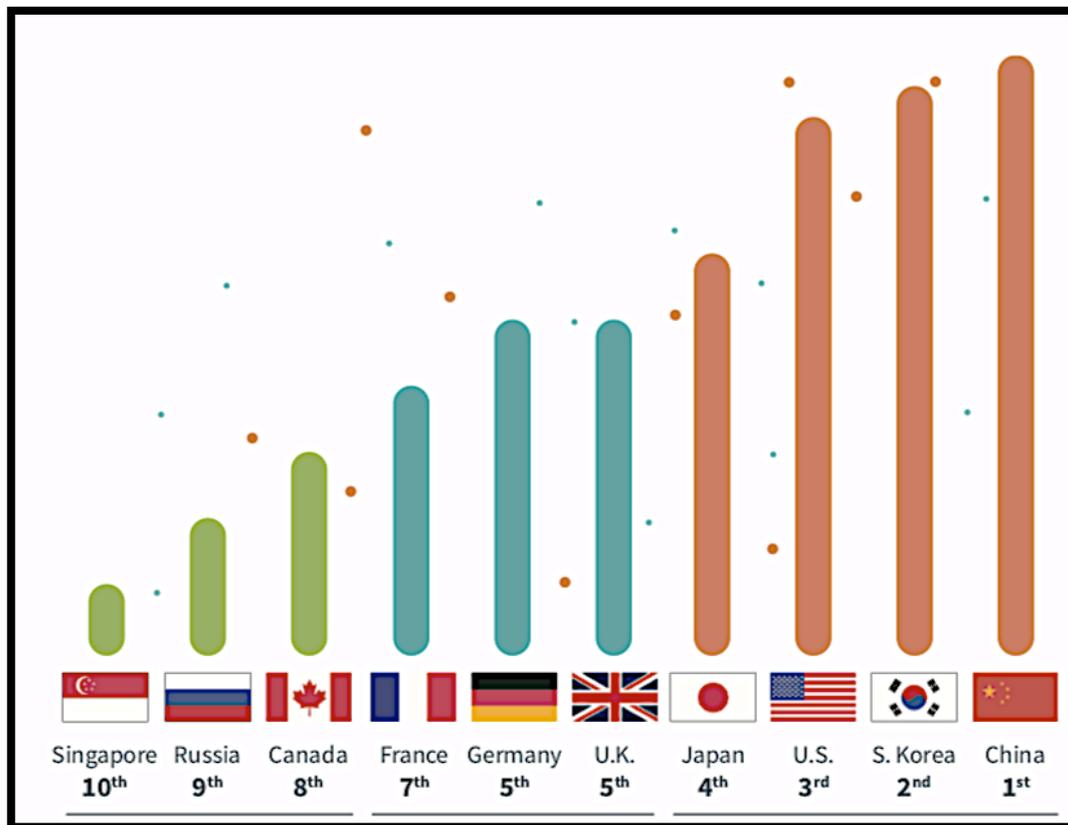


Source: GSMA Intelligence

²¹ Paul Triolo, Kevin Allison, Eurasia Group White Paper: *The Geopolitics of 5 G*, November 15, 2018: <https://www.eurasiagroup.net/live-post/the-geopolitics-of-5g>

Thus, with firm governmental support, facilities of investment and frequencies allocation, a leadership in RAN and the scale of its market, China is in the best position in the 5G race (Figure 30).

Figure 30. 5 G Readiness Index



Source: Analysys Mason, *The Global Race for 5G*, CTIA Report, 2018.

The U.S administration has been conscious of this situation early on. In January 2018, a senior National Security Council official floated the idea of rivaling Beijing with a government led effort to build a national wireless network, but regulators and elected officials rejected this proposition as "overly expensive and unrealistic"²². Since then, Washington has adopted a defensive tactic, with American officials pushing allied countries to ban Huawei from building their 5G networks, citing concerns over security and the company's unclear links to the Chinese state²³.

This does not mean that the U.S has no advantage. If the government typically avoids mandating and coordinating efforts by private firms in network infrastructure, U.S is still the leader in advanced 5G technologies. Carriers such as Verizon and AT&T have been the first to launch experiments of 5G networks in selected U.S cities in 2019. U.S firms are still dominant in key telecommunications technologies like Ethernet switches, which

²² John D. McKinnon *et al.*, "Officials Reject Idea for Government Takeover of 5G Wireless Build-Out", *Wall Street Journal*, January 29, 2018.

²³ Christopher Balding & Donald Clark have showed that 99% of Huawei is officially owned by a "Trade Union Committee", a surprising ownership structure in China, where "trade union members have no right to assets held by a trade union", *China File*, April 19, 2019: <http://www.chinafile.com/reporting-opinion/viewpoint/who-owns-huawei>

manage network traffic, Enterprise Wireless Local Area Network (WLAN), which provide communication network, and Routers, which forward data between networks, although Huawei is in second position (Figure 31).

Figure 31. World's Largest Firms in Selected Telecommunications Technologies (2017)

Key Technologies	Leading Firms (global market share based on revenue)
Mobile infrastructure hardware	Huawei (28 percent), Ericsson (27 percent), Nokia (23 percent), and ZTE (13 percent)
Enterprise wireless local area network (WLAN)	Cisco (43.6 percent), Aruba Networks* (14.9 percent), ARRIS/Ruckus† (5.9 percent), Ubiquiti‡ (5.6 percent), and Huawei (5 percent)
Ethernet switches	Cisco (54.9 percent), Huawei (8.3 percent)
Routers	Cisco (36.7 percent), Huawei (23.8 percent), Juniper (18 percent)
Smartphone semiconductors	Qualcomm (42 percent); Apple (22 percent); MediaTek§ (15 percent)

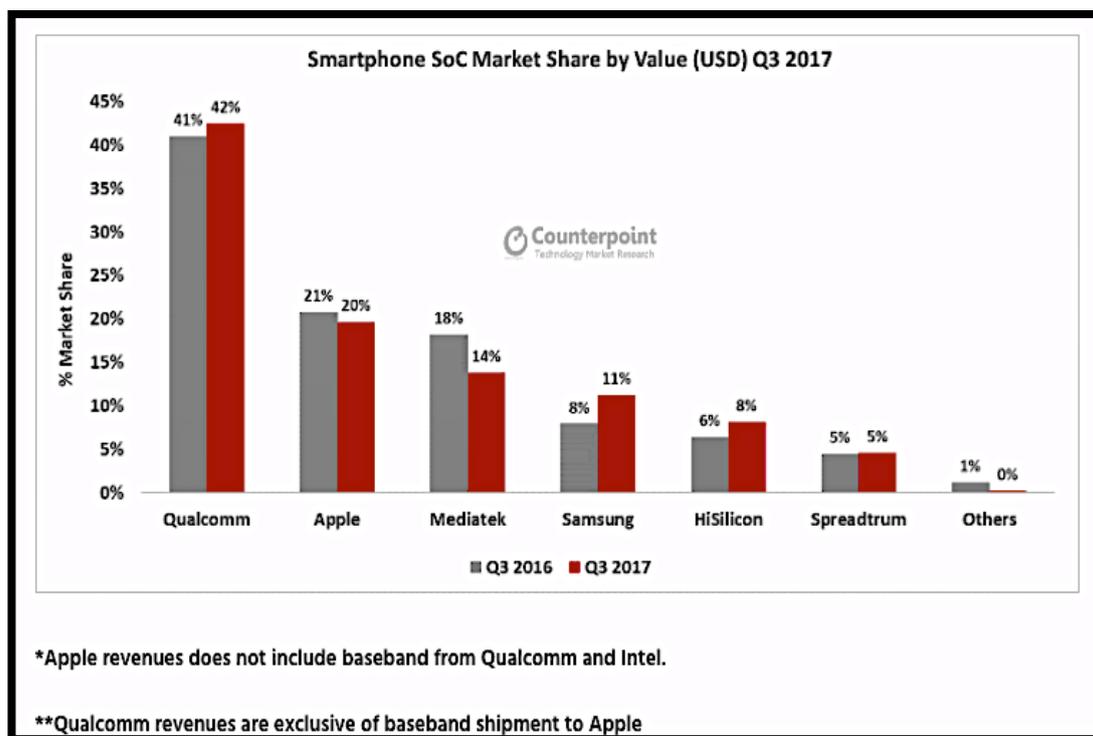
Note: Mobile infrastructure hardware comprises radio access network, switching, and core equipment.
Source: Various.¹¹⁶

Source: U.S.-China Economic and Security Commission Report, 2018, U.S. Congress.

The key U.S advantage is in smartphone semi-conductors, which allow a smartphone to connect to telecom networks. In 2016, China imported \$US 295 billion in semi-conductors, or 2,8 times the value of all the crude oil it imported that year. Only 16 percent of the semi-conductor chips consumed in China are produced domestically²⁴. In 2017, Qualcomm controlled 59, 6 percent of the US\$15 billion market for 4G modem chips, and 42 percent of the \$US8 billion global smartphone System on Chip (SoC) market, which integrates all the memory and components and enables management of all smartphone equipment (Figure 32).

²⁴ *The Economist*, May 16, 2019. The \$US 295 billion seem to include imports of equipment that are used in the manufacture of goods subsequently exported (phones, etc.).

Figure 32. Smartphone System on Chip Market Share by Value Q3 (2017)



In short, the U.S. depends on China for the bulk of electronic manufacturing, while China still relies on a number of American components, including software and chips. China has invested heavily to catch up this disadvantage in semi-conductors, which has been among the priorities of the *Made in China 2025* plan, promoting indigenous innovation. In addition, at the start of 2018, the Chinese government unveiled a package of incentives to attract specialists and students from Taiwan, which appear to be successful. In the first nine months of 2018, more than 300 senior engineers working at semi-conductor companies in Taiwan moved to China. In total, more than 1.300 Taiwan engineers have relocated to China since 2014, in search of higher paying jobs and subsidized living expenses²⁵. Despite the blacklisting of certain Chinese firms by Washington, Beijing’s push for technological sufficiency is on the verge of a major breakthrough, with the country’s nascent chip industry on track to produce around 5 percent of the world’s memory chips by the end of 2020 from virtually zero in 2018²⁶.

As mobile data is the fastest growing part of the Internet traffic (Figure 33) future technologies that enable connectivity will increasingly rely on patented technology standards such as 5G. In this context, the race for 5G Standard Essential Patents (SEP) is decisive. In 2018, Qualcomm was still dominating with 15 percent of the 5G SEP, with other U.S firms like Interdigital (9%) and Intel (7%). But the Chinese firms Huawei and

²⁵ U.S. Congress, *U.S.-China Economic and Security Commission, 2019 Report* p.467; Guilhem Fabre, “China’s digital transformation: Why is artificial intelligence a Chinese priority?”, FMSH Working Paper cited, June 2018, p.13.

²⁶ Cheng Ting-Fang & Lauly Li, *Nikkei Asian Review*, November 20, 2019:

<https://asia.nikkei.com/Business/China-tech/China-memory-chip-output-zooms-from-zero-to-5-of-world-total>

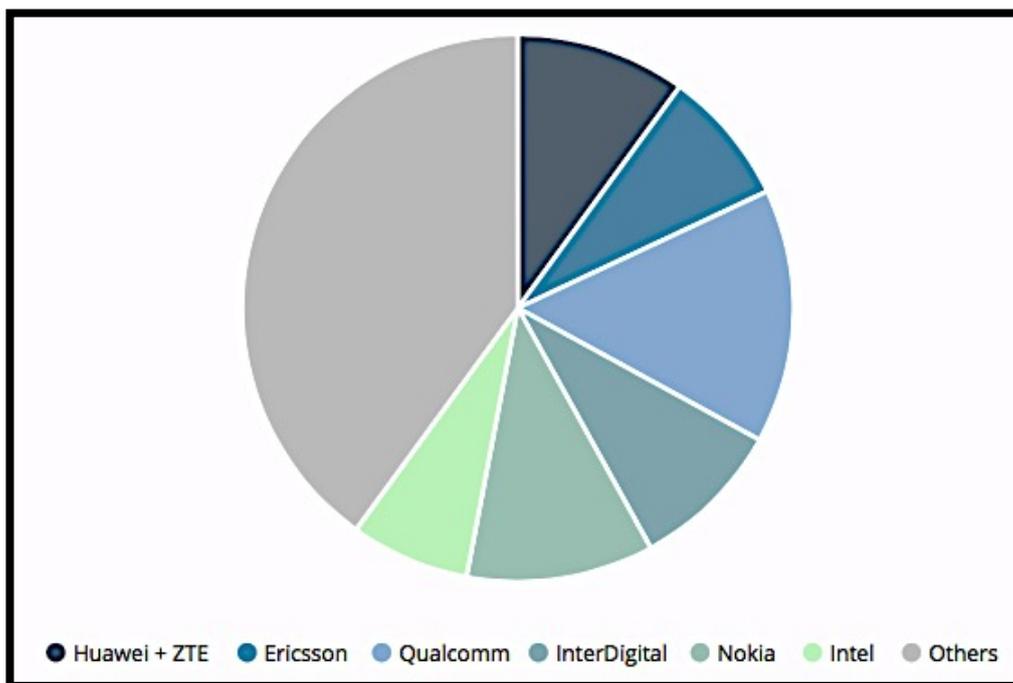
ZTE, which represented about 7 % of the 4G SEP, were rising to 10% of the 5G patents, surpassing Ericsson (9%) and running just behind Nokia (11%) (Figure 34).

Figure 33. Global IP Traffic, 2017-2022

IP Traffic, 2017-2022	2017	2018	2019	2020	2021	2022	CAGR (2017-2022)
By Type (Petabytes [EB] per Month)							
Fixed Internet	85	107	137	174	219	273	26%
Managed IP	26	31	35	40	44	45	11%
Mobile data	12	19	29	41	57	77	46%

Source: CISCO

Figure 34. Share of Critical 5G Patents by Company



Source: Lexnovo

Qualcomm, which was the clear winner in terms of 4G patents finds itself in a paradoxical position: the Chinese market, that today contributes more than 60 percent of its global revenues, with intellectual property and the production of 4G chips, also happens to be the most likely to challenge its dominant position²⁷. Huawei has learned the lesson: it has spent 15 percent of its annual revenue, 61 billion \$US, over the past decade, to develop technologies that have the potential to become global 5G telecom standards. The firm plans to increase its R&D to 15 billion \$US per year, and could reach

²⁷ Joy Dantong Ma, "From windfalls to pitfalls: Qualcomm's China Conundrum", *MacroPolo*, Paulson Institute, 2018: <https://macropolo.org/analysis/from-windfalls-to-pitfalls-qualcomms-china-conundrum/>

20 billion \$US in years to come. Huawei is building upon its established presence in 4G networks, which already amount to nearly a third of the global telecom market²⁸. If these plans are realized, Huawei could surpass Google’s Alphabet R&D investment in 2018, and reach an amount close to Amazon, the first and second MNC’s in terms of R&D expenses²⁹.

In November 2019, Huawei’s founder, Ren Zhengfei, has unveiled a plan to “repatriate” numerous experienced scientists, specialists and engineers in order to fill in the technological vacuum due to Washington’s sanctions, and a transfer of its R&D funding policy from the U.S to Canadian institutions³⁰. Huawei has been particularly active in the 5G standardization institutions, if we refer to the number of 5G office applications and grant status, to the number of technical contributions to 5G standards, and to the number of engineers attending GPP meetings on 5G (Figures 35, 36, 37)³¹

Figure 35. Top patent owner of 5G declarations as to the number of patents families as to office of application and grant status (Iplytics, November 2019)

Company name	Declared 5G families	Filed at USPTO, EPO or PCT	Granted in one office
Huawei Technologies (CN)	3,325	2,379	1,337
Samsung Electronics (KR)	2,846	2,542	1,746
LG Electronics (KR)	2,463	2,296	1,548
Nokia (incl. Alcatel-Lucent) (FI)	2,308	2,098	1,683
ZTE Corporation (CN)	2,204	1,654	596
Ericsson (SE)	1,423	1,295	765
QUALCOMM (US)	1,330	1,121	866
Intel Corporation (US)	934	885	171
Sharp Corporation (JP)	808	677	444
NTT Docomo (JP)	754	646	351
China Aca. Of Telec. Tech. - CATT (CN)	588	360	72
InterDigital Technology (US)	428	346	226
Guangdong Oppo M. Telec. (CN)	378	363	36

²⁸ Elsa B. Kania, *Securing our 5G Future: The Competitive Challenge and Considerations for U.S Policy*, Center for a New American Security, November 2019.

²⁹ Cf. Price Water House Cooper Innovation 1000: <https://www.strategyand.pwc.com/gx/en/insights/innovation1000.html#GlobalKeyFindingsTabs4>

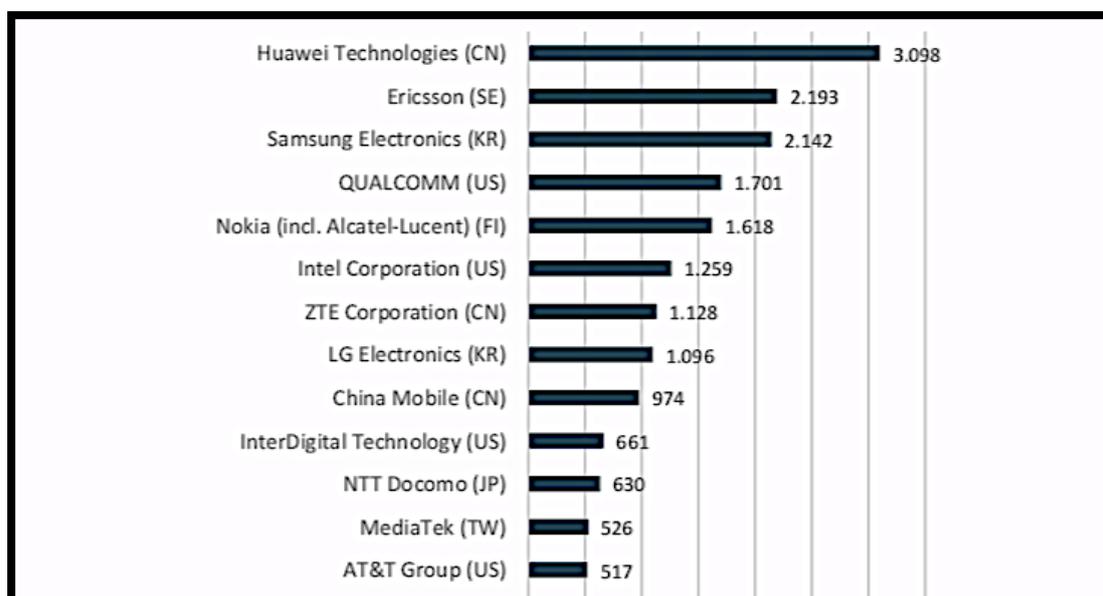
³⁰ Di Yi Caijing, November 17, 2019: <https://www.yicai.com/news/100406138.html>

³¹ Tim Pohlmann, “Who is leading the 5G patent race? A patent landscape analysis on declared SEPs and standards contribution”, November 2019, www.iplytics.com

Figure 36. Top companies submitting technical contributions for 5G standards (Iplytics, November 2019)

Contributing company	5G contributions	First contributor	Weighted	In UE groups	Approved
Huawei Technologies (CN)	19,473	17,466	11,992	11,662	5,855
Ericsson (SE)	15,072	13,195	12,690	8,936	5,114
Nokia (incl. Alcatel-Lucent) (FI)	11,555	9,633	5,314	7,195	3,804
QUALCOMM (US)	5,994	4,846	4,629	4,160	1,994
ZTE Corporation (CN)	4,692	3,628	3,492	3,117	1,188
Samsung Electronics (KR)	4,573	3,541	3,434	3,539	1,239
Intel Corporation (US)	3,656	2,895	2,752	2,798	962
LG Electronics (KR)	2,578	1,966	1,880	2,129	685
China Mobile (CN)	2,567	1,748	1,737	1,437	787
CATT (CN)	2,562	2,050	2,026	1,979	554
NTT Docomo (JP)	2,042	1,487	1,459	1,491	549
MediaTek (TW)	1,653	1,176	1,222	1,526	443
Orange (FR)	1,415	977	975	647	462
NEC Corporation (JP)	1,276	870	901	1,005	347

Figure 37. Number of attending engineers to 3GPP meetings relevant to 5G (as of Iplytics Platform, November 2019)



This data does not mean that China has a leadership position in 5G, since not all patents are of equal value. Companies may overestimate and thus over-declare the number of patents they own. But it is clear that China has changed from a relatively passive position in 4G to a contender in the global technological race. In March 2018, Washington detected Huawei's influence behind the failed attempt of the then Singapore-based Broadcom to buy the U.S chip giant and 5G leader Qualcomm Inc. in a US\$ 117 billion deal. And in July 2018, Beijing prevented Qualcomm's planned acquisition of Dutch

chip maker NXP Semiconductors NV, a deal that would have helped Qualcomm to profit from 5G investments in new markets such as connected cars.³².

CYBERSECURITY RISKS AND THE FRAGMENTATION OF THE 5 G MARKET

The same year, the U.S has taken the lead on the global stage to ban Chinese telecom and equipment companies, by emphasizing their threat on national security. After it was cut off from the U.S market, the European market became a strategic one for Huawei, which aims to clear doubts about its reliability and has established a center for cybersecurity not only in Bonn, but also in Brussels. In Brussels, Huawei is one of the most active players with an annual budget of 2,2 billion Euros and eight lobbyists with access to the European Parliament³³.

The U.S ban has contributed to a fragmentation of the European market between countries that accept, refuse or discuss Huawei's equipment (Figure 38). The ban extends to U.S allied countries in other continents (Figure 39). The debate is complex, as the reliance of 5G networks make economy and national security more vulnerable. As "there is no ability to prove the absence of malicious code or backdoor in interconnected ICT system (for any manufacturer not just Chinese), society, government and mobile operators have to trust the manufacturer to fix vulnerabilities, and this trust depends on the legal and political system in which the manufacturer operates"»³⁴. But, according to the same analyst, "much of the current debate is driven under the assumption that only the development of Chinese network equipment bears risk for national security, which is naïve". Snowden documents revealed for instance that the NSA had a special team to intercept certain CISCO software and hardware types of devices (router and servers) in order to spy chosen targets³⁵.

The "politicization of the supply chain", while almost 80 percent of 5G related spending would be used for hardware, may delay 5G implementation and generate important geopolitical implications. Japan and South Korea, which have already banned Huawei, are estimated to be the closest followers of the two giants. Emerging countries may prefer China's lower costs and equal or higher performance 5G offering, especially as part of the Digital Belt and Road Initiative³⁶. Thus Chinese influence will expand, in the South, South-East Asia, as well as in Africa. In many countries where Huawei actually operate and manage the equipment of the host telecom companies, a backdoor is not needed if you already have a key to the front door. Huawei and ZTE are already exporting face recognition technologies fuelled by 5G connectivity to repressive regimes globally, such as Mongolia, Ethiopia, Zimbabwe, Malaysia and Ecuador³⁷.

³² Josh Chin *et al.* "The 5G race", *Wall Street Journal*, September 9, 2018.

³³ Xuewu Gu *et al.*, *Geopolitics and the Global Race for 5G*, CGS Global Focus, Center for Global Studies, University of Bonn, May 2019.

³⁴ Jan-Peter Kleinhans, *5G vs. National Security: A European Perspective*, Stiftung Neue Verantwortung, February 2019: https://www.stiftung-nv.de/sites/default/files/5g_vs._national_security.pdf

³⁵ *Ibidem*.

³⁶ Xuewu Gu *et al.*, *op.cit.*, p.33 and 69.

³⁷ Charles Clancy, Testimony before the Senate Committee of the Judiciary, Hearing on 5G: The impact on national security, intellectual property and competition, US Congress, May 14, 2019: <https://www.judiciary.senate.gov/imo/media/doc/Clancy%20Testimony.pdf>

Figure 38. Discussion of Huawei Bans in Europe

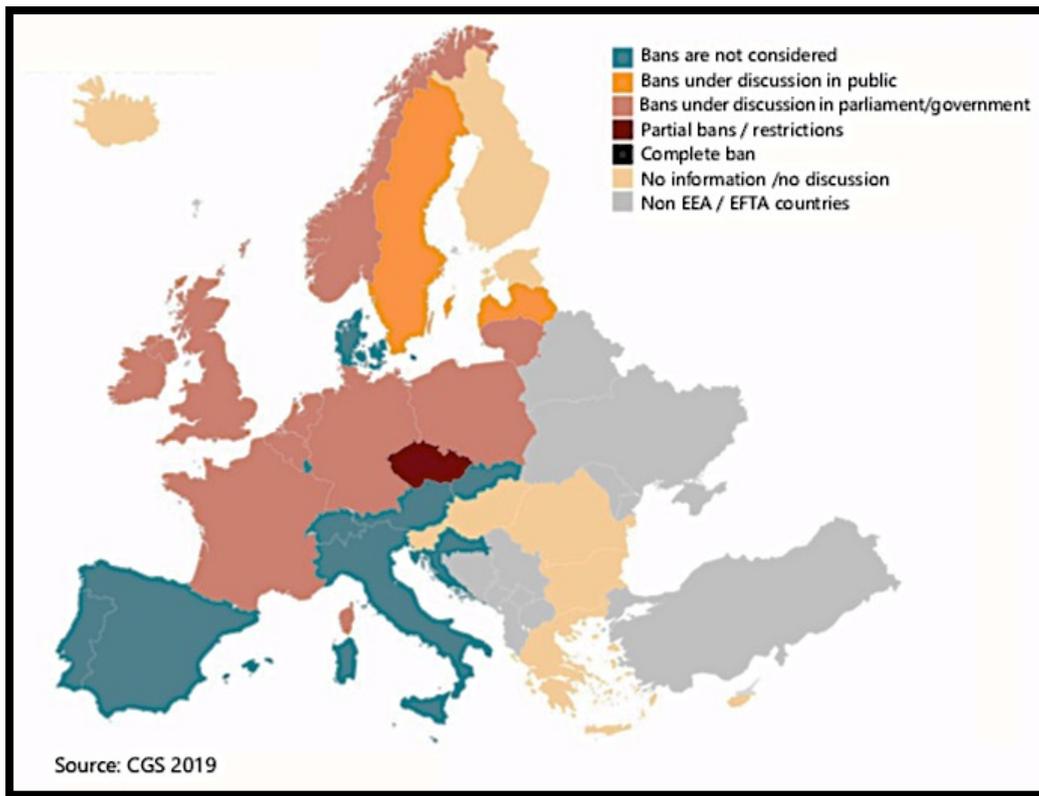


Figure 39. “14 Eyes”- Countries’ Loyalty to the United States Regarding Huawei Bans



As 5G will be a critical component of new infrastructure, a cyber-attack on these systems may not only cause data theft but also damage public safety and critical industries. The question of cybersecurity becomes central, as the consequences of insecurity could be far graver than before its implementation. Apart from the physical dimension of switches and routers, 5G is built on layers of complex software that are far more adapting and constantly updating without the user’s knowledge. Whoever controls the network, controls the information flow, and may be able to change or copy data. In case of geopolitical disagreement or conflict, this may lead to a “win without fighting situation”, the ideal of Sun Zi’s strategy, in his *Art of War*. Nevertheless, U.S attempts to dissuade nations that are considering working with Huawei are perceived as excessive or

protectionist, and do not take into account viable or positive alternatives that are to be built with allied countries³⁸.

Figure 40. Potential Vulnerabilities of the IoT

	Device	Communication Network	Data
Types of Vulnerabilities	<ul style="list-style-type: none"> • Hardware • Firmware • Software • Sensor failure • Default passwords • Denial-of-service attack 	<ul style="list-style-type: none"> • Compromised or fake communication network (e.g., Wi-Fi or cellular) • Denial-of-service attack 	<ul style="list-style-type: none"> • Software • Unsecure or compromised communication network
Risks	<ul style="list-style-type: none"> • Modification of firmware, hardware, or software without authorization • Unauthorized access to information or services • Loss of service 	<ul style="list-style-type: none"> • Loss of service • Physical tracking of user • Unauthorized access to information or services 	<ul style="list-style-type: none"> • Unauthorized access to information • Physical tracking of user • Modification of data without authorization • Impersonating a device, user, or recipient

Source: Adapted from Zubair A. Baig, "Future Challenges for Smart Cities: Cyber-Security and Digital Forensics," Digital Investigation, August 15, 2017; U.S. Department of Homeland Security and the National Institute of Standards and Technology, Study on Mobile Device Security, April 2017, 18.

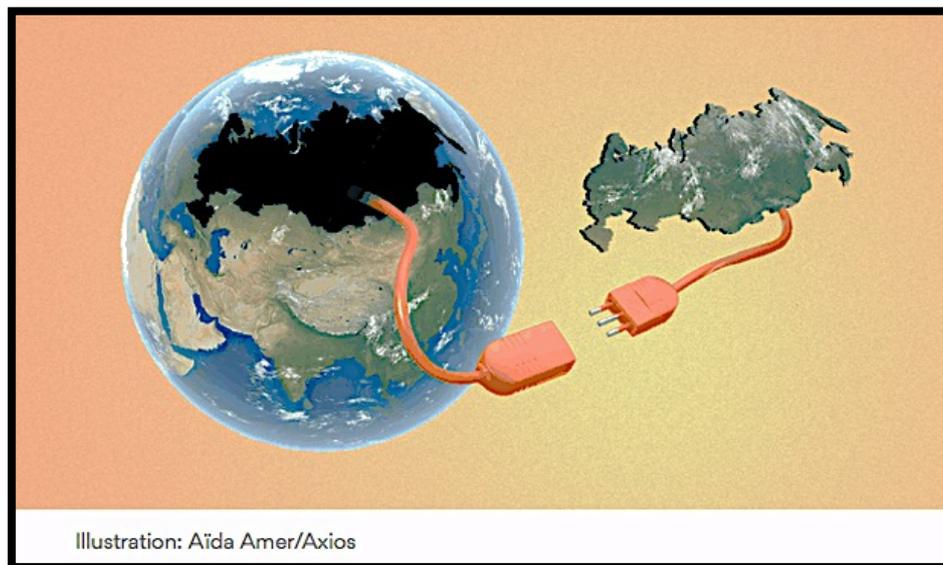
There are so many potential vulnerabilities of the Internet of Things (IoT) (Figure 40) that some countries like Russia (Figure 41), in the name of security and digital sovereignty, are planning to follow China’s “splinternet” model, where the national access to the World Wide Web is under government control. Rapid proliferation of IoT devices is worsening global security risks. The majority of these devices are manufactured in China, which through a state led approach, is trying to set IoT international standards, as part of its overall strategy to become a science and technology powerhouse, and move up the value chain, while encouraging civil-military fusion³⁹. By comparison, U.S firms are currently market leaders in industrial IoT, by market value, and IoT-enabling technologies such as semi-conductors and cloud computing⁴⁰. But here again the U.S advance is subject to the competition of Alibaba Cloud, while the Europeans do not have competitive cloud platforms such as Amazon Web Services, Google or Microsoft Azure.

³⁸ Elsa B. Kania, *op.cit.*, p.12-15.

³⁹ John Chen *et al.*, *China’s Internet of Things*, Research Report on behalf of the U.S-China Economic and Security Review Commission, October 2018.

⁴⁰ U.S. Congress, *U.S.-China Economic and Security Commission Report*, 2018, p.447-448.

Figure 41. Russian Internet is planning to go solo



CONCLUSION: WHERE ARE WE HEADING FOR?

As underlined by Elsa Kania, China has challenged the American leadership in innovation through investing heavily in 5G, a vital platform to realize the potential of frontier technologies like artificial intelligence, with its multiple and unexpected applications. It has seized a historic opportunity, which could allow it to surpass its main rival in this decisive technology where the U.S may not be able to achieve decisive leadership. In the current 5G competition, neither the Department of Defense nor the U.S are in a position to dictate the content and integration of the 5G supply chain, in part because no American companies manufacture the equipment to transfer signals between mobile phones and the tower and sites that make up the network. According to the U.S Defense Innovation Board, this mismatch may create serious security risks if the rest of the world accepts Chinese products as the cheaper and superior option⁴¹.

The technological decoupling between the U.S and China continues in areas where it is most difficult to distinguish between commercial and military applications. After Huawei and ZTE, the Trump administration blacklist extends to 200 Chinese companies, including facial recognition start-ups Sense Time, Megvii and Yitu, three of China's four dragons of artificial intelligence⁴². At the same time, the Prague 5G security conference with participants from 32 countries, announced in its recommendations that the «risk assessments of supplier's products should take into account all relevant factors, including applicable legal environment and other aspects of supplier's ecosystem» while the European Agency for Cybersecurity (ENISA), identifies Nation-States as the main threat agent in 5G networks⁴³. In this tense context, the 5G and IoT development may lead to

⁴¹ Milo Medin and Gilman Louie, *The 5G Ecosystem: Risks and Opportunities for DOD*, Defense Innovation Board, April 3, 2019. James Manyika *et al.*, *op.cit.*, Council on Foreign Relations Report, 2019, p.58.

⁴² Takashi Kawakami *et al.*, *Nikkei Asian Review*, November 19, 2019.

⁴³ Prague Proposals, 5G Security Conference: <https://www.vlada.cz/en/media-centrum/aktualne/prague-5g-security-conference-announced-series-of-recommendations-the-prague-proposals-173422/>
ENISA, *Threat Landscape for 5G networks*, November 21, 2019: <https://www.enisa.europa.eu/publications/enisa-threat-landscape-for-5g-networks>

split the Internet governance according to different national interests, and allegiance, a kind of revenge of the digital Chinese model of “internet sovereignty” on the World Wide Web.

Some countries are already responding to China’s digital unilateralism by following the same path: in Asia alone, India, Cambodia, Myanmar, Thailand, Indonesia, Brunei and Vietnam have restricted public Internet and social media access⁴⁴. In 2017, China called for a multilateral approach to governing cyberspace, with the U.N taking the leading role. In 2018, the launch of the new Digital Silk Road is another way to impact global Internet governance through Chinese trade and investment policy⁴⁵. All these developments explain the reaction of Tim Berners Lee, best known as the inventor of the World Wide Web, who launched a new international contract⁴⁶ so that “the Web remains open and a global public resource, for people everywhere, now and in the future”.



* The author would like to thank Delia Morris for her revision of the English of this paper.

⁴⁴ Hosuk Lee-Makiyama, “Will Asia’s digital integration be derailed”, *East Asia Forum*, April 7, 2019 : <https://www.eastasiaforum.org/2019/04/07/will-asias-digital-integration-be-derailed/>

⁴⁵ Adam Segal, “When China Rules the Web: Technology in Service of the State”, *Foreign Affairs*, September/October 2018: <https://www.foreignaffairs.com/articles/china/2018-08-13/when-china-rules-web>

⁴⁶ <https://contractfortheweb.org/>