A Playbook for Accelerating 5G in Europe

BCG

The Boston Consulting Group

The Boston Consulting Group (BCG) is a global management consulting firm and the world's leading advisor on business strategy. We partner with clients from the private, public, and not-for-profit sectors in all regions to identify their highest-value opportunities, address their most critical challenges, and transform their enterprises. Our customized approach combines deep insight into the dynamics of companies and markets with close collaboration at all levels of the client organization. This ensures that our clients achieve sustainable competitive advantage, build more capable organizations, and secure lasting results. Founded in 1963, BCG is a private company with offices in more than 90 cities in 50 countries. For more information, please visit bcg.com.

A PLAYBOOK FOR ACCELERATING 5G IN EUROPE

HEINZ BERNOLD

MICHAEL STEIGER

MAIKEL WILMS

WOLFGANG BOCK

RÜDIGER SCHICHT

September 2018 | The Boston Consulting Group

CONTENTS

EXECUTIVE SUMMARY

Europe's mobile industry faces a next-generation conundrum with major ramifications for mobile network operators, policymakers, consumers, and businesses. The ability of 4G technology to handle fast-rising traffic demand is approaching its end. Current networks cannot support enormous data growth without massive site "densification"—increasing the number of cell towers and antennas in heavy traffic areas—which could drive up costs by as much as three times and is generally not acceptable to city governments and residents. We estimate that 4G capacity in the typical large European city will be exhausted by 2021. Advanced 5G technologies present the best and least expensive way to accommodate traffic increases, but thanks in part to the widespread use of unlimited data plans, monetization of traffic growth is a major challenge, and network operators have little incentive to invest in, and build out, advanced networks.

Adverse policy and innovation environments have already resulted in EU nations falling behind the US and Asia-Pacific with respect to both digital innovation and the development of digital and mobile economies. Europe needs to stimulate the rapid and efficient deployment of 5G if it is to drive economic development and job creation, stem the shift of profit pools to the US and Asia-Pacific, and enjoy the consumer and business advantages of 5G high-speed connectivity. If Europe continues on its current path, it is electing to forgo the benefits of digitization.

Advanced 5G technology has the ability to substantially expand network capacity and lower its cost. Our projections show that the costs of serving increasing traffic demand with 4G technology would triple from 2020 to 2025, driven largely by site densification. Under a 5G scenario, the average annual network spending would be about half of what it would be under 4G; nevertheless the increase in absolute spending levels will still constitute a serious economic challenge for telcos.

Full 5G deployment is viable from a financial perspective, but it requires the full engagement of all stakeholders. Our analysis indicates that the investment hurdles can be overcome, but doing so will require all participants to ramp up their commitment to 5G in a con-

certed way. The telecommunications industry must lead, with the support of governments and telco ecosystem partners and the participation of network-dependent entities, such as content and service providers. Sticking with 4G is not a long-term sustainable option, especially in urban areas. Neither is building out and operating a 5G network on 4G business models.

Network operators need to change the way they think about 5G, adjusting old business cases and pursuing new ones to make the economic model work. Operators need to optimize network deployment using all available tools, including advanced analytics and artificial intelligence, to lower the cost base. The industry also needs to collectively use the upgrade to 5G, and the new services that it would enable, to explore pricing models that move away from the current data plans, which have contributed to a downward spiral in revenues per user in recent years. Operators and European industry as a whole need to work together to explore new use cases with innovative business models in such areas as mission-critical services and the so-called massive Internet of Things, which can generate new revenue streams for telcos while enhancing the global competitiveness of Europe's companies and economy.

Policymakers and regulators can help stimulate and enable change in thinking and approach. Past policy has focused on incentivizing competition and keeping prices low. Today's priority should be on incentivizing investment—especially in the next-generation infrastructure that can enable further technological advances. This paradigm shift has widespread implications for regulation in areas as diverse as spectrum auctions and municipal planning rules.

Nonoperator participants in the telco ecosystem can also benefit from facilitating deployment of 5G. For tower companies, this means working more closely with operators to prepare sites for 5G deployment, considering new partner pricing models, and potentially providing active network-sharing services. For technology vendors (including makers of equipment and handsets), it also means being first with the innovations that are most needed, such as innovative handsets and open standards for more software-based networks.

Companies in all sectors should work with their telco partners to investigate and unlock the benefits enabled by 5G capabilities. Financial-services firms, industrial-goods companies, health care providers, and others that plan to leverage digital innovation need to engage with the various players in the required ecosystem—especially with regard to connectivity to the cloud—and make their views known about the importance of reliable infrastructure. Such cooperation will give governments and operators confidence in the potential of 5G business cases and stimulate innovation and 5G leadership in Europe.

Countries in North America and Asia-Pacific have already opened a 5G lead. Operators in Europe have not been idle—one Scandinavian telco even claims the first commercial 5G network—but the transition is not happening broadly or quickly enough. In this report, we present a playbook for how the European telecommunications industry can catch up.

INTRODUCTION

The 45-year history of the mobile industry has been one of rapid growth and enormous value creation for consumers, businesses, investors, and national economies. And even as mobile penetration matures in most developed countries, growth and value generation are set to continue as more users come online in emerging markets, and new uses—such as the Internet of Things (IoT), augmented reality (AR), and artificial intelligence (AI)—enter the mainstream.

There's a big question, however: will the gains be broadly distributed, or will they be concentrated in the two centers of gravity of today's digital world—the US West Coast and the East Coast of China? (See "The New Digital World: Hegemony or Harmony?" BCG article, November 2017.) In mobile, these two gold coasts are already home to the companies with the two major smart-device operating systems (iOS and Android), many of the leading device and component manufacturers, the top enablement platform companies, and most of the application, content, and service providers. Only at the foundational levels of the mobile stack—network and infrastructure companies and telecommunications service providers—is there a global mix of multinational, regional, and national players.

Europe's mobile industry faces a particular next-generation conundrum, one with major ramifications for mobile network operators (MNOs), policymakers, consumers, and businesses. The ability of current 4G technology to handle fast-rising traffic demand, led by exploding video consumption, is approaching its end. We estimate that 4G capacity in typical large European cities will be exhausted by 2021, and expensive and often-unpopular network "densification"—increasing the number of cell towers and antennas in heavy traffic areas—measures will then be required to handle traffic growth. Advanced 5G technologies present the best, and least expensive, way to accommodate traffic increases. In Europe, however, thanks in part to the widespread use of unlimited data plans and relatively low prices, monetization of traffic growth is a major challenge, and investing in, and building out, 5G infrastructure already lags other markets.

Clearly no one benefits if Europe falls further behind. Consumers will not be able to make full use of the latest technologies and advanced applications, such as real-time translation, connected medical devices, and AR. Businesses will not be able to take full advantage of the IoT and Industry 4.0 applications, which will affect their global competitiveness. European nations and the EU as a whole will not realize the full contributions that the mobile industry can make, directly and in-

directly, to their economies. European countries will also find themselves at a competitive disadvantage with regard to other nations in the global arena for the development of new businesses and jobs. All of which seems unnecessary at the macro level, since research has shown that the economic payback on digital infrastructure investment is inordinately quick—often in less than one year. (See *Financing a Forward-Looking Internet for All*, a report by the World Economic Forum in collaboration with BCG, May 2018.)

Europe and its mobile telco industry have the opportunity and the obligation to solve the problem of exponential traffic growth, but all participants—network operators, their ecosystem partners, policymakers, and regulators—need to ramp up their commitment to 5G. The industry must lead with the support of governments and telco ecosystem partners. And as they assess infrastructure investments, telcos need to think through the opportunities for new pricing structures and products and services that enhanced network capabilities present. Sticking with 4G is not a sustainable option. Neither is building out and operating a 5G network on 4G business models.

Countries in North America and Asia-Pacific have already opened a lead in 5G. Operators in Europe have not been idle—one Scandinavian telco even claims to have created the first commercial 5G network—but the transition is not happening broadly or quickly enough. In this report, which is based on research and market simulations performed by BCG in 2018, we present a playbook for how the European telecommunications industry can catch up. (See the sidebar "About This Report.")

ABOUT THIS REPORT

Advanced mobile network infrastructure, commonly known as 5G, is essential to handle the fast-rising growth in global traffic and to take advantage of next-generation mobile products and services. Some countries and markets are moving more quickly than others to invest in, and build out, next-generation networks. Europe currently lags markets in North America and Asia-Pacific. To better understand why, and to look at how a widening gap can be closed, Huawei Technologies commissioned The Boston Consulting Group to prepare this independent report. The results have been discussed with Huawei executives, but BCG is responsible for the analysis and conclusions.

4G RUNS OUT OF ROOM

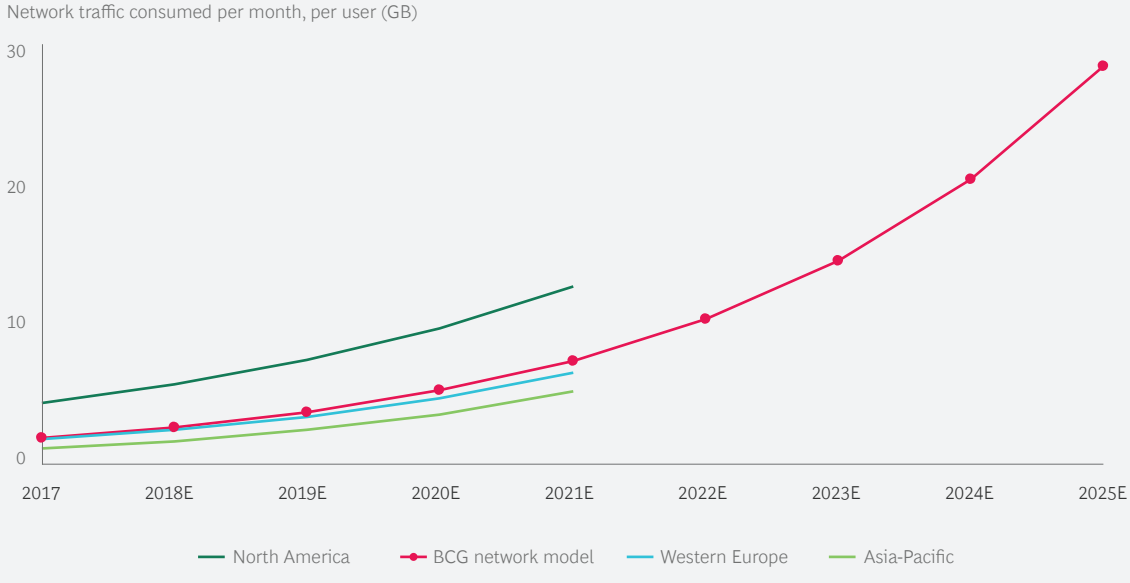
EUROPE FACES THREE INTERCONNECTED problems for mobile networks: exponential traffic growth, unsustainable site densification, and little incentive to invest in building out networks.

Traffic Growth: No End in Sight

Cellular traffic demand continues to grow exponentially, driven largely by video applications, and we expect this growth to continue for at least the next decade. Traffic growth forecasts vary among countries and operators, but according to the Cisco Visual Networking Index, consumed gigabytes (GB) per user per month ranged from 0.7 GB to 4.4 GB at the end of 2017, and growth rates are expected to range from 30% to 58% annually until 2021. (See Exhibit 1.) BCG's case experience confirms this view.

Many industry observers question whether these levels of growth can realistically continue: at some point, they say, the picture quality

EXHIBIT 1 | Europe Will Experience Exponential Mobile Data Traffic Growth



Sources: Cisco Visual Networking Index; BCG analysis.

and screen size of smartphones, and the data rates charged by carriers, will conspire to cap usage. But our research found that the young customers of one Western European operator (offering unlimited data plans) were consuming, on average, more than 30 GB a month—with no end in sight. New technological capabilities and services, such as AR and in-car entertainment, as well as an ever-improving customer experience, will continue to fuel data consumption growth. Moreover, as applications become more sophisticated, future networks must deliver enhanced capabilities—such as faster data speeds, ultra-low latency, and high reliability—if they are to support new use cases and applications, such as the development of mission-critical services.

4G Requires Unsustainable Densification

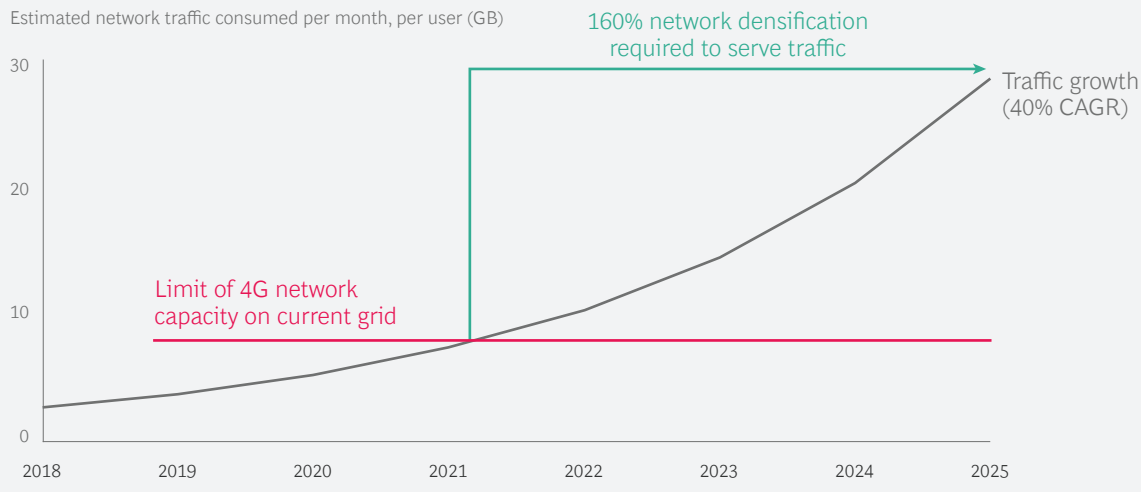
The resulting problem is that current 4G networks cannot support this enormous data growth without massive site densification, which has significant economic and social implications. Our simulations show that in a typical large Western European city (Berlin, London, Milan, or Paris, for example), 4G capacity in the existing network grid will be exhausted by 2021, and network infrastructure density will need to almost triple to accommodate the continued growth of traffic at a rate of 40% per year.[1] (See Exhibit 2.)

These targets are ultimately unrealistic given the expense, time, and unpopularity involved in adding new sites. MNOs already struggle to commission a few new sites in urban areas because of legal and regulatory issues. The lead time for new permits is long. Local opposition to new towers can be intense. In addition, already-dense network grids with low intersite distances prevent operators in many markets from further densification within current power limits.

Little Incentive for Investment

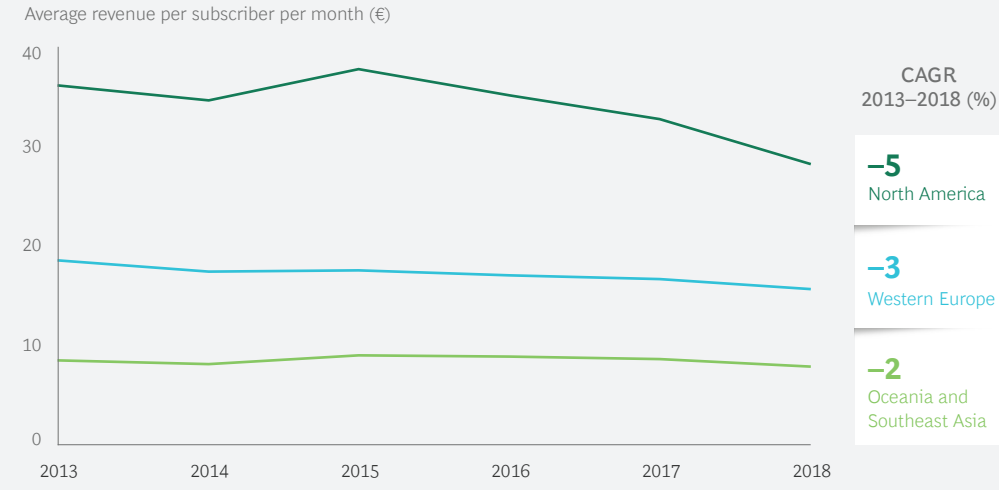
Network operators' lack of incentive for investment is also a problem. Traffic growth today is largely driven by video applications, which telcos struggle to monetize, especially in the increasing number of markets that have unlimited data plans. In fact, as the internet and associated new industries have disrupted network operators' traditional revenue streams (such as communication and entertainment services), telco revenues have either remained mostly constant or declined slowly: the average revenue per user (ARPU) fell by about 3% from 2013 to 2018. (See Exhibit 3.) Yet while mobile operators have been under pressure, the technology sector as a whole has flourished. Operators' share of industry profits, therefore, have declined steadily since 2010, limiting companies' ability to invest.

EXHIBIT 2 | 4G Networks Cannot Support Data Traffic Growth Without Massive Densification



Source: BCG network model.
Note: Densification = an increase in the number of cell towers and antennas in heavy traffic areas.

EXHIBIT 3 | For Telcos, the Average Revenue per User Is Declining, Especially in Europe and North America



Sources: Ovum; BCG analysis.

We do not expect this situation to change, even with the introduction of next-generation, high-quality broadband connectivity. Mobile subscribers historically have not had to pay more for either additional services or data enabled through new radio access technology. As a consequence, subscribers see little reason to begin doing do so now—which is something of a marketplace paradox because research shows that they would be willing to pay substantially more. Plans with large or unlimited data allowances are commonplace in many European markets, and competition among carriers makes it hard for any individual MNO to adjust its data plan structures without losing share to competitors. Previous improvements in technology, such as 3G and 4G, did not bring revenue growth for telcos by themselves. The telecommunications industry may be unique in that the 40% annual unit growth does not generate revenue growth. The introduction of 5G and the new use cases it supports (such as AR, enhanced mobile broadband, and real-time translation) present an opportunity to rethink pricing models and approaches.

All of which leads to the question that BCG and the GSMA asked earlier this year: What if the telecommunications infrastructure to support all that traffic growth hasn't been built out? Suppose the high-quality mobile broadband connectivity that is expected to provide the capacity and the capability for high-speed, highly reliable, mission-critical communications falls short. Suppose the mobile revolution slows, or even stalls, because data traffic slows or stalls—the digital equivalent of a rush-hour traffic jam on a big-city multilane motorway. Then what?

NOTE

1. For our mobile network simulation, we assumed that annual data traffic would grow by a rate of 40% per year.

5G TO THE RESCUE?

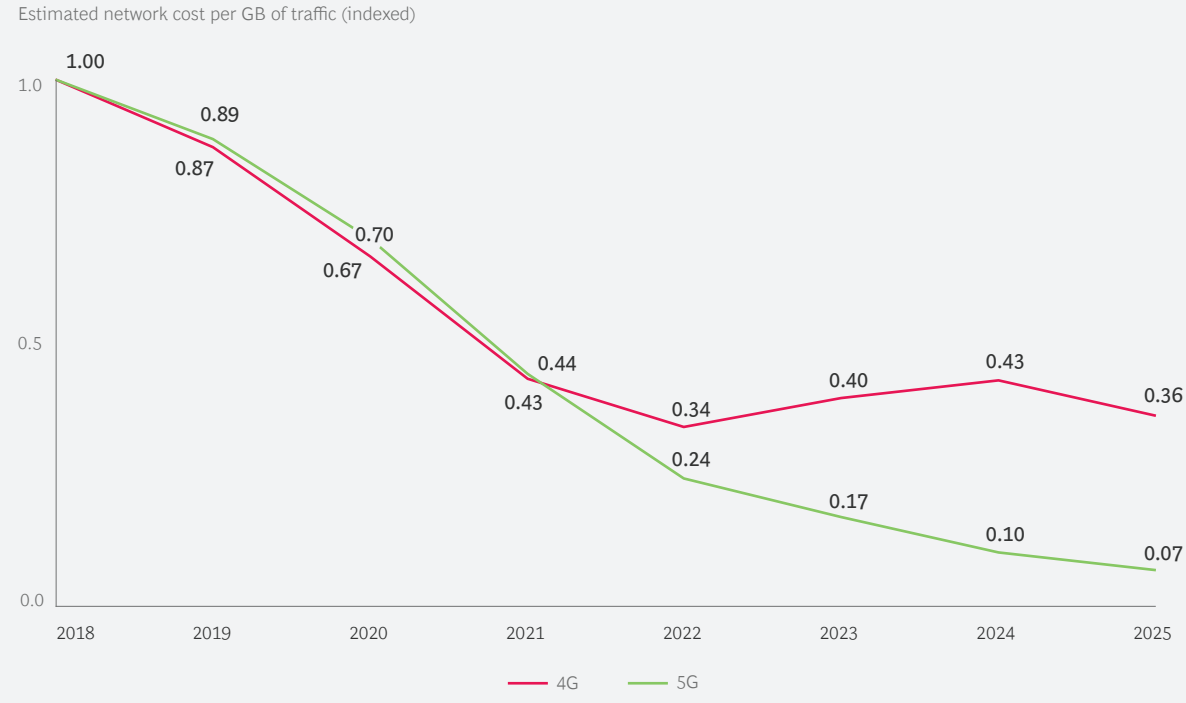
The package of technologies that go under the name 5G has the ability to both substantially expand network capacity and lower that capacity's cost because the data capacity of 5G networks is far greater than that of 4G networks, even when the latter employ the latest LTE Advanced Pro technologies. This is the result of two factors: 5G technology's ability to use much more spectrum (hundreds of megahertz versus tens of megahertz) and new technologies, such as massive multiple-input, multiple-output (MIMO) antennas. For example, a 5G network using 100 MHz spectrum in the 3.x GHz band, combined with 64x64 massive MIMO (64 antennas each for upstream and downstream signals), has up to seven times more capacity than a state-of-the-art 4G configuration—double the spectrum plus a nearly fourfold MIMO gain.[1]

The costs of serving increasing traffic with 4G technology would triple by 2025.

As capacity rises, the network cost per GB falls fast. Our simulations show that the cost per GB in a 4G-only scenario will decline by about 64% between 2018 and 2025, although it will eventually increase again with densification.[2] With the adoption of 5G, the cost per GB will fall even more—a drop of more than 90%. (See Exhibit 4.) Moreover, combining forecast mobile data consumption (in GBs per user) and cost per GB shows that 5G can keep the average network cost per user at sustainable levels, which is not possible in the long run with only 4G. (See Exhibit 5.)

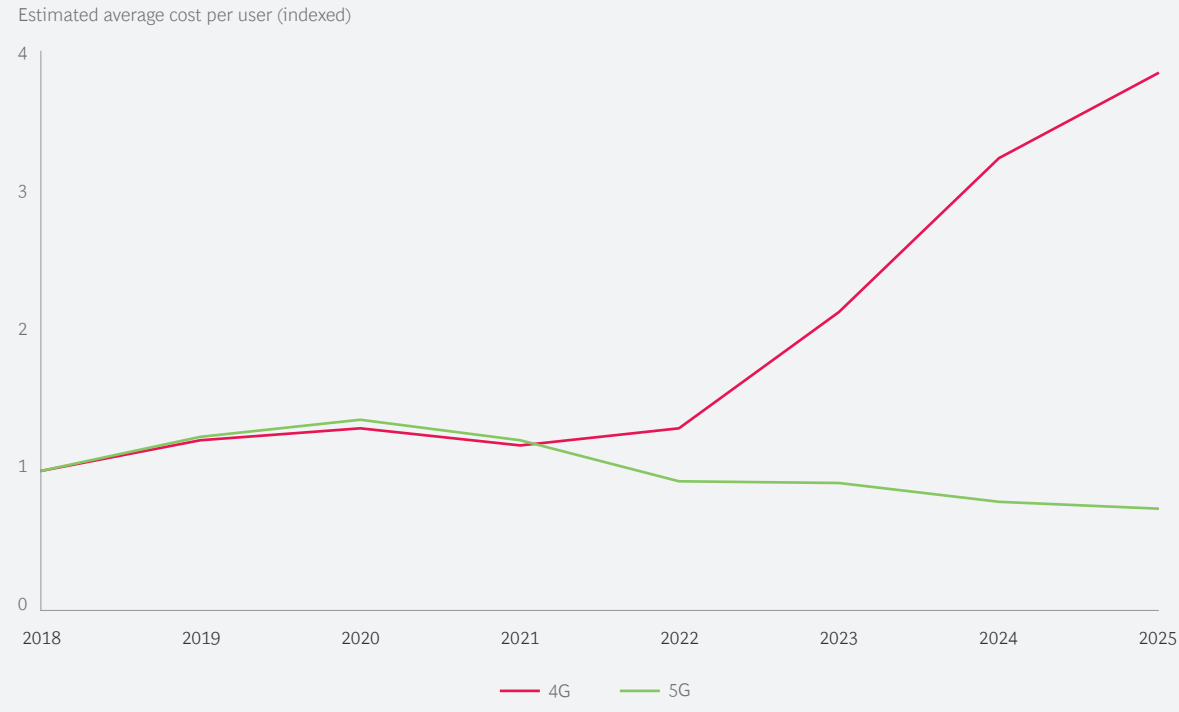
The problem is that many European telcos have little ability to monetize incremental traffic under unlimited data plans. A more telling point of reference, therefore, is an operator's network costs (including both capital and operating expenditures—capex and opex.). In our simulations, we looked at the costs for a typical integrated network operator in a large European city, starting with actual capex and opex from 2013 to 2018, the typical 4G investment cycle. Our projections showed that the costs of serving increasing traffic demand with 4G technology would triple from 2020 to 2025, driven largely by site densification.[3] (See Exhibit 6). Under a 5G scenario, however, an operator with 100 MHz of 3.x GHz spectrum using massive MIMO would not need to resort to network densification until 2025, with the exception of a few select hot spots or indoor areas. As a result, the operator's average annual network spending would be about half of what it would be under 4G, although the absolute cost would still be 60% higher than the reference period of 2013 to 2018, which consti-

Exhibit 4 | 5G Is the Cheapest Way to Serve Rising Data Demand



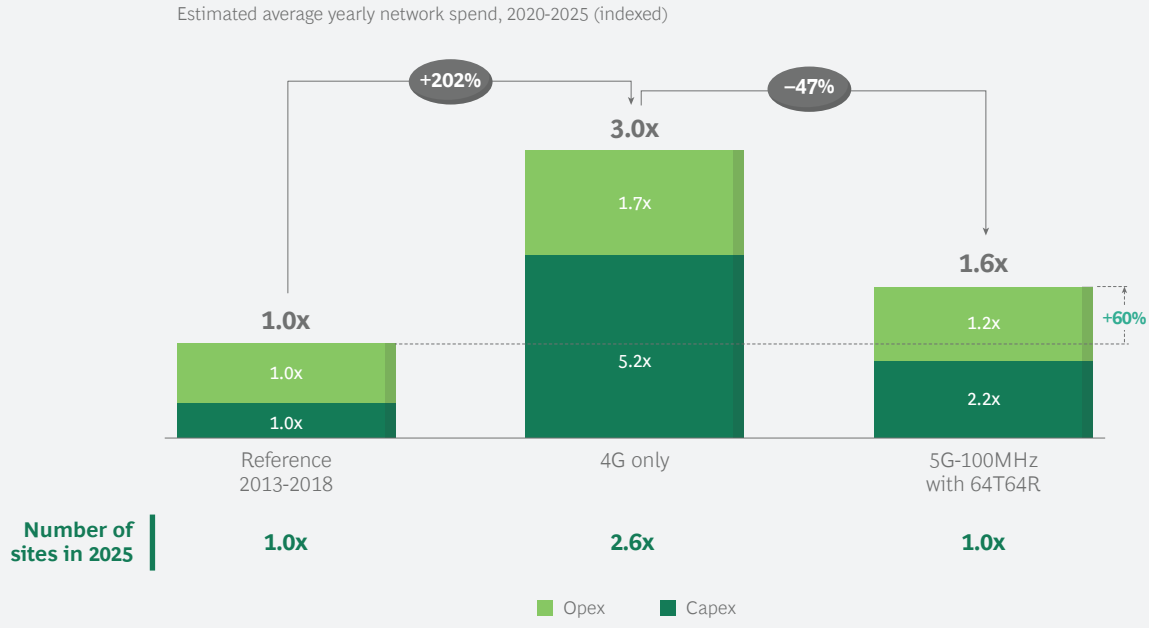
Source: BCG network model.
Note: Graph represents three-year moving average network spend.

Exhibit 5 | 5G Stabilizes Average Cost per User Despite Exploding Traffic



Source: BCG network model.
Note: Graph represents three-year moving average network spend.

Exhibit 6 | 5G Puts the Least Strain on Telcos' Network Spending



Source: BCG network model.
Note: 64T64R = 64 transmitters and 64 receivers.

tutes a serious financial challenge for telcos.[4] (See the Appendix for information about the parameters and methodology of our simulation.)

This challenge causes mobile operators to hesitate and delay. They are weighing the potential benefits from network differentiation or 5G fixed-wireless-access opportunities. But in the face of stagnating revenues, they are naturally hesitant to commit to major capex and opex increases without a clear vision of attractive financial returns.

This problem is not limited to Europe. "The investment in 5G is not easy if there is no innovative business model," the CTO of a leading East Asian operator told us. The CEO of a leading Western European operator said, "I talk to other CEOs around the world, and we've all been struggling a little bit making the 5G business case work."

MNOs inevitably will deploy 5G infrastructure. They will need to address data traffic growth, and the upgrades they will perform are natural pathways to 5G. They will also respond to competitive and stakeholder pressures. Many countries want to be 5G leaders for political reasons, and expectations are generally high for the anticipated consumer and business benefits. Still, mobile operators are likely to hedge their bets with deployment strategies that limit spending commitments and curb the broader social and economic benefits of advanced network buildout. These strategies include deploying 5G only in selected, dense urban areas (leading to a "5G divide"); delaying 5G rollout beyond the initial launch areas; and supporting existing use cases, such as mobile broadband and fixed wireless access while shunning emerging applications.

Europe faces an additional issue. Adverse policy and innovation environments have already resulted in EU nations falling behind the US and Asia-Pacific with respect to digital innovation and the development of digital and mobile economies. Impeding the rapid and efficient deployment of 5G can lead to an even wider digital gap, which will undermine broader economic development and job creation and result in the further shift of profit pools and investments to the US and Asia-Pacific.[5] (See the sidebar "The Slow Digitization of Europe.")

THE SLOW DIGITIZATION OF EUROPE

Digitization produces numerous benefits, including advancing economic progress by enabling consumers and companies to be connected all the time. Studies have shown that an increase of 10% in internet penetration leads to GDP growth, on average, of 2.8%; and when download speeds are doubled, the GDP grows by 0.3%.[1]

A study for the European Commission estimated that investing €56.6 billion in 5G could yield economic benefits of €113.1 billion annually and generate 2.3 million jobs in Europe by 2025.[2] (See the exhibit below.)

Europe has been slow to digitize. North America and Asia-Pacific are home to numerous global digital leaders—the combined market capitalization of US companies Google, Apple, Facebook, and Amazon would place them seventh on a list of the largest world economies. What's more, companies in Asia-Pacific, especially those in China, are growing strongly and staking out leading positions in digital mobility (for example, with on-demand bikes and car sharing) and e-commerce (with platforms such as Alibaba and JD .com). There is no similar phenomenon in Europe.

The slow digitization in Europe has had a significant impact on European telcos during the past decade. Looking at the global profit pool (using EBITDA) of telcos per region, the profit share of European operators has declined from 44% in 2007 to 31% in 2017. This development is especially alarming because it limits future investments. Telcos in the US and Asia-Pacific increased their profits during the same period: from 24% to 29% for North American telcos and from 32% to 40% for Asian telcos. (See the top exhibit on page 14.)

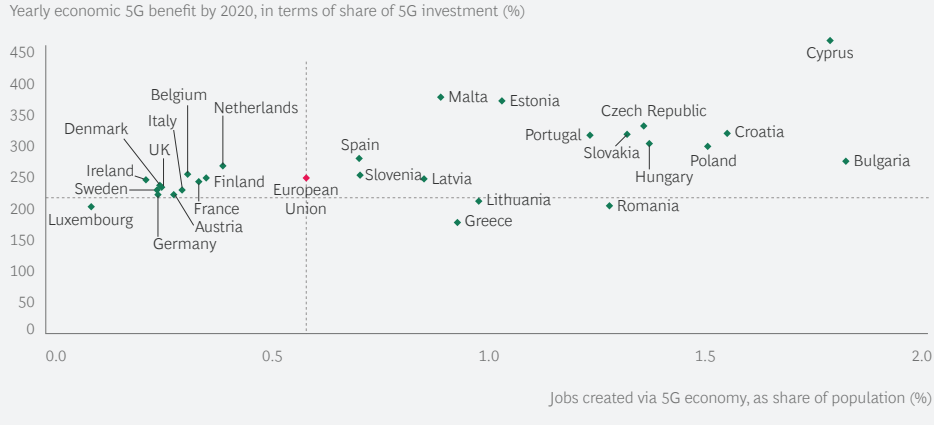
Moreover, between 2012 and 2017, only 6% of global venture capital investments in unicorns (startups with valuations of more than $1 billion) were invested in European unicorns. Overall, only 8% of unicorns receiving funding in this time period originated in Europe. (See the bottom exhibit on page 14.)

To counteract the imbalance between Europe and other developed economies, investments into digitization need to be rapidly increased.

NOTES

1. See *Financing a Forward-Looking Internet for All*, a report by the World Economic Forum, May 2018;

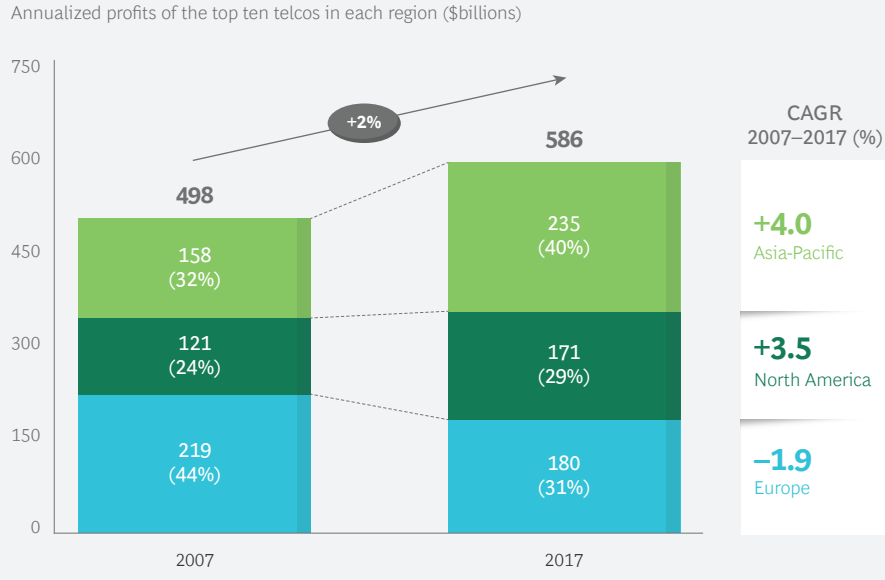
Europe's Macro Economy Benefits Strongly from 5G



Sources: *Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe,* a study for the European Commission, 2016; BCG analysis.

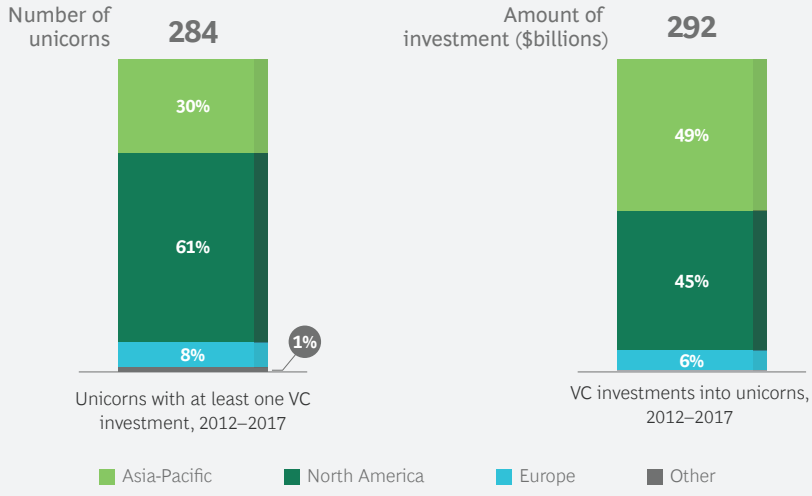
THE SLOW DIGITIZATION OF EUROPE
(continued)

Telco Profit Pools Are Growing in North America and Asia-Pacific but Declining in Europe



Sources: S&P Capital IQ; BCG analysis.

Most Venture-Capital-Backed Unicorns Are in North America and Asia-Pacific



Sources: PitchBook Data; BCG analysis.
Note: Analysis based on companies with a post-money valuation of more than $1 billion that received at least one VC investment from 2012 to 2017.

https://www.weforum.org/whitepapers/financing-a-forward-looking-internet-for-all.

2. See *Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe,* a study for the European Commission, 2016; https://ec.europa.eu/digital-single-market/en/news/5g-deployment-could-bring-millions-jobs-and-billions-euros-benefits-study-finds.

Notes

1. Scenario assumes 2x10 MHz 800 MHz, 2x20 MHz 1.8 GHz, and 2x20 MHz 2.6 GHz spectrum with 4x4 MIMO; 4G-only network spend could be lower for mobile network operators with significant TDD spectrum holdings (for example, in 2.3 or 2.6 GHz spectrum bands), deploying massive MIMO on TDD-LTE access technology. 3.x GHz spectrum was not considered for 4G due to lack of handset support.

2. Average network spending includes network capital and operating expenses (excluding spectrum fees).

3. Spectrum refarming and other available 4G levers do little to increase network capacity.

4. We note that the simulation results vary significantly depending on location, network topology, spectrum holdings, data traffic patterns, and consumption. We have computed other 5G deployment scenarios for large cities that result in the need for higher densification (including the rollout of small cells) and respective network spending.

5. See *Lead or Lose: A Vision for Europe's Digital Future,* an ETNO report, September 2017; https://etno.eu/datas/digital-age/leadorlose.pdf.

A 5G PLAYBOOK

Accelerating 5G deployment in Europe requires a concerted effort by multiple parties. All players have an interest in the success of 5G, and while they may individually understand its necessity, they need to step up and work together to make it happen. First and foremost is the telecommunications industry itself, but policymakers, regulators, and other players across this broad ecosystem have essential roles to play as well. In this chapter, we offer a playbook for each set of participants. Failing to master the 5G investment challenge will result in 5G being deployed sparsely, not yielding its full potential, and leaving Europe's consumers, businesses, and economies behind.

Making 5G Work Financially

What does it take to make 5G work financially? Returning to our simulations, we looked at the financials of a typical integrated network operator, broke down its cash flows (mobile only), and compared it with the reference case (outlined in the previous chapter) of actual revenues, costs, and profits for the five years from 2013 to 2018, indexed to 100. (See Exhibit 7.)

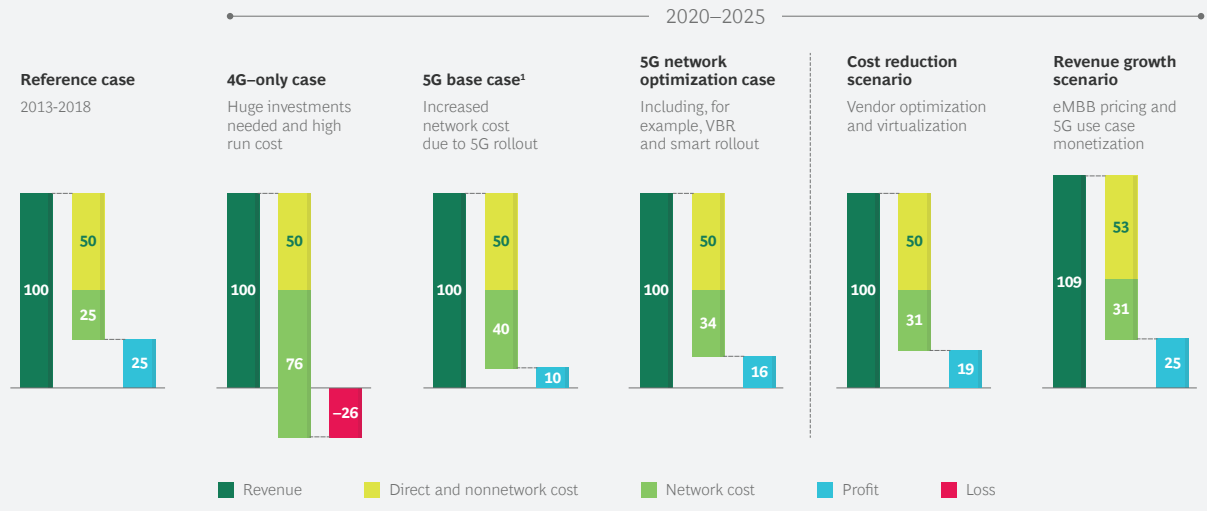
In the current 4G world, assuming a cost base of 100, network costs (including capex and opex) are about 25, and nonnetwork costs (including direct costs, such as subscriber acquisition and retention costs, and indirect costs, such as call center, administration, billing) are about 50, resulting in free cash flow of about 25.

We then compared the projected impact of various actions (or nonactions) for the period 2020 to 2025. The 200% increase in network spending under the 4G-only case (from 25 to 76) resulted in cash flow of –26, which is a nonviable result. In our 5G base case—rolling out 5G with 100 MHz of 3.x GHz spectrum and with 64 transmitters and 64 receivers (64T64R) massive MIMO—network costs increased by 60% from the reference case to 40, which resulted in a cash flow of 10.

While 5G substantially improves the financials, serving the data explosion is still an unattractive proposition for telcos, and the challenge becomes clear: can operators adjust their business models to serve the data explosion—and support the wider socioeconomic benefits—in a financially attractive way? Our analysis indicates that they can, although they need support from other key ecosystem participants. While each operator will ultimately make its own choice on how to proceed, we believe it might work as follows for a typical player.

Applying network optimization measures, such as smart deployment and value-based rollout, can reduce network costs by an additional 15% from the 5G base case. In the 5G

EXHIBIT 7 | Telcos' 5G Investment Challenge Can Be Tackled with a Mix of Cost and Revenue Actions



Source: BCG analysis.
Note: All data indexed to 100. VBR = value-based rollout; eMBB = enhanced mobile broadband.
[1]The base case assumes rolling out 5G with 100 MHz of 3.x GHz spectrum and 64 transmitter-64 receiver massive multiple input, multiple output.

network optimization case, free cash flow then increases to 16, a jump of 60%.

To reduce the costs still further, telcos can optimize contracts with vendors (such as equipment partners and tower companies) and implement new technologies (such as automation and virtualization). Many telcos—in particular, integrated network operators—also have room to become more efficient, by reducing product and service complexity and eliminating manual processes, for example. Help from regulators is also key. On the basis of our experience, we estimate that in the cost reduction scenario, operators can cut network costs by an additional 10% from the 5G network optimization case, down to 31, yielding free cash flow of 19.

To fully close the gap with current cash flows, measures to increase revenues are critical. These include restructured pricing plans for 5G (breaking the more-for-less pattern we have observed in recent years) and developing new 5G use cases. Our increased revenue scenario shows that a revenue boost of 9%—hardly a substantial increase over six years—is required for operators to match the current cash flows of 25.[1]

This analysis suggests that it should be possible to drive a profit increase from 5G when either costs are reduced or the new revenue potential is larger than the (hardly ambitious) 9%. Putting it all together, full 5G deployment is viable from a financial perspective but requires engagement of all stakeholders. Here are the actions each needs to take. (See Exhibit 8.)

Network Operators

More than anything, MNOs need to change how they think about 5G, which has multiple aspects—more capacity, lower latency, and network slicing by quality of service, for example—each with its own opportunities for monetization. Operators need to lower the cost of network deployment, stabilize or increase ARPUs, and create new revenue streams.

5G Deployment. How operators roll out 5G can significantly affect the new technology's economics. They can reduce network spending in smart ways without compromising the benefits of 5G or their own market success. In the past, telcos have typically rolled out new radio equipment using a national or regional approach until they achieved their coverage ambitions (for example, 50% 4G population coverage after 12 months, 80% after 24 months). They performed site capacity upgrades based on site load, irrespective of the economic value created.

EXHIBIT 8 | A 5G Playbook for Europe

Source: BCG analysis.
Note: eMBB = enhanced mobile broadband; FWA = fixed wireless access; WHO = World Health Organization; ICNIRP = International Commission on Non-Ionizing Radiation Protection.

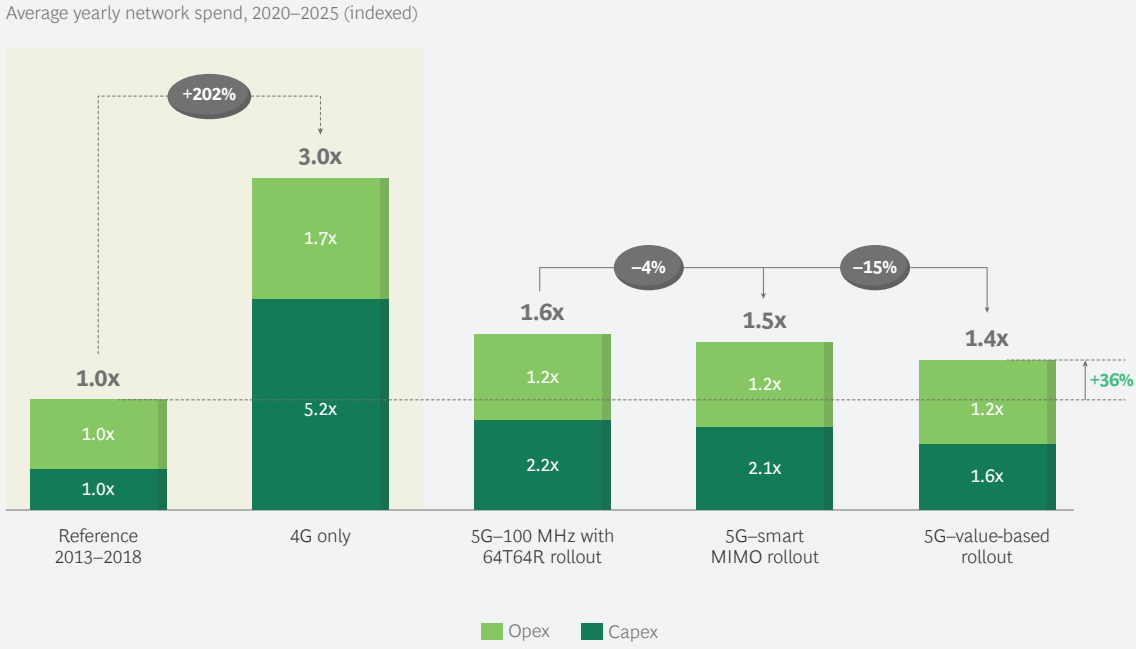
Operators can pursue more targeted and value-oriented 5G network deployment in multiple ways:

- **Smart Deployment.** MNOs that have acquired or plan to obtain 3.x GHz spectrum generally consider deploying massive MIMO antennas, usually upgrading every site with 64T64R. This approach leads to significant overcapacity as many sites require only 32T32R or 16T16R. Our simulations show that a site-specific traffic forecast can improve the relationship between network capacity supply and demand, and thus reduce average network spending by 4%. (See Exhibit 9.)

- **Value-Based Deployment.** Prioritizing site construction and capacity upgrades in a value-oriented way can further reduce network spending. Operators can employ data analytics to link network experience to every customer and site and thus determine the propensity for churn (as a metric for value), rather than performing upgrades on the basis of general network congestion. We estimate from project experience that such an approach can reduce average network spending by 15%, with no negative impact on revenue.

- **Smart Partnerships and Efficient Deployment Models.** Passive network-infrastructure sharing is common in many markets. Active network sharing is often used when cost reduction is more important than network differentiation for the sharing partners. In such agreements, capex savings of 50%, and opex savings of more than 20%, are quite common. We believe that network sharing, both passive and active, will become more important

Exhibit 9 | Smart Rollout Can Reduce Network Costs



Source: BCG network model.
Note: 64T64R = 64 transmitters and 64 receivers; MIMO = multiple input, multiple output.

with 5G, particularly in two areas: small-cell networks in urban and concentrated business areas, and suburban and rural regions where 5G investments otherwise could be significantly delayed by cost considerations. Tower companies, which often have multiple MNO customers using the same infrastructure, could play an active role in orchestrating such shared 5G deployments.

- **More Efficient Network Architecture.** Many mobile networks today operate multiple technologies—such as 2G, 3G, 4G, and narrow-band IoT (NB-IoT)—and require a significant degree of manual intervention, which increases complexity and cost. Operators that do not have legacy infrastructure and can employ a high degree of automation, such as with self-optimizing networks, can benefit from a significant cost advantage. One example is Reliance Jio in India, which built an extremely low-cost network without legacy technologies (2G and 3G). Another architectural lever is C-RAN, a centralized, cloud computing-based architecture for radio access networks (RANs). While distributed RAN architecture is still common in Europe because of the limited availability of fiber links, Asian operators, including China Mobile and SK Telecom, are moving their infrastructure toward this target architecture. As operators shut down inefficient legacy 2G and 3G networks, they will also need to work toward much more automation and virtualization to help manage the rising cost and complexity of the remaining networks.

- **Redeployment of Old Equipment.** Some operators have the opportunity to repurpose 4G equipment from urban sites to suburban or rural sites. This can help them deploy 5G at more sustainable network spending levels without compromising on the value creation of new use cases and applications. It also helps to maximize the cost benefit of the existing 4G while providing service to currently poorly served or underserved sites.

Enhanced Mobile Broadband (eMBB).

Operators should consider eMBB to be both a key to protecting their current revenue base and an opportunity to price 5G as a new technology because it delivers better customer experience and quality.

Our projections show that the lion's share of mobile operators' revenues will continue to be generated by mobile broadband—up to 90% in 2025 in many cases. Network excellence will continue to drive customer satisfaction and loyalty. To claim network leadership—and protect premium prices, market shares, and brand—operators will need to continue to invest in advanced technologies.

Recent BCG research of 4G deployments found that it is important not to lag competitors when investing in new mobile technologies. Latecomers lost market share and experienced declines in stock price—in all markets and for all new generations of technology. Moreover, market share losses or drops in ARPUs because of inferior network performance were accompanied by significant value destruction. Operators face a classic prisoner's dilemma with 5G, just as they did with 4G. A wait-and-see strategy will not pay off. *Someone* will invest in the new technology, hoping to seize more market share, and the industry will have to follow. Established operators need to consider the defensive value of an investment in 5G.

To claim network leadership, operators need to invest in advanced technologies.

That said, eMBB also offers an opportunity to halt (or at least slow down) the ARPU downward trajectory—and to set a new price point for a new technology by offering more service and significantly improved customer experience (huge improvement in speed, capacity, and latency) for a somewhat higher price. The experience of introducing technology such as 4G or fiber to the home (FTTH) shows that customers do not want to pay for a new technology per se, but that great new services, or a better customer experience, are a different matter.

BCG research in 2014 showed that the consumer surplus—the perceived value that consumers themselves believe they receive, over and above what they pay for devices, apps, services, and access—in Germany, France, the UK, Italy, and Spain was about €770 billion a year. (See *The Mobile Internet Economy in Europe,* BCG report, December 2014.) More recent research by Ericsson also indicates that consumers are willing to pay extra for new services, such as real-time translation and virtual tactile shopping.[2]

Operators need to take it upon themselves to creatively use the introduction of 5G and the new services it enables to reverse the negative data price spiral. For example, a quick adoption of 5G could obviate further capacity upgrades in the 4G network, especially in today's unlimited-data-plan markets. Operators could cap 4G service at current levels and offer unlimited data only on 5G—with a revised price structure. Another possibility is to charge separately for new services, such as AR, that require heightened network performance to work properly. (See the sidebar "Augmented Reality and 5G.")

Governments and regulators have a role to play here: they should avoid stimulating the creation of new entrants with temporarily empty networks that undermine the little pricing power the industry has left and must use to build a positive investment case.

Fixed Wireless Access (FWA). Network operators can use FWA (also known as wireless to the home) to enter fixed-line broadband markets. The business cases for 5G FWA vary strongly by market, wholesale environment, competitive setting, and available infrastructure, but we forecast an average revenue contribution of 5% to 10% for MNOs in 2025. We expect two distinct deployment scenarios, each with different revenue profiles. The first is the 5G to-the-home new entrant. We believe that 5G enables MNOs to compete with either low-speed or high-priced fixed-line services to homes and places of business. Typically, in a 3.x GHz deployment scenario, the number of customers is still the main capacity constraint, but FWA allows operators to build up their customer bases in the run up to an FTTH rollout.

The second deployment scenario is offering 5G FWA as a substitute for fixed-line broad-

AUGMENTED REALITY AND 5G

AR is a new service that could enable an ARPU uplift with consumers or help build new revenue streams with companies. Already major marketers, including McDonald's and Nissan, are using the technology to engage consumers. (See *Augmented Reality: Is the Camera the Next Big Thing in Advertising?*, BCG Focus, April 2018.)

One AR startup, Magic Leap, which has developed eyeglasses that embed virtual objects in the wearer's real-world environment, has secured funding of $2.3 billion as well as partnerships with content producers, including Lucasfilm and the US National Basketball Association. Automaker Porsche has equipped engine technicians at selected dealers with Atheer AiR AR glasses that connect to Porsche's technical support center. Technicians can share their first-person point of view with experts who can provide information and assistance using both voice and annotations that appear directly in the technician's field of view. In time, if data traffic from AR exceeds (or replaces) data traffic from smartphones, additional network capacity and coverage will be required.

Telcos need to avoid repeating the experience of in-car entertainment, when they entered wholesale agreements with the automotive industry—giving up direct customer access—at price levels far below ARPUs for smartphone connectivity. Equally, telcos that take a wait-and-see approach will most likely see massive traffic growth on their networks without significant revenue upside.

band in rural areas, where connecting households by fiber or alternative hybrid technologies comes at a very high cost. Providing 5G FWA, deployed on the macro grid using mid-frequency spectrum, may become an effective and less costly way to connect underserved areas and offer services, such as internet TV, that were not available before.[3]

Mission-Critical Services. Network slicing enables multiple virtual networks to run on a shared physical infrastructure. With this ability, operators can offer dedicated networks to service providers with mission-critical needs—emergency services, industrial automation, and medical devices, for example—including companies, such as railways, that have built their own dedicated wireless capabilities. These services typically require the low latency and high reliability that 5G can provide but 4G and earlier generations of mobile technology cannot. Heavy-equipment maker Komatsu is working with Docomo to develop a 5G mobile network to enable real-time monitoring and remote control of construction equipment by carrying high-definition videos and control signals simultaneously at high speeds and low latency.

Telcos can approach potential partners for these services (such as emergency services, airports, shipping ports, and railways) to jointly explore the benefits of moving to 5G.

Massive Internet of Things. Devices and sensors on the so-called massive IoT (such as those in smart homes and capillary networks) have their own set of network requirements that differ from those on the critical IoT (devices with mission-critical applications). Networks using 5G are well suited to serve customers needing low-power, low-bandwidth connectivity that can handle lots of low-energy devices emitting combined high quantities of data. Moreover, these networks can be deployed quickly and with limited capex. The battle for leadership has already begun: a number of operators are even now building IoT networks using current technologies (such as LoRa and NB-IoT), but 5G networks are better suited to assure the quality of service, offer global interoperability, and provide adaptability to local requirements.[4] As 5G enters the mainstream, it will enable other operators to leapfrog these dedicated IoT networks by integrating IoT network technologies into future 5G networks instead of building them from scratch. To capture the

full upside of IoT beyond connectivity, and to seize a larger share of business, telcos will need to develop other business models.

Operators are employing multiple strategies to stake out positions in the IoT market, including acquisitions, partnerships, and enterprise and end-to-end solutions. In the US, for example, Verizon has made multiple acquisitions since 2012 that focus on fleet management services and smart cities. China Telecom has struck partnerships with software and tech companies, including Cisco Systems, to sell IoT solutions and enhanced services in such industry verticals as agriculture, health care, and transportation.

Policymakers and regulators need to facilitate investment in mobile infrastructure.

Telcos already offer end-to-end solutions that combine hardware, connectivity, data, and consulting services that increase operators' revenues while supporting clients' digitization efforts. In the Netherlands, for example, KPN set up a smart asset management system for a client in the waste management industry. All containers are equipped with sensors and connected to smart devices. The real-time data is securely saved in KPN data centers. Besides the real-time tracking of the asset base, KPN and its client can analyze the saved data to improve the efficiency of the client's business processes. Europe's telcos need to develop more such business models to increase their revenue base.

In the lead up to 5G, most operators would benefit from actively targeting industry verticals and developing the capability to apply new business models to IoT opportunities.

Policymakers and Regulators

BCG and others, including the GSMA and ETNO, have observed many times that policymakers and regulators need to help facilitate and accelerate investment in the mobile network infrastructure. Incentivizing investment, furthering technological progress, and improving quality of service and innovation are all important efforts to create a sustainable telecommunications market in which a digital economy and society can thrive. As the impact of digital technologies increases in just about all areas of business and daily life, the importance of these considerations rises rapidly as well.

As with telcos, this requires a change in thinking and approach on the part of public sector stakeholders. Past policy has focused on incentivizing competition and keeping prices low, which have benefited consumers and underpinned development of a competitive market.

Today, however, with traffic rising and ARPUs stable or falling, the new priority for both policy and regulation should be investment, especially in the next-generation infrastructure that can enable further technological advances. In most markets, current policy and regulations actually inhibit investment in advanced infrastructure.

A number of areas are ripe for reexamination, including policies that maintain an artificially high number of competitors in a given market, spectrum sales that reap big gains for governments but impede investment by leaving the winning companies in a weakened financial state, and regulations that inhibit network-sharing agreements among operators. In our 2018 report with the GSMA, *Delivering the Digital Revolution*, we identified six areas in which reform could collectively cut operators' network opex and capex costs by approximately 30% to 50%. These include the following:

- **Access to Fronthaul and Backhaul Infrastructure.** Fast, high-capacity connections between the backbone network and high-capacity macro cells and small cells are especially important for eMBB, FWA, and services that require low latency, such as remote-controlled robotics. But fiber connections are expensive, they take a long time to build, and right-of-way permits are difficult to obtain. Regulatory changes that facilitate the rollout of new fiber fronthaul and

backhaul lines, as well as encourage the sharing of facilities and backhaul and infrastructure construction costs, can help to reduce overall network infrastructure costs.

- **Access to Advantageous Site Locations for Macro and Small Cells.** In addition to operational challenges, operators often face significant hurdles in acquiring or gaining the use of new site locations. One issue is cost; another is access. Granting access to public buildings and "street furniture" (such as bus stop shelters and lampposts) owned by municipalities at low or no cost would remove a significant hurdle to small-cell deployment. Moreover, new street infrastructure could be manufactured and delivered ready for deployment, with some financial support from network operators, so that operators could immediately attach their equipment.

- **Additional, Affordable Spectrum.** Making additional spectrum available in a timely fashion—and at affordable prices—is a top priority for accelerating advanced network deployment. Some government agencies, including the FCC in the US and Ofcom in the UK, provide good models for how to develop policies that build a spectrum pipeline—a well-planned and transparent process for spectrum release, which enables network operators to plan their own futures more effectively. Policymakers also have to strike an appropriate balance among competing objectives, such as maximizing proceeds from spectrum auctions, establishing low consumer prices, and enabling the build-out of new mobile broadband infrastructure.

  Studies have shown that excessive spectrum prices have resulted in low digital infrastructure investments.[5] Moreover, while fostering competition by reserving spectrum for new entrants may have been an effective way to reduce consumer prices, it undermines investment in high-quality digital infrastructure. Similarly, coverage obligations that may be seen as a good way to ensure the availability of services to the full population will need to be adjusted; the consumer experience on 5G is driven by the coverage on the full network as it is deployed over five to ten spectrum bands, rather than on an individual band. Coverage obligations should thus be rephrased into target customer experience. Spectrum auctions and the industry structure they drive will expedite investment in 5G only when they are well designed with the different characteristics of 5G in mind. Policymakers need to rethink their priorities if they don't want to kill 5G before it has been rolled out.[6]

Sharing small-cell networks can bring down each MNO's costs.

- **Freedom and Incentive to Establish Small-Cell Network-Sharing Agreements.** The high number of small cells required in the future will put significant additional opex and capex burdens on mobile operators. Sharing small-cell networks can bring down each MNO's costs. In many markets, however, such cooperative agreements run into regulatory roadblocks. Operators need the flexibility to establish sharing agreements for mobile networks, including for fronthaul and backhaul. Regulators can also take steps to encourage shared small-cell deployment. For example, operators could be incentivized to prepare small-cell locations for deployment of additional cells from their competitors in a manner similar to the deployment-ready installation of light poles.

- **Regulatory Facilitation of Small-Cell Deployment.** Cumbersome bureaucratic approval processes typically inhibit timely large-scale deployment of small cells. Regulators can facilitate next-generation infrastructure investments by streamlining their approval processes. Possible mitigation measures include simplified, transparent, and standardized application

and review processes for small-cell siting; exempting small cells that meet certain criteria from reviews of environmental and historic site preservation organizations; and accepting declarations of compliance for MNOs without requiring routine postinstallation measurement of power density.

Governments are in an excellent position to lead by example.

- **Harmonized Power Density Limits Based on Recommendations by ICNIRP and WHO.** The International Commission on Non-Ionizing Radiation Protection defined power density limits in 1998 to protect public health and safeguard the environment from exposure to detrimental levels of radiofrequency electromagnetic fields. These limits have been endorsed by the World Health Organization.[7] While most countries have adopted the ICNIRP exposure limit recommendations, some continue to apply limits that are 10 to 100 times stricter.[8] Arbitrarily strict power density limits undermine the ability of policymakers, regulators, and MNOs to speed deployment of next-generation infrastructure in all of the areas described above. ITU has published a recommendation that calls for the harmonization of power density limits.[9] Regulators should reexamine their positions and seek to harmonize limits with others and with WHO and ICNIRP recommendations.

In addition to the above six areas, governments are also in an excellent position to lead by example—implementing technology in the public sector that requires or incentivizes deployment of 5G. A number of governments, at a variety of levels, are already leading. The city of Barcelona, for instance, has set up a strategic alliance with the GSMA and the Mobile World Congress to encourage 5G equipment providers and related companies to experiment with 5G in a real-life environment. The initiative is partially funded by the European Union and began with deployment of 5G nodes in five typical environments (a busy shopping street, a hospital, a university, a municipal office, and a research institute) in order to better understand both the potential use cases for, and the limitations of, the new technology. The stated goal is for 20% of the territory to have 5G coverage by 2020.

Another example is 5G Berlin, a partnership between research and business to promote next-generation communications networks. Cofunded by Germany's Joint Federal Scheme for the Improvement of Regional Economic Structures and supported by the Berlin Senate Department for Economics, Energy, and Public Enterprises, the program's objective is to test technologies and promote new 5G applications. The initiative is currently in the startup phase, which involves setting up its two main components.

A high-performance test infrastructure, 5G Testfeld, on the north campus of the Technical University of Berlin, will sustainably test technologies under real-life conditions with components provided by the commercial partners of the initiative, including millimeter wave installations on streetlights combined with sensors and elements of edge-computing resources. In addition, an innovation cluster composed of stakeholders from regional and international companies, research institutes, industry associations, and networks will provide networking opportunities to encourage the formation of new partnerships, in particular between the telco industry incumbents and new 5G stakeholders.

In China, the city of Xi'an is emblematic of government support for smart city digitization efforts.[10] Xi'an's initiatives include:

- A virtual hospital in the cloud that connects patients, doctors, hospitals, and pharmacies, reducing the cost of care and giving individuals a simple way to receive treatment for common health issues
- A smart bus system that provides real-time arrival information and route optimization; data collected can be used for improved city planning and bus fleet management

- The education department's use of migration data, new birth numbers, and current public school data to plan mid- to long-term school capacities

Telco Ecosystem Partners

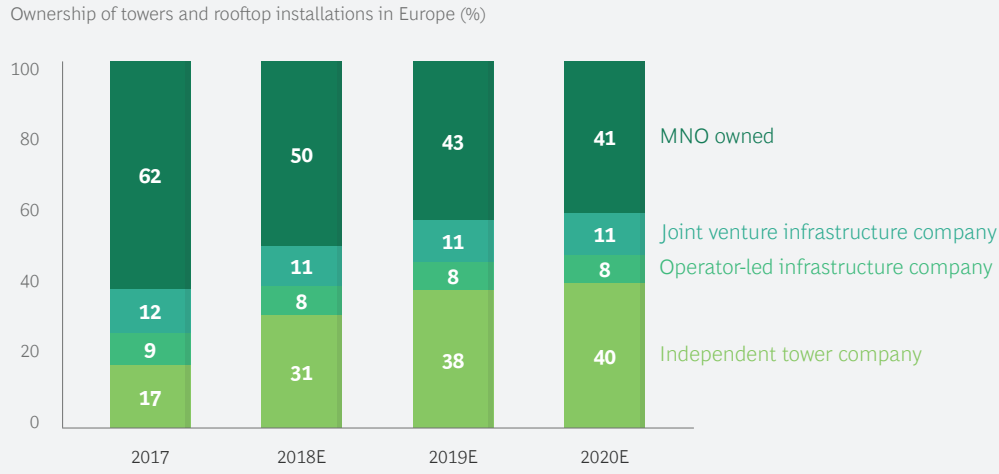
A number of nonoperator participants in the telco ecosystem can also facilitate deployment of 5G. These include cell tower companies, vendors, handset manufacturers, content and service providers, and investors.

Tower Companies. Tower companies are gaining momentum and market share in Europe. (See Exhibit 10.) Many telcos have carved out their infrastructure businesses into free-standing tower companies, which both improves efficiency (the tower company must report to its own investors) and frees up capital. Tower companies need to develop their own business models for 5G. In particular, pricing, which is often based on antenna size and weight, could be reviewed and potentially reworked to incentivize operators to accelerate 5G rollout. Tower companies can also play a key role in advancing smart network sharing among operators. Even in competitive scenarios where network differentiation is important, sharing active equipment in rural areas or small cells in urban areas can reduce costs significantly and support faster 5G rollout. Providing operational support for active sharing could be a substantial growth driver for these companies.

Vendors. Telco vendors, such as equipment makers and software companies, need to work closely with their operator partners to pilot 5G equipment and make sure that operators are aware of the technological possibilities that 5G encompasses. In addition to their commitment to robust 5G roadmaps, network vendors can develop planning tools for the most effective deployments for their telco clients. Vendors can also support a technology transformation for telcos (to cloud-based IT architecture, for example) by supporting open standards in the virtualization of the networks.

Handset Manufacturers. Handset makers need to design, test, manufacture, and distribute 5G-ready handsets in parallel with the still-evolving development of 5G technical specifications. Every technology shift introduces new and sometimes challenging requirements, such as new frequencies, unprecedented bandwidth, antenna requirements, and the like; 5G is no different. Handsets also need to be able to work on both legacy and new 5G networks, in particular the 3.x GHz band, which will be the major capacity band for 5G in the near term. To encourage adoption, handsets should be available in all price ranges as quickly as possible. Rapid adoption is critical to ensure

EXHIBIT 10 | Tower Companies Are Increasing Their Share of Sites Owned



Sources: TowerXchange; BCG analysis.
Note: MNO = mobile network operator.

the best utilization of 5G networks and avoid unnecessary investments in legacy 4G technology.

Content and Service Providers. Over-the-top (OTT) service providers benefit from 5G digital infrastructure, which enables them to enhance their offerings and create innovative new products. The largely cost-free content and service delivery approach taken by OTT companies in the past may be less effective in this transition, especially because ultra-low latency is an important feature for advanced services, and service providers will want to integrate their offerings into the telco infrastructure for that. OTT players should explore partnering options with network operators to build innovative services that depend on advanced digital infrastructure.

Investors. Investors need to understand the underlying economics of 5G network rollout and transformation. The upfront (peak) investments in the 5G cycle will be higher than the ones associated with 4G, and investors may need to adopt a longer-term perspective when considering how they deploy their capital. Attractive investment vehicles for 5G and related fiber deployments may be an option for investors to further participate in such infrastructure investments.

NOTES

1. FWA revenue opportunities are not included in this scenario because it is for an incumbent integrated operator, and in such a case, 5G FWA could mean cannibalizing existing fixed-line revenues.
2. See *Towards a 5G consumer future,* an Ericsson Consumer and Industry Insight Report, January 2018, https://www.ericsson.com/en/trends-and-insights/consumerlab/consumer-insights/reports/six-calls-to-action.
3. This applies to European spectrum allocation; deployment in other regions may differ.
4. Mustapha Benjillali, "Massive IoT vs. Critical IoT," presentation to the ITU-SUDACAD Regional Forum, Khartoum, Sudan, 13-14 December, 2017; https://www.itu.int/en/ITU-D/Regional-Presence/ArabStates/Documents/events/2017/IoTSMW/Presentations-IoT/Session1/IoT4SSC_Session_1_Benjillali.pdf.
5. See *Effective Spectrum Pricing,* a GSMA report, February 2017.
6. See *Building the Gigabit Society,* an ETNO report, November 2016.
7. EMF Guidelines (1998): http://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf; experimentally and computationally derived limits, safety factor of 50 applied for the general public, resulting in 200 W/m2 for frequencies between 400 MHz and 2 GHz and 10 W/m2 for frequencies between 2 GHz and 300 GHz.
8. Poland's Ministry of Environment (2003): http://prawo.sejm.gov.pl/isap.nsf/download.xsp/WDU20031921883/O/D20031883.pdf.
9. See *The impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment,* ITU K.Sup14, a report by the telecommunication standardization sector of ITU, May 2018; https://www.itu.int/rec/T-REC-K.Sup14-201805-I.
10. See *Development and Practice of Smart City in China,* a report by ITU and CAICT, November 2017; https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/SiteAssets/Pages/Events/2017/Oct2017CIIOT/CIIOT/15.Session5-5%20Development%20and%20Practice%20of%20Smart%20City%20in%20China-%E5%B4%94%E9%A2%96V2red.pdf.

WINNING THE RACE

THE PROBLEM OF GROWTH in data traffic is not going away. Neither are the competitive advances of the US and Asia-Pacific. Capturing the economic benefits of mobile technology is a race—against both time and other regions.

Europe needs to catch up. Telcos, governments, regulators, and industry players need to cooperate, much as the members of a relay team do. If they do not, and if they do not use all the tools available, the deployment of 5G will be delayed and fragmented. In addition to the telecommunications industry, the losers will include Europe's consumers, businesses, and national economies. If, on the other hand, the stakeholders of the mobile ecosystem pull together, Europe's telcos—as well as its consumers, businesses, and nations—can all stand among the winners in the mobile and digital economies of the future.

APPENDIX

MODELING METHODOLOGY AND SENSITIVITIES

We simulated the network rollout for a typical MNO in a large European city (for example, Berlin, London, Milan, or Paris). The simulation was based on the existing infrastructure (sites, antennas, and configuration) and current traffic load. We forecast data traffic evolution through 2025 and determined the required network capacity to build out a network on a site-by-site basis, including new sites, site upgrades, and other network investments.

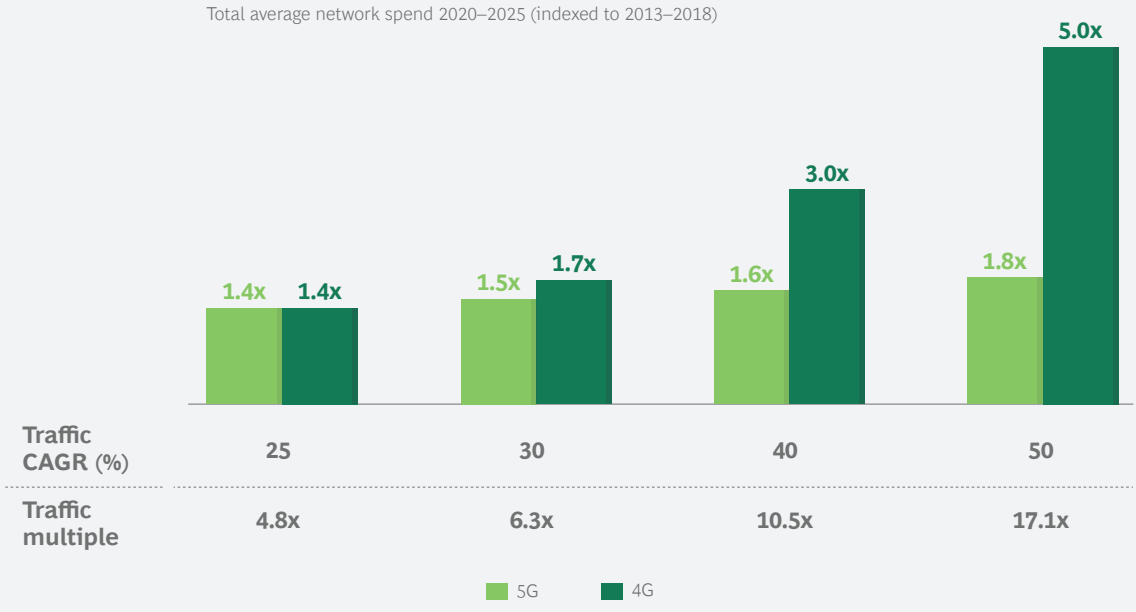
The simulation model compared mobile data traffic demand with supply in each year and triggered the network capacity upgrades accordingly. The capacity of a mobile network is a direct function of the amount of spectrum (MHz) multiplied by the spectral efficiency (bits per second and Hz) and then multiplied by the number of sites, sectors, and technologies used. In our simulation, the network capacity upgrades were performed each year on all the sites that had reached the site load limit.

The capacity buildout was simulated for four different scenarios:

- **4G Only:** capacity buildout using 4G technology only (including 4T4R MIMO and refarming of current 2G and 3G spectrum)
- **5G–100 MHz with 64T64R:** capacity buildout using 100 MHz of 3.x GHz spectrum and 5G technology (only 64T64R)
- **5G–Smart MIMO:** same as the previous scenario but only the minimum needed MIMO (8T8R, 32T32R, and 64T64R) is built out
- **5G Value-Based Rollout:** same as the previous scenario, but the network is built out using a value-based approach

The yearly growth in data consumption of 40% was calculated on the basis of industry forecasts and BCG case experience. (See the exhibit on page 29, which shows the sensitivity of the model to the assumed traffic growth.) Starting from a growth rate of 20%, 5G is more cost efficient than 4G in our modeling, and the cost advantage of 5G increases with higher traffic growth. For capex and opex costs, we used our extensive cost benchmarks (including civil work, maintenance cost, site rent, active and passive equipment, and energy) and assumed yearly declines or increases depending on the category. We applied a rate of handset adoption from 4G to 5G for this simulation that was calculated on the basis of our experience.

With Higher Traffic Growth, 5G Cost Benefits Grow



Source: BCG network model.
Note: Analysis is based on 5G–100 MHz with 64 transmitters and 64 receivers and no smart deployment or value-based rollout.

NOTE TO THE READER

About the Authors

Heinz Bernold is an associate director in the Zurich office of The Boston Consulting Group. **Michael Steiger** is a former principal in the firm's Zurich office. **Maikel Wilms** is a director in BCG's Amsterdam office. **Wolfgang Bock** is a senior partner and managing director in the firm's Munich office. **Rüdiger Schicht** is a senior partner and managing director in BCG's Zurich office.

Acknowledgments

The authors wish to thank the following colleagues for their insights and assistance: François Candelon, Valeriy Elbert, Patrick Forth, Magnus Hambleton, KJ Lee, Franck Luisada, Stéphane Meyer, and Marc Schuster.

The authors are also grateful to David Duffy for his help in writing the report and to Katherine Andrews, Gary Callahan, Lilith Fondulas, Kim Friedman, Abby Garland, Paola Oliviero, and Alex Perez for their assistance with its editing, design, production, and distribution.

For Further Contact

For more information please contact one of the authors:

Heinz Bernold
Associate Director
BCG Zurich
+41 44 388 86 66
bernold.heinz@bcg.com

Maikel Wilms
Director
BCG Amsterdam
+31 20 548 4000
wilms.maikel@bcg.com

Wolfgang Bock
Senior Partner and Managing Director
BCG Munich
+49 89 231 740
bock.wolfgang@bcg.com

Rüdiger Schicht
Senior Partner and Managing Director
BCG Zurich
+41 44 388 86 66
schicht.ruediger@bcg.com

9/18

BCG

THE BOSTON CONSULTING GROUP

bcg.com