Techno-Politics Series: 2

# Europe's Future Connected
## Policies and Challenges for 5G and 6G Networks

Edited by
**Erik Bohlin**
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# Foreword

## Daniel Kaddik, ELF Executive Director

Communication technologies have revolutionised our lives, turning our society into a 'network society'. New and venture technologies in this field can also revolutionise the way we think about the industry, the future of work and the market. We have been hearing about 5G ever since it was announced. The discourse created around this innovative type of network communication immediately attracted the attention not only of experts and scientists but other actors too, including governments, politicians, and sociologists, all wondering how best to integrate the innovative potential of the technologies into our societies. At the same time, as we speak, the sixth generation of networks (6G) is becoming a reality.

This means that technological advancement does not always necessarily go hand in hand with our institutions' regulatory pace and adaptability. Fortunately, the (free) market has always played its part in enhancing the efficiency of our societies, in this case by bringing 5G (and soon 6G) to our homes, businesses, and streets.

Cutting-edge technology and any breakthrough in this field represents a strategic advantage.

But there is a geopolitical dimension to the new 5G and 6G communication technologies. This involves implementing strategies to collaborate effectively with trusted partners and to coexist with rivals.

Europe is at a critical juncture: on the one hand, the digital transition offers unprecedented opportunities. On the other hand, this must be supported by intelligent policy choices. Regulations affecting the internal market must be informed by listening to and building on the knowledge of the industry. In this way, we can ensure that new technologies are implemented at all levels, avoiding technocratic overregulation that risks hampering technological advancement.

5G and 6G are excellent platforms from which to reconsider how Europe should organise its relationship with technology and such related notions as strategy, resilience, and autonomy. This is because the ubiquity in terms of both application and innovation that accompanies these new communication technologies represents a potential to strengthen the domestic market while at the same time revolutionise the way we communicate. Moreover, these complex technological processes are accompanied by growth in terms of research, development, new technologies and applications in various fields, from smart cities to medical instruments, from financial markets to autonomous driving. Europe cannot but be ready for the future.

This study, edited by Professor Erik Bohlin and Francesco Cappelletti, focuses on these and other essential aspects, such as the most appropriate policies and regulations in Europe, while at the same time offering a perspective on the world's significant pioneers in the deployment of this technology. This volume, a bridge between academia and policymakers, represents an important step for the European Liberal Forum towards this new way of thinking that considers policymaking as a tool to support our future. Being future-oriented means creating a virtuous link between technology and the individual. Embedding techno-politics in our societies is the way to make Europe ready for its digital future.

# Editorial: Future Mobile Policy

**Erik Bohlin**, Chalmers University of Technology

**Francesco Cappelletti**, European Liberal Forum

New technologies have added value to civilisation, improving and even lengthening our lives, recently heralding the advent of a digital society, and making technological determinism a reality. Exploring the potential and transcending the limits of knowledge has driven humans to make the technology capable of integrating into the infrastructure of our daily living. Already new communication technologies are shaping the way we live and new technologies are appearing before our eyes as more effective methods of communication are invented, tested, and implemented.

However, the impact of and interrelationships between these technologies must be considered in light of the existing structures of our societies. It is crucial to consider new technologies as transition points towards new models of everyday life. To do so, it is in turn essential to fully understand how they work, what the main challenges are and to be able to decide accordingly how best they should be integrated into our lives.

This volume focuses on future policy for the current fifth-generation mobile system (5G) and forthcoming mobile systems (6G). While 5G is still in a relatively early deployment phase, 6G is being researched and increasingly planned in standards and technical fora. Common to both is the fact that the new capabilities of these systems are generating new policy and regulatory challenges, along with the new requirements these systems and the new standards have for deployment and adoption. This has led to a search for appropriate policy frameworks to deal with them, a search conducted by regulators and governments, promoted by industry and research, sometimes independently and sometimes in joint research projects.

This volume seeks to contributes to this search for answers and analysis of future policy challenges, issues and frameworks, as raised by the new mobile network systems.  The chapters address these complex issues from several thematic angles:

- Business models
- Market design
- Innovation
- Sustainability
- Security
- Policy goals
- Competition and openness
- Artificial intelligence
- Network neutrality
- Comparative studies of China, South Korea, and Thailand
- Strategic autonomy

While the chapters differ in topic and scope, some common themes and significant policy conclusions are worth emphasising. The study as a whole builds discussion based on the belief in the market mechanism as a way to enable the growth and progress of future mobile systems and technologies. Conversely, there is agreement that governments need to design market and regulatory parameters that are fit for the digital revolution. This points to the requirement for better coordination between market and government actors to succeed in (cyber) security and innovation and foster a competitive marketplace. Finally, further analysis of specific government tools such as spectrum assignment, network neutrality, anti-trust and security coordination is necessary for a 'smart' deployment of these technologies across the European Union.

With the recent emergence of strategic autonomy as a fundamental goal for the European Union, questions have been raised concerning how and whether 5G/6G can support these goals.

How should a mobile policy be organised to support future strategic autonomy, especially digital strategic autonomy? Is it possible to formulate a decomposition of the fundamental goal of strategic autonomy such that new generations of networks become pillars and supporting structures to the overriding goal?

While the volume does not provide a blueprint for such policy integration, the chapters offer some clues. In short, these revolve around themes of continued support of the market mechanism coupled with a proactive governmental role in enabling a sustainable and innovative marketplace.

The chapters are grouped into three parts:

- Part I: Workable Policy Frameworks
- Part II: Specific Policy and Business Challenges
- Part III: Comparative Studies of leading Asian economies

Generally, the first two parts take a chronological approach, starting with the most immediate considerations and gradually moving to discussion of more distant and future technologies and applications.

## OVERVIEW OF THE STUDY

### Part I: Workable Policy Frameworks

This section presents an overview of significant trends in the regulation of new network technologies. Having the EU as its focus, this section aims to identify the most effective implementation at the legislative level to enable the integration of these new technologies into the Union's regulatory framework.

*Martin Cave, Imperial College*
*5G and the Wider Goals of Digitalisation in the EU*

*Pier Luigi Parcu, European University Institute*
*Policy Options for Digital Strategic Autonomy and 5G*

*Johannes Bauer, Michigan State University*
*A Framework for 5G and 6G Market Design*

*Petri Ahokangas, Oulu University*
*An Action Plan for Profiting from European Innovation in Future Mobile Connectivity*

*Maria Alessandra Rossi, University G. d'Annunzio of Chieti-Pescara*
*5G and the European Competitiveness Challenge: The Case for Demand-side Innovation Policies*

The chapter by Cave seeks to set the development of 5G within the broader framework of the digitalisation of the EU and other economies and societies. Cave suggests that the innovations embodied in 5G technology may be particularly well equipped to deal with the problems and potential of digitalisation. On the one hand, 5G has the disruptive potential to restructure the mobile operator industry, with new players entering, and, on the other hand, generate innovations that will resolve several challenges of EU digitalisation.

Parcu's chapter discusses the need for a strategic rethinking of the policies that promote 5G's deployment in Europe. The question is whether or not a more effective and proactive policy from the EU is required in this field: Parcu concludes by favouring an industrial policy that takes on the whole of the EU, instead of just single, individual Member States.

The chapter by Bauer argues that a policy framework for 5G and 6G must build on insights from innovation economics, specifically perspectives on general-purpose technologies. With such a starting point, Bauer advances three broad aspects of market design: the need for flexible and adaptive spectrum policy, measures to facilitate coordination among players, and the balancing of differentiation and non-discrimination needs. The chapter concludes by outlining how to align the direction of 5G and 6G innovation with overarching societal goals.

Ahokangas's chapter outlines an action plan framework for Europe for benefiting from 6G innovation in the future, both as a developer and as a user of 6G technologies. As 6G is envisioned as a general-purpose technology that can transform the whole of society, a broader perspective that that of earlier technology generations has to be adopted in order to benefit from innovation in 6G. This proposed framework comprises five elements: a competitive innovation policy; values-based anticipatory regulation; triple bottom line sustainability; trustworthiness that addresses the privacy, security, and safety of users; and national and European sovereignty. It is argued that Europe needs both *ex ante* and *ex post* actions to competitively develop and deploy future 6G technologies.

The chapter by Rossi continues exploration of general-purpose technologies and deepens this into aspects of demand-led policy. Based on insights from the EU competitiveness debate, Rossi points to the need to complement early on supply-side efforts at speeding up network deployment with demand-side innovation policies, that is, technology diffusion policies that actively leverage the potential for novel collaborations in innovation along the many new 5G-connected digitalised value chains, and to the need for improved vertical and horizontal governance of EU policies in this domain.

## Part II: Specific Policy and Business Challenges

This section highlights the need, especially for policymakers, to fully understand the needs and implications of telecommunications-related business. Also brought to the fore are the specific challenges of integrating legislative aspects.

*Jason Whalley, Northumbria University*
*Creating Value with 5G*

*Wolter Lemstra, Nyenrode Business University*
*Leadership with 5G in Europe: The Benefits of Open Networks*

*Christopher S. Yoo, University of Pennsylvania & Tiffany Keung, Williams & Connolly LLP*
*Network Neutrality, Network Slicing, and the Deployment of 5G and 6G*

*William Lehr, MIT*
*Implications of the Increased Convergence of AI and 5G/6G*

*Simon Forge, SCF Associates*
*6G Means Redesigning Mobile Software Architecture for an Insecure World: Replacing WWW and the Internet*

*Marja Matinmikko-Blue, Oulu University*
*Sustainability and Innovative Spectrum Management: Defining Future Mobile Connectivity*

The chapter by Whalley posits that 5G is a transformational technology. Through its widespread adoption, 5G promises to generate significant economic value and create countless jobs. But it will not be easy for mobile operators to capitalise on this opportunity. 5G will further complicate the sector's value chain and encourage the presence of many more actors within the industry, potentially marginalising the role played by mobile operators in the more lucrative areas where it will be adopted.

Lemstra's chapter provides recommendations on how the EU may assume a leadership role with 5G based on an analysis of the regional and global success of 2G-GSM, with openness as the fundamental property. The chapter identifies 5G wholesale access as a critical openness enabler for building market momentum, an essential ingredient for achieving leadership. The review of the economic literature on wholesale access and the historical record suggests that leadership with 5G and potentially 6G will only be realised through policy action.

The chapter by Yoo and Keung suggests that deployment of 5G and 6G may depend on a new business model known as network slicing, which allocates different levels of shared components to different business verticals, as needed. This chapter examines network slicing's compatibility with European net neutrality regulation. In the process, it explores how categorical rules erected in a prior context are often poorly suited to accommodating new business and technological approaches and how artificial distinctions between technical and business justifications can bar innovations that could benefit consumers. The result is a useful case study of the impact that categorical regulation can have on innovation.

Lehr's chapter suggests that the convergence between the real and virtual worlds depends on two essential information and communication technology (ICT) developments that previously have proceeded along parallel but largely separate paths: (1) the realisation of sufficiently capable 5G networked ICTs, and (2) the availability of suitably 'smart' software applications (also known as artificial intelligence, or AI). The 5G/AI convergence will depend critically on the progress of yet another cluster of rapidly developing technologies: smart contracts (SCs) and the blockchain and cryptocurrency technologies with which they are associated. To avoid losing control of the accelerating 5G/AI convergence, policymakers need to engage now in developing coherent and coordinated strategies for regulating SCs and the role they may play in shaping the future of automation.

The chapter by Forge contends that the mobile cellular technologies that lie behind LTE-A-Pro and 5G NR networks promise both significant risks as well as potential rewards. These trends drive the need to dispel cybersecurity risks, especially those of 5G. To respond adequately, novel trust models are needed to implement much enhanced security paradigms for mobile networks. These measures must cover threats both to our physical infrastructure and to our personal lives. Otherwise, the ultimate conclusion on mobile is that it will be the most vulnerable of our future core critical infrastructures, unless 6G can provide adequate security. This requires radical measures, departing from much of today's online technologies.

Matinmikko-Blue's chapter elaborates on digitalisation and the green transition. Green transition and its broader form of sustainable development are finding their way into different sectors of society with the help of digital solutions. ICTs are important enablers in this dual transition, which is not only about technology development and deployment but involves several challenging business and regulatory decisions that have a fundamental impact on our future society. This chapter focuses on future mobile connectivity in the context of sustainability, highlighting discussion points that need to be addressed in Europe. It also explores one concrete example of the complex interactions of technology, business, and regulation, in the form of spectrum management, which has a fundamental role in defining the future mobile connectivity market.

### Part III: Comparative Studies of Leading Asian Countries

It is undeniable that Europe has lagged behind the forerunners in communications technology. Being an importer of technology is a very delicate issue in the context of the digitisation of our continent. We need to understand how partners (and rivals) have been champions in developing such technological vanguards.

*Yu-li Liu, City University of Hong Kong, & Gusong Shau, Shanghai Jiao Tong University*
*China's 5G Development Strategies and Challenges in the Context of Global Competition*

*Seongcheol Kim, Korea University*
*Leadership in 5G: The Korean Example*

*Chalita Srinuan, King Mongkut's Institute of Technology Ladkrabang (KMITL), & Pratompong Srinuan, National Broadcasting and Telecommunications Commission*
*5G Development and Use Cases in Thailand: Collaboration vs Competition*

The chapter by Liu and Shao applies Michael Porter's diamond model to discuss China's 5G development regarding the role of government, factor conditions, related and supporting industries, demand conditions, strategy, structure, rivalry, and chance. This chapter argues that the rapid development of 5G in China has benefited from the Chinese government's commitment to supporting the advancement of this technology and from its financial subsidies, with implications for development factors, industrial chain, user demand, and competitive strategies.

Kim's chapter elaborates on the Korean government's interventionist approach as well as its role as a catalyst in technological and business innovation, which enabled the country to become the epicentre of an advanced 5G mobile environment. Korea became the first country in the world to launch a nationwide 5G network and to commercialise 5G services. As of January 2022, Korea had registered 21.56 million 5G subscribers, roughly 42 per cent of the total population in the country. Though 5G network availability is still limited and there is a lack of killer applications, the Korean government plans to be a leader in the sixth generation (6G) beyond 5G.

The chapter by Srinuan and Srinuan describes the development of 5G in Thailand. A decade after the first spectrum auction, Thailand has established itself within the first group of 5G commercial country users. The market alone cannot drive the development of 5G, as the roles of different institutions are essential to support the development of the technology. Collaboration between several institutions helps ease 5G development, with regulators, government agencies, and private companies needing to work closely together for successful and smooth implementation.

## CONCLUSION

Without claiming to be exhaustive, this volume aims to investigate the challenges and opportunities of new and forthcoming network technologies. At the same time, the recommendations proposed here – based on knowledge from academics, policymakers, and practitioners – aims both to provide information and offer concrete solutions for the implementation of 5G and 6G. In conclusion, the following pages have the added value of acting as a bridge between academia and policymakers in order to provide as comprehensive a picture as possible concerning the deployment and policy solutions for these technologies. In moving towards a future in which technology is fully embedded into our societies, where the potential of the new digital society is unleashed, it is vital, now, to adopt *smart* and future-oriented policies. And to identify these policies we can do no better than adopt the motto 'to know in order to deliberate'.

Part 1

# Workable Policy Frameworks

# 5G and the Wider Goals of Digitalisation in the EU


## Martin Cave



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### ABSTRACT

**This chapter seeks to set the development of 5G within the broader framework of digitalisation of the European Union and other economies and societies. We are rightly and constantly reminded that (almost) no act of production, exchange, or consumption will avoid the impact of digitalisation, whether it is performed by public or private organisations or by individuals on their own account, whether it involves direct human labour or does not, whether the goods or services involved are tangible or intangible, new or old, or priced or free at the point of consumption.**



### THE AUTHOR

Martin Cave is currently Visiting Professor at the London School of Economics and was formerly Professor at Warwick Business School. He specialises in the economic regulation of network industries and in competition policy, has worked closely with many regulatory agencies in several sectors and continents, and is co-author of the textbook *Understanding Regulation*. He holds BA, MPhil and DPhil degrees from Oxford University.


### INTRODUCTION

This chapter seeks to set the development of 5G within the broader framework of digitalisation of the European Union (EU) and other economies and societies. We are rightly and constantly reminded that (almost) no act of production, exchange, or consumption will avoid the impact of digitalisation, whether it is performed by public or private organisations or by individuals on their own account, whether it involves direct human labour or does not, whether the goods or services involved are tangible or intangible, new or old, or priced or free at the point of consumption.

It also happens that the period of time in which 5G was developed and came into use has been the one in which the above realisation has increasingly dawned on the public and our political and governmental institutions, resulting in a flood of digitalisation strategies both in the EU and elsewhere.

I argue below that – fortuitously or otherwise – the innovations embodied in 5G technology may be particularly well equipped to deal with the problems and potential of digitalisation, the two generating a major process of disruption in the mobile communications sector – a sector which has, without fundamental disruptive change, maintained a remarkably consistent economic structure (in terms of both number and type of player, and what they do) over the first four generations while accommodating a range of radical innovations, notably the combination of data services and smartphones.

In what follows, I look briefly at the potential of 5G, at the tasks which digitalisation might have it perform, and at the policy challenges created and their impact on the mobile sector.

## 5G

5G has been quite a long time in coming, and it was recognised at the outset that it would not all come at once. As a European Telecommunications Standards Institute (ETSI) official noted in 2017,

> the initial focus would be on enhanced mobile broadband (probably relying on sub-6GHz spectrum and technology) with the two other key elements of 5G – ultra-reliable low latency and massive machine-type communications, coming along later, perhaps in the mid-2020s.[1]

This analysis was later crystallised by Lemstra (2018) in two variants:

- a limited version, in which 5G is a faster and more efficient version of 4G, specialising in enhanced mobile broadband; and
- an expansive version in which very fast and low latency communications capacity is going to be available everywhere and employed in 'verticals' not yet much penetrated by connectivity, such as connected cars, advanced manufacturing, and e-health.

One possibly indirect technological indicator of the balance between the two is the proportion of 5G networks in use which were SA (stand-alone – that is, wholly separate from a 4G precursor) rather than non-stand-alone (NSA) (still using 4G assets). In mid-2021, less than a quarter were SA.

We examine the full potential of 5G further in the light of the large cluster of innovations which it has brought to life across the whole value chain, but three key characteristics will be discussed at the outset: densification, versatility, and Open RAN (radio access network).

### Densification

Realisation of the expansive version of 5G requires a much denser network of base stations, capable of meeting higher demand and accommodating the use of higher spectrum bands. This has cost and delay implications, especially in jurisdictions where environmental restrictions are more intense. (This may be a factor in explaining why, in 2021, two-thirds of base stations were installed in China.)

It also expands demand for backhaul, which generally uses wired technologies in all but remote areas. A US study has examined the degree to which the value of 5G spectrum licences increases with the availability of wired assets, finding that such a relationship exists with spectrum used for 5G deployments but not for earlier generations (Bazelon et al., 2021).

### Versatility

Versatility, in the particular form of 'network slicing', has two aspects. The first is software-defined networking (SDN). This transfers the functionality needed in the network such as switching and handover from hardware to software, enabling variation in services and functionality to be made more readily.

The second is network function virtualisation (NFV). This involves implementing the functions of the communications infrastructure in software running on standard computing equipment, following the precedent of data centres, which went through a similar transformation. This reduces costs and simplifies the addition of new services. The framework for these developments has been standardised by bodies such as ETSI. The thrust of this development in the mobile sector is to strengthen the trend towards the heterogeneity of network provision, the implications of which are discussed below.

The combination of these two advances allows network capabilities to be decentrally chosen by a variety of customer parties which combine their own physical and virtual resources as individually required to meet their own needs. This is often described as 'network slicing'.

There are several versions of 'network slicing': one in which different network capabilities are offered by the mobile network operator (MNO) to different customers using common hardware resources; another involving customers configuring networks for themselves but using the hardware resources of the MNO; and a third with the customer owning the hardware and software, which is essentially the customer running its own network.

### Open RAN

Current RAN technology is provided as a hardware and software integrated platform. The ambition for Open RAN is to create a multi-supplier RAN solution that allows for separation – or disaggregation – between hardware and software with open interfaces and virtualisation, hosting software that controls and updates networks in the cloud. The promised benefits include supply chain diversity, solution flexibility, and new capabilities leading to increased competition and further innovation.

## FUSING DIGITAL AND PHYSICAL PROCESSES IN A UNIVERSAL DIGITAL TRANSFORMATION

The telecommunications sector was itself the first to be subject to a digital transformation, beginning in the 1980s. The same process for broadcasting started a little later. By now, all over the world, analogue communications exist mainly in small pockets and specialised uses.

Government digital strategies (not always fully implemented) for the whole economy or the public sector alone have appeared with increasing frequency in recent years. Within the EU, Estonia has been a leader in digitising its public sector, including public administration, recognising that, in order to avoid the expensive coexistence of analogue and digital processes, universal take-up of the latter is required.

Consultancies have not only proffered advice on strategy but have also prepared copious international league tables. For example, the Financial Times/Omdia Digital Economies index computes 16 digital economy measures for 39 countries for 2020–2024 (Financial Times, 2021). The measures comprise two for connectivity, four for devices or Internet of Things (IoT), two for enterprise information technology (IT) spend, six for entertainment, and three for payments.

The focus here on data transmission and communications is apparent. However, a whole-economy digitalisation requires the fusion of digital and physical processes. While data downloads and telephone calls require only the transport of bits, which may of course fulfil the aims of education or health, as well as entertainment, the provision of transport or energy, for example, also requires such physical assets as a driverless car or a gas pipeline. Equally, the extensive use of IoT within an advanced manufacturing factory involves physical processes, including tangible capital assets, and other physical inputs and outputs, even if it is all accomplished within a few square kilometres. The prospect of this digital/physical fusion vastly widens the scope and ambition of digitalisation strategies, and interaction with all the related scientific disciplines.

This conceptual shift has been captured in recent work by Katz and Jung (2021) for the International Telecommunication Union as part of its Benchmark of 5th Generation Regulation, which is designed to

Given digitalisation's near-universal applicability . . . a proper strategy must be ambitious and comprehensive

provide governments with a set of guidelines for what needs to be achieved from an institutional standpoint to accelerate the growth of the digital economy. The two authors have developed and populated a measurement framework comprising four pillars relating to national collaborative governance (including links between the digital and other sectoral regulators), policy design principles (covering procedures and transparency), a digital development toolbox (including an overall digital strategy and links to international development goals, such as the United Nations' Sustainable Development Goals or the EU's strategic objectives), and a digital economy policy agenda. Having calculated the index for a cross-section of many countries for 2020, the authors investigate the relationship between GDP, many conventional determinants, *and* the index itself, noting that the data point to a positive link between the index and the performance of the national economy.

In other words, given digitalisation's near-universal applicability and consequences, a proper strategy for it must be ambitious and comprehensive. This is illustrated in the European Commission's proposal for a *Path for the Digital Decade*, to deliver the EU's digital transformation by 2030, and the accompanying *Digital Compass* 2030 (European Commission, 2021).

The *Compass* embraces a list of digital rights, including:

- universal access to the Internet
- universal digital education and skills training
- access to digital systems that respect the environment
- accessible and human-centric public services
- ethical principles for human-centric algorithms
- access to digital health services.

Further, it includes a set of supporting pillars with associated 2030 targets:

- a digitally skilled population: more than 80% having digital skills;
- sustainable digital infrastructures: all households with one gigabit, populated areas covered by 5G, and 20 per cent of world semiconductors made in the EU by 2030;
- digital transformation of business: 75 per cent of enterprises using cloud computing, and more than 90 per cent of small and medium-sized enterprises at basic digital level;
- digitisation of public services: 100 per cent of provision of key public services digitised.

The gap between current performance and the 2030 targets is between 15 and 80 per cent, averaging about 50 per cent.

The document identifies five key ecosystems for digital transformation: manufacturing, health, construction, agriculture, and mobility. It contains a proposal for improved measurement of performance, and it relies heavily upon developing international partnerships.

Thus the EU strategy does go some way to acknowledging the universality of the changes which will occur.

### 5G AND UNIVERSAL ONE GIGABIT CONNECTIVITY

The *Digital Compass* sets a 2030 target for all households to have one gigabit connectivity, and the populated area to be covered by 5G. These factors are key to the whole digitalisation project, which combines both economic efficiency goals and equity ones, relating particularly to public services. The efficiency and equity objectives are mutually

## The marketplace in most advanced jurisdictions continues to have a 'tight oligopoly'

reinforcing, in the sense that universal connectivity is a precondition for abandoning the expensive duplication of analogue and digital modes of delivery.

Relevant to this discussion is the question of whether disadvantaged groups of users and regions in the EU can use 5G to 'leapfrog' the expensive and time-consuming process of progressively extending high-capacity fixed communications, via increasing use of fibre, thus saving both cost and time. This substitution can cover use not only of a radio access network but also of microwave for backhaul.[2] In the EU a projection has been made that by 2026, close to 90 per cent of households will have full fibre to the home (FTTH) connections.[3] The remaining 10 per cent would clearly amount to a severe block on the digitalisation of universal household services.

More generally, the nature of the relationship between fibre and 5G – simultaneously complementary and rivalrous – has called into question whether the regulators should apply to the choice between the two the principle of technological neutrality, which has been favoured but not mandated in the EU regime for the regulation of electronic communications services since 2002. Some argue that, as a 'future-proof' technology and the beneficiary of particularly large externalities, FTTH should be favoured. However, FTTH is *very* expensive in more remote areas (Rossi, 2021).

### EXPLOITING THE FLEXIBILITY OF 5G

We now return to the cluster of innovations currently being delivered as part of the roll-out of 5G networks. The accompanying box, taken from advertising material for Dish's brand new US 5G network entrant Dish from 2021, provides a vivid summary of what is now possible (Dish, 2021).

**Box: the capabilities of Dish's new 5G network**

Of the four major wireless providers in the country, DISH Wireless is the only one to rely fully on 5G. There is no previous infrastructure for DISH Wireless or clients to maintain and the company is building its 5G network from the ground up.

[We adopt] the practice of using different tiers of spectrum bands, known as versatile spectrum. Each band of the 5G spectrum will work together as best needed to provide more data capacity. By combining the bands, DISH Wireless ensures a better 5G network where all of its spectrum works together towards a common goal.

By using network slicing, DISH Wireless can take a portion of its 5G network and create a private end-to-end 5G network for a specific purpose. These 5G network "slices" can also be changed over time to fit the needs of subscribers as they change.

By creating a cloud-native 5G network, DISH Wireless will provide the structure necessary to sustain a large number of applications. Remember, 5G is making the impossible possible, [by] widespread applications for 5G in far-reaching industries. Using cloud computing is allowing these applications to perform at their best. Both AWS [Amazon Web Services] and VMware are playing important roles in hosting DISH's 5G network in the cloud.

Rural markets . . . can struggle to find quality Internet connections due to a lack of investment and/or competition. DISH Wireless is changing this with its dedicated focus on delivering 5G-powered fixed wireless Internet to millions of Americans.

## THE POTENTIAL DISRUPTIVE EFFECT OF 5G ON THE CONNECTIVITY MARKETPLACE

I have described elsewhere the remarkable structural stability of the mobile market – across five generations of technology in a 40-year period of existence in which global take-up has gone from nearly zero to nearly universal, and services have expanded, via smartphones from exclusively analogue voice to mainly digital data (Cave 2021).

The marketplace in most advanced jurisdictions continues to have a 'tight oligopoly' structure – normally involving three or four vertically integrated operators, with extensive asset sharing in some countries.[4] Some but not all operate major fixed networks as well. New network entry has proved difficult in increasingly saturated markets, but where it has been accomplished, notably in France, it has had a marked disruptive effect.

But this stability now faces its severest threat at the start of the 5G era, from a combination of demand- and supply-side factors. The key overall demand-side change is the universality of the process of fusing digital and physical transformation, which will lead to a still barely calculable increase in the demand for connectivity and data transfer.

Providers of these services have requirements which differ with respect to speed and latency. The network slicing capability of 5G conveniently enables these to be met by the same network. But the provider of a digital education or transport service may choose to buy connectivity wholesale and bundle it with the rest of its service, thus cutting the mobile operator's direct and probably profitable commercial tie with the end user.

The potential cloud-based nature of advanced 5G services also introduces new players into the game. An early example is Rakuten in Japan. The new US Dish network described above is, 'except for antennas and cables, mostly a cluster of code that runs on Amazon Web Services' (The Economist, 2022). This 'cloudification' of networks brings new giant firms into the game. It is notable that AWS has announced a new managed service to help enterprises set up and scale the new private 5G networks described below (see Mobile Europe 2021).

What else might happen? Lehr and others identify some other areas where entry might occur (Lehr et al., 2021; see also Bauer & Bohlin, 2021). One example is wide-area coverage for niche applications. This may be needed to support a growing number of IoT applications with fairly homogeneous geographical needs. Both existing networks meeting enhanced mobile broadband needs and niche low-density (and also satellite) networks might be active here. Examples cited include smart metering, public safety networks, and broadcasting.

The second example cited is the marketplace for local coverage and capacity meeting the needs of a group of contiguous end users, who may be a specified private interest group, such as a group of firms in an industrial park, a group of firms offering driverless vehicles (possibly brigaded by a local authority), or individual members of a residential community.

In this case, it could be a private network provided by an (entrant or incumbent) mobile operator for a single firm. Or it could be fully self-supplied, relying on a bespoke spectrum assignment to the relevant firm (or shared spectrum).

In the recent German 3.4–3.8 GHz auction, the regulator (BNETZA) reserved a quarter of available spectrum for verticals – against strong opposition from some mobile operators who were concerned about (among other things) the effect on spectrum auction prices. Closed user group assignments have been made available to local industry. Each user must negotiate local arrangements with its neighbours. A

> The *Digital Compass* sets a 2030 target for all households to have one gigabit connectivity

fee of €31,000 was charged per square kilometre for access to 100 MHz over ten years. Applications for spectrum on a similar basis in the 24.25–27.5 GHz band were accepted from 2021 (Heutmann, 2020). A mid-2021 progress report showed that the regulator had received 137 local 5G network applications in the lower band, of which 117 had been approved by March 2021. By mid-2021, five higher band licences had been received and granted.[5] A less radical way of achieving the same end is to authorise or mandate localised spectrum sharing in appropriate bands. This was applied by the United Kingdom during and after its EU membership. This, of course, would favour a scenario in which existing mobile operators can and do compete. According to the European Telecommunications Network Operators' Association (ETNO), 111 publicly disclosed applications had been deployed across Europe as of October 2021, of which 45 involved mobile operators as the main contractor (ETNO, 2022: 89).

Finally, many mobile operators have sold their masts to specialised companies, which now, particularly in the light of the above changes, have the capacity to integrate into network provision and become wholesale-only operators.

In combination, these changes have the potential to lead to a major shift in the structure of the mobile market.

## CONCLUSION

It has been argued above that 5G has arrived on the scene at the start of an era when digitalisation in the broad sense, including what has been defined as the fusion of the digital and the physical, is taking wing in every sector. This necessitates a digitalisation strategy which both is very broad and has connectivity at its core. The EU strategy, mentioned but not evaluated above, is one such approach.

This combination of circumstances is beneficial because the innovative aspects of 5G – network slicing, movement to the cloud, Open RAN, versatile spectrum – in combination with densification and increase in capacity, provide a form of connectivity capable of meeting users' needs side by side with FTTH.

The result may be a shake-up of the structure of the mobile sector on a scale not seen in recent decades. This includes significant new entry – from new universal or niche mobile operators, and self- or other-supplied private networks. Equally, 5G operators may enter fixed fibre markets, and vice versa. It is reasonable to expect that these pro-competitive changes will benefit end users of all services, even if the rate of change and the capacity of the existing operators to influence the direction of travel remain highly uncertain.

### NOTES

1. Speech from Adrian Scase, ETSI, available at https://www.ucm.es/data/cont/media/www/pag-115737/MadridPreso1_210918%20Martin%20Cave%20ppt.pdf.
2. This general notion has been suggested in relation to middle income economies as a whole, which lack any extensive connections. It is analogous to the way in which, in energy, countries can leapfrog the stage of expensive fossil-fuel power stations by going straight to renewables.
3. https://en.idate.org/tag/ftth-en/.
4. This is shown vividly by figure 1 in Lehr et al. (2021).
5. See Telcotitans, available at https://www.telcotitans.com/bundesnetzagentur-bnetza/207.subject.

### REFERENCES


Bauer, J. & Bohlin, E. (2021). 'Regulation and Innovation in 5G Markets'. *Telecommunications Policy* 46(4), 012260. https://doi.org/10.1016/j.telpol.2021.102260

Bazelon, C., the Brattle Group, Paroma Sanyal, & Ryan Taylor. (2022). 'The Changing Dynamics of Wired and Wireless Networks'..

Cave, M. (2021). 'How Disruptive Is 5G?' *Telecommunications Policy*, 42(8), 653–658.

Dish. (2021). 'Dish Spectrum Holdings and 5G Plans'. 12 August. https://godish.com/dish-spectrum-holdings-and-5g-plans/.
The Economist. (2022). 'Will the Cloud Eat the 5G Networks Business?' 8 January. https://www.economist.com/business/will-the-cloud-business-eat-the-5g-telecoms-industry/21806999.
ETNO (European Telecommunications Network Operators' Association). (2022). 'The State of Digital Communications'. Brussels: ETNO.
European Commission. (2021). *Europe's Digital Decade*. https://digital-strategy.ec.europa.eu/en/policies/europes-digital-decade.
Financial Times. (2021). 'FT-Omdia Digital Economies Index: Spotting the Next Tech Growth Markets'. 1 December. https://www.ft.com/content/d6ebd098-3f81-4638-afba-b1a1a572163c.
Heutmann, T. (2020). 'Frequencies for Industry in Germany'. ITU & CITC Workshop: Radio Spectrum for IMT-2020 and Beyond, 8–10 December.
Katz, R. & Jung, J. (2021). 'Collaborative Digital Regulation: A Much-Needed Approach for Achieving Growth of the Digital Economy'. *ITU Journal on Future and Evolving Technologies*.
Lehr, W., Queder, F., Lehr, W. & Haucap, J. (2021). '5G: A New Future for Mobile Network Operators, or Not?' *Telecommunications Policy*, 45, 102086.
Lemstra, W. (2018). 'Leadership with 5G in Europe: Two Contrasting Images of the Future, with Policy and Regulatory Implications'. *Telecommunications Policy*, 42, 587–611.
Mobile Europe. (2021). 'AWS Private 5G Out of the Box – An Unwelcome Surprise for Operators'. 1 December. https://mobileeurope.co.uk/press-wire/16346-aws-private-5g-out-of-the-box-is-an-unwelcome-surprise-for-operators.
Rossi, M.A. (2021). 'The Advent of 5G and the Non-Discrimination Principle'. *Telecommunications Policy* 46(4), 102279. https://doi.org/10.1016/j.telpol.2021.102279.

# Policy Options for 5G Success in the EU


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**ABSTRACT**

**This chapter discusses the need for a strategic rethinking of the policies that promote 5G's deployment in Europe, which appears crucial in determining the future influence of 5G on the digital economy. Taking inspiration from results that have emerged from the debate on 5G technological leadership and considering the current state of 5G deployment, the chapter discusses whether there is a need for a more effective and proactive policy from the European Union in this field. The conclusion is in favour of an industrial policy that takes on the whole European Union as the scale of action, instead of just the individual Member States.**



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### 1. INTRODUCTION

The fifth generation of the mobile network (5G) is emerging as a new global standard that is capable of connecting not only people but also machines, devices, and objects. In this respect, it cannot be considered simply as an advance on previous mobile technologies (Suryanegara, 2016). This is because, in addition to those features that are expected to introduce incremental changes (i.e., increased speed and lower latency in data transmission), 5G also has other features which will enable the introduction of radical changes that will improve interactions between machines (even without direct human agency) and increase the relevance of edge computing (Ren et al., 2019). Due to all its new features, 5G technology is expected to enable, or accelerate, digitalisation in many areas, and thus it will influence a broad spectrum of sectors (Cave, 2018; Campbell et al., 2017; Rao & Prasad, 2018). In fact, the success of the Internet of Things (IoT), which is often called the next Industrial Revolution, is heavily dependent on the development and implementation of 5G technology.

According to recent estimates, there will be more than 27 billion IoT connections by 2025 (IoT Analytics, 2021). The economic impact of 5G is also expected to be enormous. The roll-out of 5G is projected to produce up to €2 trillion in sales growth and to add up to 20 million jobs across all sectors of the economy between 2021 and 2025 (Accenture, 2021).

Given these estimates, and all the features of the new generation of mobile networks, it seems clear that the changes introduced will go well beyond the telecommunications industry (Cave, 2018). However, the sectors in which 5G will demonstrate its major relevance are not yet clear, and, as was the case for all previous generations, the fields covered and the new applications will appear autonomously through the growing use of the technology and will surely cover more areas than expected (Campbell et al., 2017). Among the sectors in which the predictions are more solid, we should mention the smart city and the smart home (Aazam, Zeadally, & Harras, 2018; Knieps, 2017), smart agriculture, industrial manufacturing, healthcare, the automation of vehicles, and logistics (Anwar & Prasad, 2018; Knieps, 2019).

Considering the wide range of its fields of application, its expected worldwide spread, and its large-scale adoption, 5G may have the potential to become the first mobile technology to emerge as a general-purpose technology (GPT), thus becoming, if not comparable to, then at least in the same category as such momentous innovations as personal computers and the Internet. A technology can be defined as a GPT when it shows three main features: 1) it must be so diffused that it is present across most sectors of the economy; 2) it should be an enabler of new processes of innovation; and 3) it should be characterised by fast evolution (Bresnahan & Trajtenberg, 1995; Knieps & Bauer, 2022). The emergence of 5G as a GPT is crucially connected to its future diffusion, which in turn depends on its adoption as the new universal standard for human mobile communication and machine-to-machine communication. In this respect, the standard-setting institutions will play a pivotal role in favouring and fostering 5G's worldwide diffusion.

Considering that 5G may become a GPT, the debate surrounding leadership in its development and roll-out is heated. The discussion is evolving in two main directions: the first relates to industrial and/or geopolitical leadership in technological innovation (Parcu, Innocenti, & Carrozza, 2022; Teece, 2021), and the second is around the challenges related to 5G's deployment around the globe.

The next section summarises the debate on technological leadership with reference to studies that attempt to evaluate it, going beyond the mere counting of patents. Section 3 focuses on the state of its deployment, which appears to be crucial in determining the future influence of 5G on the digital economy. Section 4 discusses whether there is a need to develop an industrial policy on the regional scale in order to foster deployment. The last section draws some conclusions on the need for a strategic rethinking of the policies that promote 5G's deployment in Europe.

## 2. TECHNOLOGICAL LEADERSHIP: DELAYS AND CATCH-UPS

Contributions have shown that the advancements in 5G technology, and the ownership of the most relevant patents, are led by the United States and China (Parcu, Innocenti, & Carrozza, 2022; Buggenhagen & Blind, 2022; Mendonça et al., 2022). Recent works have followed various methodologies in order to investigate technology leadership in 5G. From the simple counting of patents (Pohlmann, Blind, & Heß, 2020), to the assessment of the quality of those patents that are owned by countries (Teece, 2021), to citation analysis or essentiality checks (Noble, Mutimear, & Vary, 2019; Tsilikas, 2020; Buggenhagen & Blind, 2022), to patents' attributes (USPTO, 2022), and finally to the measuring of technological complexity (Parcu, Innocenti, & Carrozza, 2022), no result finds the European Union at the front of the race.

Despite the clear leadership of the US and China, some studies show that going beyond the simple counting of patents and digging into the 'quality' of the technologies owned can nonetheless show

5G is a new global standard capable of connecting not only people but also machines, devices, and objects

a slightly different picture. According to Parcu, Innocenti, and Carrozza (2022), single European countries are lagging behind, but the EU 27 Member States as a whole are not so far behind the North American and Asian countries. This study adopts the concept of economic complexity (Hidalgo & Hausmann, 2009) to define the positions of countries in terms of technological leadership in relation to 5G, using two main dimensions: *diversity* (how many specialisations are present in a country) and *ubiquity* (how common/rare those specialisations are). According to the notion of economic complexity, the countries that possess many different specialisations, and that are able to combine them, will also lead in those that are rarer. Parcu, Innocenti, and Carrozza (2022) clearly confirm that key specialisations are owned by a few countries, that the disparities among leaders and followers is growing over time, that the US and China occupy leadership positions in relation to 5G technology, and that most European countries are relatively weak in this respect. However, they also show that, if Europe is considered as a whole, it may be a relevant player with respect to the two leading regions (North America and Asia).

These results suggest that the competitiveness of Europe in such a strategic technology may be boosted by integration among the Member States in a joint effort to advance and innovate in the 5G area, as many of the rare and complex technologies are, in any case, present in Europe. An EU-wide coordinated effort towards the common use of advanced technologies that are created by all its industries could close most, or even all, of the present gap with the leading regions, fostering and enhancing the internal digital market.

As has been previously mentioned, the extent to which 5G will deliver the expected socio-economic benefits on a global scale will also strongly depend on the existence and efficient functioning of those institutions that enable and facilitate global cooperation in its technological development and, particularly, in the worldwide adoption that is favoured by standard development organisations (SDOs). Strengthening the standard-development process, as well as facilitating access to its results, has become a priority for the EU, as was stated in a recent communication from the Commission that launched an EU Strategy on Standardisation (European Commission, 2022).

In this respect, notwithstanding the absolute relevance for the EU of being at the technical leading edge of such an important technology, the development of the standardisation system will, in any case, offer a global opportunity to use and implement 5G. What seems relevant and urgent, in the next few years, is, therefore, that EU Member States adopt a timely deployment of the new networks in step with the evolution of the technology. However, as the next section will discuss, the deployment of 5G networks in Europe is lagging behind given the challenges related to investment in what appears, if compared with other regions of the world, to be a quite fragmented landscape (Lemestra, 2018; Blackman & Forge, 2019).

## 3. THE SLOW DEPLOYMENT OF 5G IN THE EU

As is widely known, the 5G Action Plan,[1] which was launched by the Commission to boost the deployment of 5G in the EU, has set ambitious goals. These have become even more ambitious with the 2030 Digital Compass (European Commission, 2021), which has set 2030 as the deadline for 5G coverage of all populated areas. However, according to several analyses (GSMA, 2021; European Court of Auditors, 2022), the MS are lagging behind in 5G implementation and are at risk of failing both the 2025 and the 2030 targets.

According to the last quarterly report produced by the European 5G Observatory (2022), with the first commercial 5G service, which was launched in Lithuania in January 2022, the target of having fully commercial 5G services in at least one major city by the end of 2020 has now been completed for the EU 27. However, these data may be misleading, since the lack of uniformity in the expected quality of services (in terms of minimum speed and maximum capacity) creates the risk of different interpretations among Member States, which in turn may lead to serious inequalities in 5G services in the EU (European Court of Auditors, 2022). So far, only Germany and Greece have created specific definitions in terms of the quality of 5G services.

The two main levers to accelerate deployment are *spectrum* and *infrastructure* policies.

With respect to spectrum assignment, due to the COVID-19 pandemic, which delayed 5G auctions, progress has been quite slow: the objectives set for the three pioneering bands in the 5G Action Plan have not yet been achieved in all Member States (European 5G Observatory, 2022). Observers have commented that the average spectrum prices have trended upwards in Europe, and a recent survey of EU auctions (Kuś & Massaro, 2022) has shown significant differences in reserve prices. High reserve prices may make it more difficult for new players to enter the market and, above all, as stated by mobile network operators (MNOs) globally, may mean fewer resources to invest in 5G deployment and, therefore, delays to the roll-out of the 5G network.

With respect to infrastructures, 5G networks are expensive to deploy, and they face a sort of chicken-or-egg problem: the demand that will be sufficient to justify the large investments required cannot be taken for granted because, in many cases, cutting-edge 5G-enabled services and applications are not yet widely available (Brake, 2020).

The architecture of 5G, compared with previous mobile generations, requires network 'densification', that is, many more cellular base stations, each of which will provide connectivity over a much smaller coverage area, or 'small cells'. In this respect, the more subscribers who can use a base station, the easier it is to repay its cost of deployment: countries of different sizes and population distributions will face different challenges during deployment. More specifically, according to the evaluation of the European 5G Observatory, countries with larger countries (e.g., Finland, Germany, Spain, Romania), those with a dispersed urban population (e.g., Belgium), and those with a small population (e.g., Slovakia, Hungary, Slovenia, Estonia, Luxembourg) will all face greater difficulties. As a general result, 5G coverage (as a percentage of populated areas) is already quite diverse among the MS: it is almost 50 per cent for the EU 27, but with significant differences among the MS, with countries in which the indicator is still at 0 per cent (European 5G Observatory, 2022).

European telecommunications operators, in relation to their counterparts in the US and Asia, are encountering severe challenges in running a timely and effective deployment because of specific market dynamics that reduce investment, and this is probably exacerbated by what has been described by the operators in the region as excessive regulation (ETNO, 2022). European operators have experienced several years of steady decline in their revenues for fixed and mobile services,[2] which in turn has put pressure on their investment capacity. In fact, even if, with respect to their revenues, European operators appear to be heavy investors, There will be more than 27 billion IoT connections by 2025

given the intense price competition, their capital expenditure is relatively low compared with that of international competitors.

Network-sharing agreements are among the most common of the responses for effective and cost-reduced deployment and for investment risk mitigation, with the amounts of savings being dependent on factors such as the type of sharing (passive or active),[3] the technology, and the geographical coverage. Even if concerns have been raised about the potential anti-competitive effects of cooperation among competitors (see, as an example, the merger investigation on the joint venture INWIT, between Telecom Italia and Vodafone),[4] network-sharing deals have been approved in most cases and have even been encouraged in many markets. Tower companies, which primarily generate revenue by leasing space on their communication sites to wireless carriers and other tenants, are a relatively recent trend in this scenario, and they have shown a rapid growth, particularly in North America, where the leading independent tower company, AMT, was initiated. In Europe, the market leader is Cellnex, with a portfolio of about 128,000 sites across the whole continent.

In this regard, it is also important to note that the new European Electronic Communication Code has introduced the innovative Article 76,[5] which is intended to foster co-investment, with the explicit purpose of favouring faster deployment of very high capacity networks (VHCNs) in the EU. Its concrete effects, and the extent of any potential contrasts with competition law assessments of the co-investment agreements among competitors, is still too early to evaluate.

Open radio access network (Open RAN) is another of the technology trends that are being leveraged in the new generation of mobile communications in order to help telecoms operators reduce costs while increasing network capacity and operational efficiency. The ambition for Open RAN is to create an open and interoperable multi-vendor architecture that enables the separation between hardware and software and the 'softwarisation' of the network (network virtualisation). At the beginning of 2021, the major European telcos (Deutsche Telekom, Telefónica, Vodafone, and Orange) published a joint 'Memorandum of Understanding'[6] to provide a framework for their commitment to supporting the development of an Open RAN ecosystem for deployment. Furthermore, it is important to note that this investment opportunity is certainly not reserved for large telecom operators but can directly interest small and medium-sized enterprises (SMEs) in the EU.[7]

As much as this technology sounds promising, political (see, e.g., Cerulus, 2021) and technological challenges surrounding its development suggest that it will probably take a few years for it to become significant.[8] While Open RAN could become an opportunity for Europe to strengthen its leadership in network technology in the future, especially if it is able to involve its numerous innovative SMEs in the process, at present Europe is losing ground in this crucial phase of deployment. Furthermore, the COVID-19 pandemic has further strengthened the perception of the digital infrastructure as being essential for our societies, offering another reason to rethink the current approach to 5G infrastructure in Europe.

## 4. IS THERE A NEED FOR AN EU INDUSTRIAL POLICY ON 5G NETWORKS?

In addition to internal differences, the progress of implementation in the European region also appears to be slow compared with other parts of the world

(GSMA, 2021): the estimate of 5G connections as a share of the total number of mobile connections by 2025 is around or above 50 per cent in all of the more advanced economies, with the exception of Europe, where the estimate is 35 per cent. The delay in European countries is also evident with respect to migration from 4G to 5G access infrastructure and to constructing a stand-alone 5G access infrastructure, in which the EU countries' performances are dwarfed by those of South Korea and are significantly behind that of the US (ERT, 2020).[9]

It needs to be considered that, in those countries where the situation is more advanced, roll-outs have been driven less by consumer demand, which remains limited, and more by government ambitions. As is well known, the South Korean government played an essential role in the development of 5G in that country, setting up a detailed timeline for its deployment and commercialisation and guaranteeing consistent public investment. In particular, the government prepared a deployment model that helped the three major telcos to achieve faster deployment and to split the deployment costs (Massaro & Kim, 2022). As for China, the support of 'national champions' who could lead 5G has been, in recent decades, an explicit policy that is aimed at helping the country's telecommunications operators to move quickly to stand-alone 5G, in order to enable the widespread use of IoT applications and upgrades in advanced manufacturing (Triolo, 2020). Thanks to strong government guidance and control, with focused government investment in technology research and development, Chinese industry has been able to benefit from the economies of scale in its home market, which has effectively been protected from foreign competitors.

In the United States, in January 2021, the National Telecommunications and Information Administration released the long-awaited National Strategy to Secure 5G Implementation Plan, a government-wide plan to lead the development and deployment of secure and resilient 5G wireless communications infrastructure. The Plan builds on the Secure 5G and Beyond Act, which was signed into law by President Trump in March 2020, and differs from earlier strategies because it lists the specific actions that the federal government will take along four identified 'lines of effort', the first of which is to 'Facilitate Domestic 5G Rollout'. This Plan was the result of growing and bipartisan support for the promotion of an industrial policy regarding the planning of 5G, which is based on the widespread conviction that a successful deployment of 5G, as well as sustained wireless innovation beyond 5G, are opportunities that are of national importance (Brake, 2020).

Furthermore, the geopolitical relevance of 5G also has important implications for Europe's ability to achieve strategic autonomy in key areas such as mobile communications and the IoT. The relevance of an industrial policy on 5G, in fact, is not only technological but also relates to security. As Kaska, Beckvard, and Minárik (2019) have pointed out, the roll-out of 5G needs to be recognised as a *strategic* rather than merely a *technological* choice, and many countries, notably the US, have imposed restrictions on the use of Chinese 5G solutions as a result of national security concerns. The main reason is that 5G architecture reduces the separation between edge and core communications networks, implying that it is no longer possible to limit vendor impact to the edge; therefore, a potential threat at any point of the communication network becomes a threat to the whole network. Consequently, the objective of achieving the fast deployment of secure networks has become a priority within the EU, and this has been consistently reiterated by the Member States and the EU institutions in a field in which the EU and the MS have concurrent powers (Robles-Carrillo, 2021).

Given the possible nature of 5G as a GPT; its technological architecture, which is radically different from those of previous generations of mobile technologies; the disruptive potential for innovation in many sectors; and, last but not least, the strategic and security concerns just mentioned, it seems legitimate to ask if there is a need for a more effective and proactive policy from the EU in this field, and, in particular, for an industrial policy that takes on the whole Union as the scale of action, instead of just the MS.

One of the key issues in this respect is that the telecoms industry structure in Europe today is extremely fragmented, counting more than 70 companies in the region, while the main international competitors count only a handful of big operators. While this fragmentation of actors has certainly delivered benefits in terms of low prices and retail service innovation, it has also come at the cost of a decline in revenues for EU telecoms, which makes it hard for many local and small telecom companies to sustain the growing investment cost that is associated with 5G. Clearly, national fragmentation also creates the need for companies to deal with various regulations across borders, as well as a multitude of application procedures and permits that are needed in order to instal 5G equipment, which further aggravates the deployment costs.

Furthermore, the ability to develop strong European industrial leadership in 5G could also help EU SMEs to make an impact by developing and providing new services that use or enable the use of 5G, multiplying the opportunities this strategic technology can bring to society overall. Corporate venture capital vehicles, originating especially from telecom operators, are already a factor in sustaining start-ups and SMEs in their efforts to accelerate the 5G transition in Europe, but it is evident that greater availability of funds and an increase in scale in this kind of operations could signify a step change in the role of EU SMEs.

The traditional question of 'how many big players are needed for healthy competition in telecoms markets?' – which in the past found an empirical answer in pursuing (at least) four players in each market – may require rethinking in the current 5G scenario, particularly if one takes seriously the idea of an EU single market and thus assumes a continental scale rather than a national one.

To pursue the path of cross-border consolidation in the telecoms sector, the EU should probably adapt and reorient its merger control policy. While this approach may cause regulators obvious concerns, in that the reduction in the number of EU operators could lead to higher prices and less choice for consumers, nonetheless the emergence of a few European champions may allow for the investments needed for innovation, ultimately benefiting consumers in the long term. If the Commission starts to assess mergers on the basis of a pan-European market, as long as they produce merger-specific efficiency gains in terms of international competition which outweigh any anti-competitive effects, there would be no grounds to prevent the creation of European champions, with the important caveat that national retail competition should not be substantially reduced or altered.

While these considerations may have some general relevance in the electronic communications sector, their weight appears more significant in the presence of the potential gain of a rapid and strong 5G deployment, which can be contrasted with the

> 5G may have the potential to become the first mobile technology to emerge as a general-purpose technology

objective difficulties that the European telecoms industry appears to be facing. Outside the EU, some recent cases seem to suggest that a merger's impact on the ability of MNOs to invest and innovate may gain a more prominent role.[10]

In this respect, it should also be determined whether the dearth of cross-border consolidations in the EU in the past was caused by regulatory resistance or by a lack of sufficient incentives for firms to engage in such complex transactions. The real weight of heterogeneous consumers' behaviour across countries, differences in infrastructure and spectrum allocations (which are particularly relevant in the context of mobile and, hence, 5G markets), and different tax and labour regulations all may have significantly diminished the potential economies of scale and scope in the EU. The question is: can the arrival of 5G trigger a different set of conveniences and incentives, for both companies and for public decision-makers?

## CONCLUSIONS

In this chapter we have explored the question of whether a more proactive EU industrial policy might act as a trigger for 5G deployment, considering the delay the EU is experiencing in this important phase of the transition to a 5G-based economy.

At the beginning of the chapter, we recalled a recent study (Parcu, Innocenti, & Carrozza, 2022) suggesting that the fragmentation of research and development efforts in 5G means that Europe is losing ground compared with other advanced areas of the world. However, the competitiveness of Europe in such a strategic technology may be boosted by a joint attempt by the EU and the MS to advance and innovate together in the 5G area, as many of the rare and complex technologies involved are already present in Europe.

The analysis in the next sections lend support to the idea that something quite similar may be necessary on the deployment side: a too fragmented EU telecoms industry is an obstacle to mobilising the necessary amount of investment to ensure that European consumers and citizens can enjoy the rapid deployment of 5G networks. As a possible remedy, we discuss the need for a more careful examination of possible industry agreements and cross-border mergers that are based on taking the idea of the single market seriously when originally national networks are also concerned. This EU-wide industrial consolidation would not need to be pursued at the expense of competition on the retail markets and certainly could integrate and benefit from the contribution of innovative EU SMEs along the value chain.

In the current political and economic scenario, which, as a consequence of the COVID-19 pandemic and the war in Ukraine, is clearly more open to industrial policy considerations, and in which – regarding 5G – nearly all of the countries have systematically engaged in some form of industrial intervention, notwithstanding their different economic choices, this is a conversation that should not be further delayed.

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### NOTES

1. The launch of early 5G networks by the end of 2018, fully commercial 5G services in at least one major city by the end of 2020, and uninterrupted coverage in cities and along main transport routes by 2030.

2. Prices and spends in digital communications services in Europe remain extremely low in comparison with other regions of the world, as has been reflected in the long-term trend of low average revenue per user (ETNO, 2022).
3. Passive sharing refers to the sharing of the passive elements of network infrastructure (mast, sites, cabinet, power, conditioning) while active sharing refers to the sharing of active elements in the radio access network (e.g., antenna, radio network controller (RNC)). See BEREC (2018) for details.
4. https://ec.europa.eu/commission/presscorner/detail/en/IP_20_414.
5. Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018.
6. https://www.politico.eu/wp-content/uploads/2021/01/20/POLITICO-Memorandum-of-Understanding-OPEN-RAN-big-four-operators-January-2021.pdf.
7. According to a recent report on 5G and SME: 'The Open ran ecosystem is expected to create opportunities for smaller players, including SMEs, to innovate on certain network functions, or even particular processes and subfunctions of network operations, and to create new functionalities tailored for new use cases' (European Investment Bank, 2021: 33).
8. The Deloitte Report 'The Open Future of Radio Access Network' discusses some of the technological challenges of telcos regarding Open RAN (Deloitte, 2021).
9. Peering into the future, even on 6G Europe may be moving too slowly and starting to accumulate delays (see Tomás, 2022).
10. See two recent four to three non-EU mergers (T-Mobile/Sprint in the US, and VHA/TPG in Australia), which have dealt with precisely the issue of 5G network investment.

**REFERENCES**


Aazam, M., Zeadally, S., & Harras, K.A. (2018). 'Offloading in Fog: Computing for IoT: Review, Enabling Technologies, and Research Opportunities'. *Future Generation Computer Systems*, 87, 278–289.

Accenture. (2021). 'The Impact of 5G on the European Economy'. Accenture Strategy.

Anwar, S. & Prasad, R. (2018). 'Framework for future Telemedicine Planning and Infrastructure Using 5G Technology'. *Wireless Personal Communications*, 100(1), 193–208.

BEREC (Body of European Regulators for Electronic Communications). (2018). 'Report on Infrastructure Sharing'. BoR 18(116), 14 June.

Blackman, C. & Forge, S. (2019). *5G Deployment: State of Play in Europe, USA and Asia*. Luxemourg: European Parliament.

Brake, D. (2020). 'A US National Strategy for 5G and Future Wireless Innovation'. Information Technology and Innovation Foundation.

Bresnahan, T. & Trajtenberg, M. (1995). 'General Purpose Technology: Engines of Growth'. *Journal of Econometrics*, 65, 83–108.

Buggenhagen, M. & Blind, K. (2022). 'Development of 5G–Identifying Organizations Active in Publishing, Patenting, and Standardization'. *Telecommunications Policy*, 46(4), 102326.

Campbell, K., Diffley, J., Flanagan, B., Morelli, B., O'Neil, B., & Sideco, F. (2017). 'The 5G Economy: How 5G Technology Will Contribute to the Global Economy'. In *IHS Economics and IHS Technology*. https://www.sipotra.it/wp-content/uploads/2017/01/The-5G-economy-How-5G-technology-will-contribute-to-the-global-economy.pdf

Cave, M. (2018). 'How Disruptive is 5G?' *Telecommunications Policy*, 42(8), 653–658.

Cerulus, L. (2021). 'After Huawei, Europe's Telcos Want "Open" 5G Networks'. *Politico*, 20 January. https://www.politico.eu/article/oran-reflow-huawei-europe-telecoms-5g/

Deloitte. (2021). 'The Open Future of Radio Access Networks'. https://www2.deloitte.com/content/dam/Deloitte/pt/Documents/technology-media-telecommunications/TEE/The-Open-Future-of-Radio-Access-Networks.pdf

ERT (European Round Table for Industry). (2020). 'Assessment of 5G Deployment Status in Europe'. September. https://ert.eu/wp-content/uploads/2020/09/ERT-Assessment-of-5G-Deployment-Status-in-Europe_September-2020.pdf.

ETNO (European Telecommunications Network Operators' Association). (2022). 'The State of Digital Communications 2022'. February. https://etno.eu//downloads/reports/state_of_digi_2022.pdf.

European 5G Observatory. (2022). '5G Observatory Quarterly Report 14. Up to January 2022'. https://5gobservatory.eu/wp-content/uploads/2022/02/5G-Obs-PhaseIII_Quarterly-report-14_FINAL-Clean-for-publication_16022022.pdf.

European Commission. (2021). 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, "2030 Digital Compass: the European way for the Digital Decade"'. COM 118.

European Commission. (2022). 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, "An EU Strategy on Standardisation: Setting Global Standards in Support of a Resilient, Green and Digital EU Single Market"'. COM 31.

European Court of Auditors. (2022). '5G Roll-Out in the EU: Delays in Deployment Of Networks with Security Issues Remaining Unresolved'. Special Report 3/2022, https://www.eca.europa.eu/Lists/ECADocuments/SR22_03/SR_Security-5G-networks_EN.pdf.

European Investment Bank. (2021). 'Accelerating the 5G

Transition in Europe: How to Boost Investments in Transformative 5G Solutions'. Report, February. https://www.eib.org/en/publications/accelerating-the-5g-transition-in-europe.

GSMA. (2021). 'The Mobile Economy 2021'. https://www.gsma.com/mobileeconomy/wp-content/uploads/2021/07/GSMA_MobileEconomy2021_3.pdf

Hidalgo, C.A. & Hausmann, R. (2009). 'The Building Blocks of Economic Complexity'. *Proceedings of the National Academy of Sciences*, 106, 10570–10575.

IoT Analytics. (2021). 'State of IoT, 2021'. https://iot-analytics.com/product/state-of-iot-summer-2021/

Kaska, K., Beckvard, H., & Minárik, T. (2019). 'Huawei, 5G and China as a Security Threat'. NATO Cooperative Cyber Defense Center for Excellence (CCDCOE), 28.

Knieps, G. (2017). 'Internet of Things and the Economics of Smart Sustainable Cities'. *Competition and Regulation in Network Industries*, 18(1–2), 115–131.

Knieps, G. (2019). 'Internet of Things, Big Data and the Economics of Networked Vehicles'. *Telecommunications Policy*, 43(2), 171–181.

Knieps, G. & Bauer, J.M. (2022). 'Internet of Things and the Economics of 5G-Based Local Industrial Networks'. *Telecommunications Policy*, 46(4), 102261.

Kuś, A. & Massaro, M. (2022). 'Analysing the C-Band Spectrum Auctions for 5G in Europe: Achieving Efficiency and Fair Decisions in Radio Spectrum Management'. *Telecommunications Policy*, 46(4), 102286.

Lemstra, W. (2018). 'Leadership with 5G in Europe: Two Contrasting Images of the Future, with Policy and Regulatory Implications'. *Telecommunications Policy*, 42(8), 587–611.

Massaro, M. & Kim, S. (2022). 'Why Is South Korea at the Forefront of 5G? Insights from Technology Systems Theory'. *Telecommunications Policy*, 46(5), 102290.

Mendonça, S., Damásio, B., de Freitas, L.C., Oliveira, L., Cichy, M., & Nicita, A. (2022). 'The Rise of 5G Technologies and Systems: A Quantitative Analysis of Knowledge Production'. *Telecommunications Policy*, 46(4), 102327.

Noble, M., Mutimear, J., & Vary, R. (2019). 'Determining Which Companies Are Leading the 5G Race'. *Wireless Technology, IAM-Media,* Aug, 49, 35–40. Parcu, P.L., Innocenti, N., & Carrozza, C. (2022). 'Ubiquitous Technologies and 5G Development: Who Is Leading the Race?' *Telecommunications Policy*, 46(4), 102277.

Pohlmann, T., Blind, K., & Heß, P. (2020). 'Fact Finding Study on Patents Declared to the 5G Standard'. iPlytics.

Rao, S.K. & Prasad, R. (2018). 'Impact of 5G Technologies on Industry 4.0'. *Wireless Personal Communications*, 100(1), 145–159.

Ren, J., Yu, G., He, Y., & Li, G.Y. (2019). 'Collaborative Cloud and Edge Computing For Latency Minimization'. *IEEE Transactions on Vehicular Technology*, 68(5), 5031–5044.

Robles-Carrillo, M. (2021). 'European Union Policy on 5G: Context, Scope and Limits'. *Telecommunications Policy*, 45(8), 102216.

Suryanegara, M. (2016). '5G as Disruptive Innovation: Standard and Regulatory Challenges at a Country Level'. *International Journal of Technology*, 7(4), 635–642.

Teece, D.J. (2021). 'Technological Leadership and 5G Patent Portfolios Guiding Strategic Policy and Licensing Decisions'. *California Management Review*, 63(3), 5–34.

Tomás, J.P. (2022). 'South Korea Aims to Launch Commercial 6G Around 2028: Report'. RCRWireless, 16 March. https://www.rcrwireless.com/20220316/network-infrastructure/south-korea-aims-launch-commercial-6g-around-2028-report.

Triolo, P. (2020). 'China's 5G Strategy: Be First Out of the Gate and Ready to Innovate'. In S. Kennedy (ed.), *China's Uneven High-Tech Drive: Implications for the United States*, pp. 21–28. Washington, DC: Center for Strategic and International Studies (CSIS).

Tsilikas, H. (2020). 'To Make Effective 5G IP Decisions Policy-Makers Need the Full Picture'. IAM-media.

USPTO (US Patent and Trademark Office). (2022). 'Patenting Activity Among 5G Technology Developers'. US Patent and Trademark Office of Policy and International Affairs.

# A Framework for 5G and 6G Market Design

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**ABSTRACT**

**Advanced wireless services develop in a system of interdependent, complementary innovation. Designing a policy framework for these services must build on insights from innovation economics. This chapter reviews the essential elements of a forward-looking framework for fifth-generation (5G) and sixth-generation (6G) markets. After a brief discussion of the emerging value systems and the economics of complementary innovation, it discusses three broad aspects of market design: the need for flexible and adaptive spectrum policy, measures to facilitate coordination among players, and the balancing of differentiation and non-discrimination needs. The chapter concludes with an outlook on how to align the direction of 5G and 6G innovation with overarching societal goals.**

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## 1. INTRODUCTION

Details of the value system that will support sustainable business models for fifth-generation (5G) and sixth-generation (6G) services are in development. Although some similarities to earlier generations of wireless services will exist, value generation in the gradually maturing 5G and the emerging 6G systems will probably also deviate in important aspects from these earlier systems (Knieps & Bauer, 2021; Yrjölä, Ahokangas, & Matinmikko-Blue, 2022). Rational, regulatory policy models must build on and learn from past experiences. However, reliance on policy blueprints that worked in the past will probably result in obsolete and inefficient policy designs in fast-paced, interdependent social and technological environments (Vogelsang, 2017). To avoid this dilemma, the policy model must be forward-looking and appropriate to the emerging sectoral conditions.

This chapter examines the challenges that forward-looking 5G and 6G policy must consider and their repercussions for the rational design of a market and regulatory framework. A crucial point of departure is that neither empirical observations and theory suggest that there is a single, best approach. There is also mounting evidence that neither tightly nor loosely regulated information and communication markets harness the full benefits of advanced, digital technology. A third way, a 'smart, strategic state', is needed (Aghion & Roulet, 2014). Research and experience also show that specific, market design choices will have consequences for sector performance; each choice entails trade-offs. Policymakers have an opportunity to influence the overall direction of the system, its investment and innovation rates, and the equitability of available services.

This increased importance changes the ways in which policy can influence developments. Future policy will not be able to control or steer the mobile system in a specific direction. Rather, one of its main roles will be to influence and orchestrate interactions among participants in the value system. This requires a focus on the broader constitution of wireless markets in addition to attention to specific details. The chapter will explain what such a future framework might look like. It begins with an overview of the organisation of the future, wireless value system and then examines the repercussions of increasing interdependencies and higher levels of risk and uncertainty in the sector. Sections 4–7 examine important aspects of market design and how they can be aligned with the material conditions of the sector and envisioned policy goals. The concluding section reiterates the main policy implications.

## 2. THE CHANGING WIRELESS VALUE SYSTEM

The system of wireless value generation has changed multiple times during the past decades. In the eras of first-generation (1G) and second-generation (2G) technology, mobile voice communication was a differentiated, vertical segment of the telecommunications industry. Third-generation (3G) and fourth-generation (4G) services introduced a stronger horizontal, layered model, which, in important aspects, resembled the general-purpose, end-to-end architecture of the public Internet. With it, the mobile services industry experienced the entry of specialised service providers. Many of them were not vertically integrated but offered services on one or a few layers of the stack only. Among the fresh players were mobile virtual network operators (MVNOs), mobile virtual network enablers (MVNEs), and mobile virtual network aggregators (MVNAs).

In contrast to the vertical and horizontal organisation of prior technologies, 5G and 6G networks will probably weave together horizontal and vertical elements to develop a hybrid architecture (Bauer, 2022; Bauer & Bohlin, 2021). Saad, Bennis, and Chen (2019: 134) believe that today's 5G systems can readily support evolutionary services, such as enhanced mobile broadband (eMBB), massive Machine Type Communications (mMTC), and ultra-reliable and low-latency communications (URLLC) services. However, the systems have not been able to support the envisioned revolutionary services, given slow and costly millimetre wave (mmWave) deployment. Consequently, next-generation 6G technologies are needed that can support and 'simultaneously deliver high reliability, low latency, and high data rates, for heterogeneous devices, across uplink and downlink' (Saad, Bennis, & Chen, 2019: 134). Visions of the range of 6G services suggest that the technical and engineering components of 6G systems must be able to support massive convergence beyond traditional information and communication technologies.

In emerging 6G applications and services, these coordination tasks will be even more complicated. However, the elements of sustainable business models have not yet fully emerged. Major coordination and management issues exist in the three major 5G application realms – eMBB, mMTC, and URLLC. These issues include making spectrum flexibly available so that local networks can flourish and coordinating rights of way, urban planning, and standardisation among service providers and important user groups (e.g., healthcare, energy, transportation, logistics, industry, and agriculture) (Ahokangas et al., 2020, 2021).

Both 5G and 6G services constitute systems of complementary innovation in which numerous players must be orchestrated (Bauer & Bohlin, 2021). This goes beyond the technical design and development of specifications for services, such as extended reality (XR), advanced telemedicine, haptics, flying vehicles, brain–computer interfaces, and autonomous systems (Saad, Bennis, & Chen, 2019: 134). In addition to orchestrating digital assets and functions, this typically requires coordination with players that have historically not been part of standardisation processes and other forms of voluntary cooperation. Although new intermediaries may supply some of these functions, policy arrangements also influence how effective coordination tasks will be accomplished.

## 3. THE ECONOMICS OF INTERDEPENDENT, COMPLEMENTARY INNOVATION

Advanced wireless systems will support general-purpose connectivity upon which a large range of specialised services can be configured. They constitute a system of interrelated markets in which numerous complementary innovation processes unfold. Each of the complementors responds to business conditions in their own market segments, particularly the innovation opportunities, the contestability of the market, and the related appropriability of innovation premiums (Shapiro, 2012). Each player also considers the business and innovation conditions in related, complementary markets. For example, a network that supports a more differentiated quality of service (QoS) will open additional innovation opportunities for complementors. In turn, new applications and services will stimulate network operators to further upgrade the capabilities of the infrastructure. These effects create a virtuous, mutually enforcing cycle of innovation with systemic spillover effects and externalities. Stronger (weaker) complementarities will amplify (reduce) these synergies.

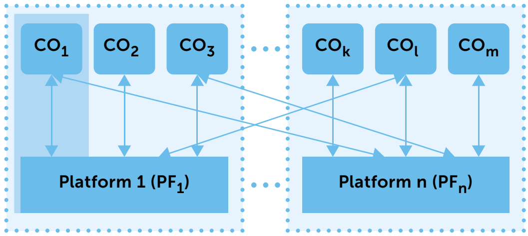


FIGURE 1: **A highly stylised model of complementary innovation in 5G and 6G systems. To simplify, the figure shows only two layers of the complex value systems (platforms and complementors). However, the model is generalisable to multiple layers and organisational forms of players. Complementarities between PF and CO influence innovation activity positively, but coordination costs influence it negatively. $PF_1$ and $CO_1$ through $CO_3$ form one platform ecosystem; $PF_n$ and $CO_k$ through $CO_m$ form a competing platform ecosystem. If complementary functions are vertically integrated with a platform (e.g., $CO_1$ and $PF_1$), the platform may have stronger incentives to exclude other complementors.**

Moreover, transaction and coordination costs are relevant in innovation ecosystems. Such coordination costs exist in the vertical relations between individual platforms and their complementors (e.g., $PF_1$ and $CO_1$ in Figure 1). They also affect relations across platforms and complementors in the form of cross-platform vertical coordination costs (e.g., $PF_n$ and $CO_3$) and possibly in the form of horizontal coordination costs between platform ecosystems. Players in such interrelated innovation ecosystems will take these interdependencies into consideration. However, they may only have an incomplete view of parts of the ecosystem that are beyond their own operations. In that sense they are myopic, and their individual optimisation decisions may result in inefficient outcomes for the whole ecosystem. Thus, decentralised decisions can result in system-wide coordination failures. Historically, this has been recognised, and market players have adopted measures to reduce that threat. Standardisation and interoperability are two important instruments to reduce such coordination problems and the associated efficiency losses. A key question is whether similar solutions will evolve from decentralised interactions among players in 5G and 6G markets or whether policy coordination would be beneficial.

Public policy and regulation influence these relations directly, indirectly, and systemically. Specific interventions can affect the conditions of innovation as well as the transaction and coordination costs. For example, a regulatory obligation that a mobile network operator (MNO) must put together a reference offer for MVNOs reduces the transaction and coordination costs between MNOs and MVNOs. It enhances the innovation opportunities of the MVNOs. The increased MVNO innovation activity, in turn, increases the incentives of network operators to improve the infrastructure. At the same time, a regulatory mandate limits the flexibility of the MNO to differentiate contractual offers to the MVNO. Thus, it may exert a dampening effect on its innovation efforts at the network level (Kim et al., 2011). The net outcome of these counteracting effects is difficult to anticipate. In response to similar conditions that affected innovation in the Fourth Industrial Revolution, an increasing number of countries have introduced adaptive and agile forms of regulation that are better suited to these conditions (World Economic Forum, 2020). A lesson that is portable to 5G and 6G services is that the risk and uncertainty of innovation require the business and policy arrangements to support experimentation and learning. Moreover, they require capital markets that provide sufficient funding and can absorb failure.

In contrast to the more linear value systems of the past, there is no single, best policy approach in a dynamic, interdependent system – only different choices along multiple trade-offs. Alternative policy arrangements will position a place (country, region) differently and will be visible in characteristic patterns of performance metrics. An understanding of the likely dynamic effects of policy choices is therefore an important precondition for designing a suitable market framework. The importance of providing an appropriate institutional fabric for markets has been recognised more clearly during past decades and has received additional attention with the emergence of algorithmic markets (Ezrachi & Stucke, 2016; Roth, 2018). How can policy effectively fulfil this role? The next three sections discuss the policy options in critical, interrelated areas. Section 7 explores the implications for European policy.

## 4. FLEXIBLE, ADAPTIVE SPECTRUM POLICY

It is widely recognised that spectrum availability in the low, mid-, and high bands is critically important for 5G and 6G services. Similarly, it is important to find the right mix of licensed and unlicensed spectrum bands. Spectrum assignment mechanisms that support innovation and facilitate dynamic adaptations of assignments have received less attention. Envisioned 5G services in smart manufacturing, smart agriculture, and similar applications will require local spectrum access, for example in a port or in an industrial location. In response, countries are starting to experiment with new licensing schemes, including highly granular, local licences in addition to national and regional licences (e.g., Matinmikko-Blue et al., 2021). Other countries have adopted provisions to improve liquidity in and the working of secondary markets (e.g., Gomez et al., 2019; Lehr, 2020). Germany uses spectrum set-asides, and Italy has introduced use-it-or-lose-it provisions. Policymakers ought to monitor these experiments closely to see whether any of these strategies are better suited to advance 5G innovation.

Few countries have started to develop a forward-looking strategy that addresses new future spectrum needs. For example, 5G and particularly 6G technologies support beamforming. This will enhance the efficiency of spectrum use, but it also will raise new, complex coordination issues.

Stakeholders should invest in conceptual and experimental work to develop approaches that can assign spectrum efficiently. New forms of spatial, real-time auctions, reliance on algorithms to improve the technical coordination between signals, and economic arrangements that facilitate secondary transactions are needed. Furthermore, 6G technologies will require licences that accommodate beamforming technologies not only in a terrestrial plane but also in a third, vertical, spatial dimension, as new forms of mobility and technology (e.g., flying automobiles, drones) and new antenna technologies, such as large intelligent surfaces (LIS), are increasingly utilised (Basar, 2019).

As the spectrum needs of 5G and 6G applications expand, policymakers must develop innovative solutions for reconciling established and emerging services. Such tussles emerge in areas where assignments via spectrum auctions compete or conflict with assignments made on other principles, such as administrative licensing. They include potential conflicts between 5G and 6G services and over-the-air broadcasting or services with a strong, public interest component, such as passive weather satellites. Providers of services that are not subject to pressure from competitive market forces have only weak incentives to increase the efficiency of spectrum use. This mismatch in how usage rights are specified needs to be addressed with innovative solutions (Krishnamurthy, Murtazashvili, & Weiss, 2021; Weiss et al., 2021). A potential solution that is in discussion is depreciating licences that require continuous efficiency increases (Kwerel & John, 2010; Milgrom, Weyl, & Zhang, 2017). Solutions, such as the two-sided, incentive auction conducted in the United States to reallocate broadcasting frequencies to commercial mobile wireless services, work under certain circumstances (Milgrom, 2017).

## 5. MITIGATING COORDINATION COSTS IN SUPPORT OF INNOVATION

Coordination costs include transaction costs among players and costs of the adaptation of technology developed by one player to the requirements of other players and the larger ecosystem. During the early stages of 5G and 6G development, market-making costs (Spulber, 2019) are caused by the necessity to orchestrate collaboration between numerous players who are required to create sustainable innovation. These costs are also caused by the need to experiment and by the cost of failure and learning. Examples are the costs of negotiating and contracting efforts for rights of way, the development of application programming interfaces (APIs), or the negotiation of MVNO agreements. Once a market has been established in its basic contours, these costs consist primarily of market-transaction costs (Spulber, 2019). Examples are the need of application providers to negotiate with multiple MNOs to launch services or the need to adapt a service to run on different network protocols.

Because coordination costs increase the cost of innovating and reduce expected gains from innovation, they create a negative feedback loop among the innovation activities of different players, other things being equal. Coordination costs are not unique to the digital economy, but they are particularly relevant in 5G and 6G value systems, given the substantial number of interdependent players, the differentiation of the value system, and the need to produce a tightly integrated, synchronous service. Market and non-market arrangements facilitate coordination and reduce these costs; they include standards, open and transparent technology solutions (e.g., Open Radio Access Networks, O-RAN), and the digital platforms that orchestrate players in digital ecosystems. At a minimum, policy needs

> Future policy will not be able to control or steer the mobile system in a specific direction

to facilitate such arrangements. It also must examine whether additional public policy actions could improve technical, economic, and social coordination (Bauer, 2019). However, the answer will depend on specific, national, and regional market conditions, and that answer is not necessarily affirmative.

The need to coordinate effectively interacts positively and negatively with market power. Vertically integrated players that operate across multiple layers may be able to manipulate the coordination costs incurred by other players. For example, they may charge fees or implement overly stringent, and hence more costly, QoS requirements. This risk is lower vis-à-vis complementors, because non-myopic players will be aware of the mutually beneficial interdependencies. However, the risk is higher for competitors, who may need access to services provided by the integrated firm, which may be able to gain strategic advantages from impeding access. To reduce coordination costs and such potential distortions, some authors have proposed regulatory interventions to modularise the architecture of 5G and 6G systems (e.g., Lemstra, 2018). An emerging discussion suggests the modification of the existing system of patents to facilitate access to the more than 15,000 5G and 6G patents.

Measures in the first group include requiring large players to offer standardised and open APIs or to mandate that network operators offer standard conditions to other players in the wireless ecosystem, such as MVNOs, MVNAs, and MVNEs. Measures that target patents aim to clarify the meaning of fair, reasonable, and non-discriminatory conditions to create better access to Standard Essential Patents (Spulber, 2020). Although these types of intervention might reduce coordination costs in the system in the short term, they will probably impede the ability of decentralised actors to negotiate mutually beneficial arrangements in the medium and long term.

Thus, it is not self-evident that regulation should develop such measures because regulation typically suffers from inertia and incomplete foresight about how technology might evolve. Rather, it would be preferable to rely on alternative solutions to provide legitimate safeguards against discriminatory behaviour. Options to introduce more generic safeguards that are more compatible with the dynamics of innovation ecosystems include a general obligation to negotiate in good faith combined with a most-favoured-nation (MFN) provision. This will allow complementors to benefit from access conditions negotiated by other players if they so choose. It will also contribute to modularisation and standardisation of business relations where this is beneficial.

Problems that the stakeholders cannot resolve within this decentralised framework may require an intervention by a regulatory agency with the power to mediate and resolve conflicts. Other policy approaches exist, such as the imposition of more specific, regulatory interventions, including standard offers and regulated prices. However, in the nascent 5G and 6G markets, it is highly advisable to use them sparingly if other measures fail, and the evidence for them is compelling. These instruments are not well suited as precautionary measures.

### 6. PERMITTING DIFFERENTIATION WITH NON-DISCRIMINATION SAFEGUARDS

The heterogeneity of services and the diversity of user needs in 5G and 6G services require differentiation in technical, economic, and organisational dimensions. Network operators, new system integrators, other intermediaries, and new specialised market entrants will seek to assemble the components and functions of the general-purpose

> 5G and 6G networks will weave together horizontal and vertical elements to develop a hybrid architecture

technology, for example by creating specialised network slices to best support the broad range of envisioned services (Knieps, 2021; Knieps & Stocker, 2016). It is likely that players will possess varying degrees of control over essential inputs and differential market power. Policymakers need to answer two key questions: under which conditions can these differences impede the working of the innovation ecosystem? How can policy responses safeguard competition and improve outcomes?

An issue that has generated considerable concern is how to prevent large players with a high market share in one or more layers of the innovation system from sabotaging or disadvantaging other players. It is necessary to differentiate two scenarios. One is the relationship between a large player and competitors who need access to their resources. Another scenario is situations in which large players are trying to extract supernormal rents from complementors. In the first case involving competitors, integrated players have a stronger incentive to exclude or to disadvantage. Cases in the second category have attracted considerable scrutiny, for example the fees assessed by Apple from developers who sell in the AppStore as well as fees charged from complementors who sell from within an app (Geradin & Katsifis, 2021). Other players also make similar arguments. For example, network operators increasingly assert that they have insufficient influence to negotiate contributions from large content providers to network infrastructure investments. Network neutrality provisions are sometimes considered a policy that further weakens their ability to differentiate network services (Frias & Martínez, 2017).

These concerns are difficult to address because of the many interdependencies among players and the direct, indirect, and systemic effects that all regulatory interventions have. A first step in analysing the issues is to question whether unfair competitive practices are in play, or whether the complaints reflect a conflict over the distribution of profits. Unless they are myopic, even dominant platforms understand the value of complementors and do not have an intrinsic strategic incentive to exclude them from participation in the ecosystem. These incentives may change, however, if a platform starts to offer services developed by a complementor itself. Moreover, consumers may be heterogeneous. Some consumers may appreciate that a platform exerts quality and security control over the services provided, whereas others may experience a welfare loss from potentially higher prices or more restrictive usage conditions of a device. Such heterogeneity might result in differentiated service tiers in a competitive market. Alternatively, consumers may opt to join a different platform. However, in a monopolistic environment, it is possible that such endogenous forces do not fully align with the interests of stakeholders.

The imposition of neutrality requirements is one policy option that has gained considerable traction in the past decades and that also applies to 5G and 6G markets. The debate has broadened from an initial focus on network neutrality to services, devices, and even 'full stack' neutrality (e.g., ARCEP, 2018; Easley et al., 2018). If applied broadly, neutrality requirements might address a subset of these concerns. However, neutrality requirements will reduce the ability of players to differentiate services and engage in the experiments necessary to explore the range of innovation opportunities. In the emerging 5G and 6G environments that are contingent on innovation experiments and differentiation, these downsides probably outweigh the benefits of neutrality obligations, even though the empirical evidence to assess the likelihood of either outcome is very sparse (Briglauer et al., 2020).

As in the case of reducing coordination costs, policymakers should look for new, innovative solutions that address these concerns and employ regulatory instruments that support the dynamics of platform innovation. Given the open nature of digital innovation and the associated uncertainties, discretionary, specific regulatory interventions are less advisable than general rules that delineate acceptable from unacceptable behaviours. For example, a general obligation to negotiate in good faith combined with transparency and MFN provisions can mitigate the exclusion of competitors. Similar general rules could address concerns about extraction of supernormal rents from complementors and overly restrictive conditions to join a platform (see for example Geradin & Katsifis, 2021). Such rules would ideally apply generically and symmetrically to all players, unlike the approach embedded in the European Digital Market Act, which singles out specific players.

## 7. BROADER STRATEGIC CONSIDERATIONS

Innovation is a directed, evolutionary search process, an entrepreneurial exploration of new processes, products, services, business models, and designs. The knowledge, skills, and the economic and regulatory incentives under which specific innovators operate will narrow the search to a specific segment of the vast, digital, innovation opportunities space. From a societal perspective, it is therefore desirable to explore multiple directions simultaneously, because it is not known a priori which search strategies will reveal the most promising innovations. Workable competition among innovators is one mechanism to promote the search in different directions. However, there is reason to believe that players with commercial incentives will not explore all directions that might yield societally beneficial novelty, or that they may not realise them as part of their operations. This suggests that it would be a useful meta-strategy to support the diversity of innovation in the private sector, in public–private partnerships, in the public sector, and in the non-profit sector. Moreover, it would be useful to facilitate collaboration and knowledge sharing among participants in the innovation ecosystem.

Implementing such a meta-approach would require leaving aside the framing of 5G and 6G innovation as a 'global race'. Instead of imagining the development of advanced wireless technologies as a race (that will end with a 'winner'), it would be more useful to understand it as an open-ended, infinite game (Sinek, 2019) with the goal to harness wireless technology for society. Seen from this perspective, it will be important to gain more clarity on specific goals of wireless innovation. Trust in the ability of decentralised market players to develop innovative, novel solutions will be a vital component. However, additional efforts are needed to facilitate public interest innovation (McGuiness & Schank, 2021) and specify with greater clarity the notion of responsible innovation (Schomberg & Hankins, 2019).

Among them are policies to facilitate cooperation between players in the 5G and 6G innovation ecosystem, which is already happening in numerous local, national, and European experiments and programmes (European Commission et al., 2022). These efforts must go beyond traditional technology players and include, for example, infrastructure planners (e.g., autonomous vehicles, smart cities), players in traditional activities such as healthcare and education, and a broad range of related

> The risk and uncertainty of innovation require the business and policy arrangements to support experimentation and learning

stakeholders. These initiatives will also include new forms of transborder coordination and a stronger willingness to adopt Europe-wide solutions.

Thus far, national and European policy remains narrowly focused on spectrum assignments, service coverage, and a commercial pilot project. The broader imaginary that inspires these measures is deeply rooted in a trust that digital transformation will almost automatically solve pressing problems of society. Even though there is a kernel of truth in this vision, its appeal has diminished during the past decade. As part of a broader 'tech-lash' there is a risk that there will be increased demands for traditional regulatory interventions. This misses an opportunity to engage in a discussion about the specific goals that a technological society should pursue. Such a discussion is perhaps more deeply informed by an applied values and ethical reference framework that could help develop a framework of general principles and goals for 5G and 6G technology (Bauer, 2022).

## 8. CONCLUSION

This chapter has sketched the contours for a forward-looking policy framework for 5G and 6G markets that is rooted in insights from innovation economics. It cautions against a framework that leans too heavily on traditional forms of regulatory intervention. In contrast, it argues for the need to focus policy on establishing 'guardrails' and a 'constitution' for wireless markets that enables decentralised market transactions. Details of such a framework are exemplified for three areas. They are, first, illustrated for agile, flexible spectrum policy. Second, measures to facilitate coordination and reduce innovation-hampering transaction and adaptation costs are discussed. Third, the chapter explores efforts that can reconcile the need to allow differentiation while providing reasonable safeguards against anti-competitive discrimination.

General, symmetric obligations to negotiate in good faith, MFN clauses, and broad non-discrimination safeguards seem best suited to achieve the goal of vibrant, innovative 5G and 6G markets. In addition, public policy can actively support institutional diversity that creates not just competition in the marketplace but competition for different types of markets and transactions. Dynamic markets will benefit from complementary measures that assist in workforce development and facilitate coordination among the numerous stakeholders in the advanced wireless ecosystems. Finally, digital transformation policies would benefit from clearer mid-range goals for how advanced wireless can be harnessed for individuals, communities, and society.

### REFERENCES


Aghion, P. & Roulet, A. (2014). 'Growth and the Smart State'. *Annual Review of Economics*, 6(1), 913–926.

Ahokangas, P., Matinmikko-Blue, M., Yrjölä, S., & Hämmäinen, H. (2020). 'Future 5G Platform Ecosystems: Case Study of a Digitalized Port Stakeholders' New Interactions and Value Configurations'. Paper presented at the Conference of the International Telecommunications Society (ITS), June 14–17, Gothenburg, Sweden. Online. Available at http://hdl.handle.net/10419/224842.

Ahokangas, P., Matinmikko-Blue, M., Yrjölä, S., & Hämmäinen, H. (2021). 'Platform Configurations for Local and Private 5G Networks in Complex Industrial Multi-Stakeholder Ecosystems'. *Telecommunications Policy*, 45(5), 102128.

ARCEP. (2018). 'Smartphones, Tablets, Voice Assistants . . . Devices, the Weak Link in Achieving an Open Internet'. Autorité de Régulation des Communications Électroniques et des Postes (ARCEP). Paris. Accessed on 31 July 2021 at https://www.arcep.fr/uploads/tx_gspublication/rapport-terminaux-fev2018-ENG.pdf.

Basar, E. (2019). 'Transmission through Large Intelligent Surfaces: A New Frontier in Wireless Communications'. Paper presented at the 2019 European Conference on Networks and Communications (EuCNC), June 18–21, Valencia, Spain.

Bauer, J.M. (2019). 'Technical, Economic, and Social Coordination Requirements of Internet-Based Innovation'. Paper prepared for presentation at the 47th Research Conference on Communication, Information and Internet Policy (TPRC 47), 21–22 September, Washington, DC. Available at https://ssrn.com/abstract=3423613.

Bauer, J.M. (2022). 'Toward New Guardrails for the Information Society'. *Telecommunications Policy*, 46(5), 102350.

Bauer, J.M. (2022). 'Agile Regulation: Experiments in Flexible Governance'. In F. Birke, G. Brunekreeft, V. Stocker, & H.-J. Weiß (eds.), *Perspektiven der Netzökonomie – Beiträge zu Ehren von Günter Knieps*. Baden-Baden: Nomos.

Bauer, J.M. & Bohlin, E. (2022). 'Regulation and Innovation in 5G Markets'. *Telecommunications Policy*, 46(4), 102260.

Briglauer, W., Cambini, C., Gugler, K., & Stocker, V. (2020). 'Net Neutrality and High Speed Broadband Networks: Evidence from OECD Countries'. Unpublished manuscript, 31 December. Available at https://lnkd.in/dafieAy.

Easley, R. F., Guo, H., & Krämer, J. (2018). 'Research Commentary—From Net Neutrality to Data Neutrality: A Techno-Economic Framework and Research Agenda'. *Information Systems Research*, 29(2), 253–272.

European Commission, Valdani Vicari & Associati, Spectrum Tracker, & LS Telecom. (2022). '5G Observatory Quarterly Report up to January 2022. Study on "European 5G Observatory phase III" (CNECT/2021/OP/0008)'. Available at https://5gobservatory.eu/observatory-overview/observatory-reports/.

Ezrachi, A. & Stucke, M.E. (2016). *Virtual Competition: The Promise and Perils of the Algorithm-Driven Economy*. Cambridge, MA: Harvard University Press.

Frias, Z. & Martínez, J.P. (2017). '5G Networks: Will Technology and Policy Collide?' *Telecommunications Policy*, 42(8), 612–621.

Geradin, D. & Katsifis, D. (2021). 'The Antitrust Case against the Apple App Store'. *Journal of Competition Law & Economics*, 17(3), 503–585.

Kim, J., Kim, Y., Gaston, N., Lestage, R., Kim, Y., & Flacher, D. (2011). 'Access Regulation and Infrastructure Investment in the Mobile Telecommunications Industry'. *Telecommunications Policy*, 35(11), 907–919.

Knieps, G. (2021). 'Data-Driven Sector Coupling in 5G-Based Smart Networks'. *Competition and Regulation in Network Industries*, 22(1), 53–68.

Knieps, G. & Bauer, J.M. (2021). 'Internet of Things and the Economics of 5G-Based Local Industrial Networks'. *Telecommunications Policy*, 46(4), 102261.

Knieps, G. & Stocker, V. (2016). 'Price and QoS Differentiation in All-IP Networks'. *International Journal of Management and Network Economics*, 3(4), 317–335.

Krishnamurthy, P., Murtazashvili, I., & Weiss, M.B.H. (2021). 'On the Coexistence of Disparate Spectrum Users: A Property Rights Mismatch Approach', 2 August. Available at https://ssrn.com/abstract=3897993.

Kwerel, E. & John, W. (2010). 'The Spectrum Regulator's Dilemma in a Dynamic World: Limiting Interference without Stifling Innovation'. Available at https://siliconflatirons.org/documents/conferences/2010.11.12-862/Kwerel.pdf.

Lemstra, W. (2018). 'Leadership with 5G in Europe: Two Contrasting Images of the Future, with policy and Regulatory Implications'. *Telecommunications Policy*, 42(8), 587–611.

Matinmikko-Blue, M., Yrjölä, S., Ahokangas, P., & Hämmäinen, H. (2021). 'Analysis of 5G spectrum awarding decisions: How do different countries consider emerging local 5G networks?' Paper presented at the 2021 ITS Biennial Conference, 20–23 June, Gothenburg, Sweden.

McGuiness, T.D. & Schank, H. (2021). *Power to the Public: The Promise of Public Interest Technology*. Princeton, NJ: Princeton University Press.

Milgrom, P. (2017). *Discovering Prices: Auction Design in Markets with Complex Constraints*. New York: Columbia University Press.

Milgrom, P., Weyl, E.G., & Zhang, A.L. (2017). 'Redesigning Spectrum Licenses'. *Regulation*, 40(3), 22–27.

Roth, A.E. (2018). 'Marketplaces, Markets, and Market Design'. *American Economic Review*, 108(7), 1609–1658.

Saad, W., Bennis, M., & Chen, M. (2019). 'A Vision of 6G Wireless Systems: Applications, Trends, Technologies, and Open Research Problems'. *IEEE Network*, 34(3), 134–142.

Schomberg, R. v. & Hankins, J. (eds.). (2019). *International Handbook on Responsible Innovation: A Global Resource*. Northampton, MA: Edward Elgar.

Shapiro, C. (2012). 'Competition and Innovation: Did Arrow Hit the Bull's Eye?' In J. Lerner & S. Stern (eds.), *The Rate and Direction of Inventive Activity Reconsidered*, pp. 361–404. Chicago, IL: University of Chicago Press.

Sinek, S. (2019). *The Infinite Game*. New York: Portfolio/Penguin.

Spulber, D.F. (2019). 'The Economics of Markets and Platforms'. *Journal of Economics and Management Strategy*, 28, 159–172, https://doi.org/10.1111/jems.12290.

Spulber, D.F. (2020). 'Licensing Standard Essential Patents with FRAND Commitments: Preparing for 5G Mobile Telecommunications'. *Colorado Technology Law Journal*, 18, 79–159.

Vogelsang, I. (2017). 'Regulatory Inertia versus ICT Dynamics: The Case of Product Innovations'. *Telecommunications Policy*, 41(10), 978–990.

Weiss, M.B.H., Palida, A., Murtazashvili, I., Krishnamurthy, P., & Erickson, P. J. (2021). 'A Property-Rights Mismatch

Approach to Passive–Active Spectrum Use Coexistence'. Paper presented at the 2021 IEEE International Symposium on Dynamic Spectrum Access Networks (DySPAN), 13–15 December, Online.
World Economic Forum. (2020). 'Agile Regulation for the Fourth Industrial Revolution: A Toolkit for Regulators'. Davos, Switzerland.
Yrjölä, S., Ahokangas, P., & Matinmikko-Blue, M. (2022). 'Value Creation and Capture from Technology Innovation in the 6G Era'. Published online 7 February. *IEEE Access*, 10.

# An Action Plan for Benefiting from European Innovation in Future Mobile Connectivity

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**ABSTRACT**

**This chapter contributes to the discussion of 6G visions and European policy development, outlining an action plan framework for Europe for benefiting from 6G innovation in the future, both as a developer and as a user of 6G technologies. As 6G is envisioned as a general-purpose technology that can transform the whole of society, there is a need to adopt a broader perspective to benefit more from innovation in 6G than from earlier technology generations. This proposed framework comprises five elements: a competitive innovation policy; values-based anticipatory regulation; triple bottom-line sustainability; trustworthiness that addresses the privacy, security, and safety of users; and national and European sovereignty. It is argued that Europe needs both *ex ante* and *ex post* actions to competitively develop and deploy future 6G technologies.**

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## BACKGROUND

The fifth-generation mobile communication (5G) networks that are currently implemented are quickly making mobile connectivity as an enabling technology the backbone of digitalisation in modern society (Matinmikko et al., 2018). Consequently, 5G rollouts have been considered a strategic rather than a technological choice (Kaska, Beckvard, & Minárik, 2019). In turn, the future sixth generation (6G) is expected by 2030 to merge connectivity with sensing, imaging, and increasingly accurate positioning to enable a myriad of new services and use cases with the aid of artificial intelligence (Latva-aho & Leppänen, 2019). 6G will converge connectivity platforms with other digital platforms, giving rise to the emergence of a platform economy with respective ecosystems (Ahokangas et al., 2021; Uusitalo et al., 2021). Several ground-breaking capabilities of 6G will make it essential for modern societies in the 2030s. 6G will be the platform for providing ubiquitous near-instant and unlimited mobile connectivity, serving increasingly autonomous things and robots and supporting multisensory applications and services such as virtual reality, connecting human, physical, and virtual worlds (Hexa-X, 2021). 6G will also ensure the privacy, security, and safety of its users and enable massive dynamic twinning, while emphasising sustainability from integrated economic, societal, and environmental perspectives. It is even projected to lead to transhumanism with new human–machine interfaces (Yrjölä et al., 2021).

However, the development and planned deployment of 6G will take place in a different situation from that of the earlier generations of mobile connectivity. Single-company innovation still characterises the development of 5G. In addition, coordinated industry-level standardisation and the cross-licensing of key technologies will ensure interoperability across vendor solutions and extendibility across technology generations. The development of 6G as a new general-purpose technology platform (Yrjölä et al., 2021) with business ecosystem-wide innovation efforts (Yrjölä, Ahokangas, & Matinmikko-Blue, 2022a) is increasingly framed by new tensions. These tensions can be understood as arising from four policy spheres: sharpened *innovation and competition policies* and fragmented *regulatory developments* (Van Duijvenvoorde, 2020) at national levels that aim to maintain *national sovereignty* (Timmers, 2020), and the *privacy, security, and safety* of users, whether humans or machines (Yrjölä, Ahokangas, & Matinmikko-Blue, 2020). In addition, global pressures to improve the *triple bottom line of sustainability* – that is, economic, societal, and environmental sustainability (Matinmikko-Blue et al., 2021) – are increasing.

Current discussion and visions of the future of 6G show fundamental differences in how the big three economic blocs – the United States, China, and Europe – are driving 6G development. The US vision of 6G highlights wireless ecosystem leadership, security at all levels, and military needs. The Chinese vision emphasises state sovereignty, global initiatives, and the digital silk road. The EU vision stresses research sovereignty, the United Nations' Sustainable Development Goals (UN SDGs), and human centricity (Yrjölä, Ahokangas, & Matinmikko-Blue, 2022b). Indeed, given the current geopolitical tensions, many researchers and businesses are concerned with the fragmentation of the global 6G markets, technologies, and regulations, especially concerning the use of artificial intelligence (e.g., Feijóo et al., 2020). Europe is well positioned to succeed in global competition with its strong ecosystem of technology vendors, mobile operators, and end users in various industry verticals that are forecast to become the key drivers of new value creation and capture in 6G. However, benefiting from European innovation and avoiding the risk of falling behind in competition in 6G calls for clear, strong, holistic, determined, and timely policies, matched with coordinated funding and effective investments.

Building from the starting points discussed above, this chapter aims to contribute to the discussion on 6G visions and European policy development. First, the chapter identifies must-win battlefronts where Europe needs to be competitive, thereby outlining an action plan framework for Europe to benefit from 6G innovation in the future – both as a developer and as a user of 6G technologies. Teece (2018) focused on enabling technologies and discussed how appropriability (that is, the ability to capture profits), the complementarity of solutions, standardisation of technologies, and intellectual property needed to be addressed to profit from innovation. Because 6G is being envisioned as a general-purpose technology that can transform the whole society, there is a need to adopt a broader perspective to benefit from 6G innovation. This chapter proposes a holistic framework for the European action plan to benefit from 6G innovation and discusses the interdependencies within the framework. The proposed framework builds on themes recognised in recent research, extends Teece's profiting from innovation (PFI) framework, and considers both the *ex ante* and *ex post* actions needed to develop and deploy 6G.

## A FRAMEWORK FOR A EUROPEAN 6G ACTION PLAN

The earlier European 5G action plan put forward an agenda for aligned roadmaps and priorities for the coordinated deployment of 5G.[1] It stressed the importance of removing spectrum-related bottlenecks, promoted early deployment and


FIGURE 1: **A framework for a European 6G action plan**

multi-stakeholder trials with 5G, facilitated venture funds, and called for leading actors to be united to promote global standards. Traditionally, at the national level, European governments and national regulatory agencies have collaborated extensively. However, regarding 5G and especially non-mobile network operator (MNO) operated local networks, different countries have run quite diverse strategies (Matinmikko et al., 2018; Cave, Genakos, & Valletti, 2019). The 5G action plan followed the principles of Teece's (2018) PFI framework. This chapter posits that Europe needs to adopt a more holistic framework for 6G, one that enables the creation of a virtuous circle of competitiveness addressing the European human-centric, rights-based, and triple bottom line sustainability-motivated approach to 6G, *ex ante* when it is developed and *ex post* when it is deployed. Furthermore, this framework should be applied and coordinated at the national and European levels. Figure 1 depicts the elements of the proposed framework, which comprises 1) a competitive innovation policy; 2) values-based anticipatory regulation; 3) triple bottom-line sustainability; 4) trustworthiness highlighting the privacy, security, and safety of users; and 5) national sovereignty. These will be discussed in detail next.

## Competitive innovation policy

The first front and impetus for building European 6G are the innovation policies applied within the EU. Innovation policies directly and indirectly impact firms' innovation practices and intellectual property creation, thereby providing the basis for competitiveness. General purpose technologies such as 6G call for cross-industry sector innovation efforts (Yrjölä et al., 2022a), and achieving global competitiveness requires goal-oriented global collaboration from the start. Furthermore, 6G is also expected to build on the extended use of several complementary technologies such as artificial intelligence, which itself is a general-purpose technology, making the development and standardisation of 6G a cross-industry effort in which both leading developers and users of 6G need to collaborate – with both the developers and users of the complementary and adjacent technologies.

The 'global race for 6G' has started (Bajpai, 2021). The first national 6G flagship programme was initiated in Finland in 2018 (http://www.6gflagship.com), and it was soon extended to the European level with the Hexa-X programme (https://hexa-x.eu/). Similar initiatives have been launched in several countries. Given the 6G visions of China, the US, South Korea, and Japan, and especially their respective investment programmes in these countries, Europe and the European countries need to be quick to initiate relevant collaboration efforts and ensure sufficient funding for national and international research collaboration to develop 6G and its ecosystems. It is of fundamental importance to go beyond the European Research Area, which aims to create an internal market for European research, technology, and innovation and extend and deepen 6G collaboration with like-minded countries to influence the creation of a global 6G. As the international joint vision work by International Telecommunication Union's Radiocommunications Sector (ITU-R) on Information Management Technology (IMT) for 2030 and beyond that will become 6G has already started, aiming to reconcile global visions of technology trends (2022) and international mobile telecommunications standards (2023), it is important to act promptly to support European universities and companies with a competitive innovation policy.

5G networks are quickly making mobile connectivity as an enabling technology the backbone of digitalisation in modern society

## European values-based anticipatory regulation

The provisions of the European Electronic Communications Code (EECC) Directive present the legal framework for the provisioning of electronic communications, regulating the organisation of the sector, networks, and services. However, the EECC needs to be complemented with new regulations that consider, for example, artificial intelligence and cybersecurity. Regulations related to economic, societal, and environmental issues should also be considered (Robles-Carrillo, 2021). The examples of the European general data protection regulation and the regulations stemming from different societal and environmental pressures have paved the way to analysing the potentially evolving and different vertical-specific regulations. In the 5G context, emerging new service concepts such as local 5G operators enable new entrants to enter the business, provided that the regulation makes it possible. However, analysis covering the access, pricing, competition, privacy and data, and authorisation of networks and services has made researchers propose, for example, a new local spectrum licensing model (Matinmikko et al., 2018). Since we are approaching the 6G era, it is evident that the second front, the EU's regulatory frameworks in the EU, will increasingly be challenged and will require a careful strategic European values-based consideration (Cave et al., 2019).

Feijóo et al. (2020), although focusing on artificial intelligence, discuss the differences between the market-based US approach, the rights-based European logic, and China's government push-based logic for developing and utilising technologies. European values and goals should be at the heart of European regulation, defining the rules for *ex ante* developing 6G, and *ex post* when deploying the services. The parallel consideration of both *ex ante* and *ex post* regulations also contributes to the recent discussions on the need to make the whole regulatory process more agile with anticipatory regulation (Serentschy, 2021) in the context of emerging technologies. Anticipatory regulation means a proactive, iterative, and responsive approach to evolving markets' regulation, emphasising flexibility, collaboration, and innovation. In reviewing the evolution of European regulation – from open telecom markets (version 1.0) to a new (combined) perspective on innovation, investment, and regulation (version 2.0), the birth of the EECC (version 3.0), and regulation of all digital players (version 4.0) – Serentschy (2021) argues for change. As a support for anticipatory regulation, Cioffi, Kenney, and Zysman (2022), in their analysis of platform regulation, expect the European Digital Market Act and Digital Services Act released in December 2020 to have far-reaching international impacts on businesses relying on digital platforms. As 6G as a connectivity platform is increasingly expected to converge with other digital platforms, the whole regulatory landscape will face convergence in the future. It is argued that agile and anticipatory approaches to regulation work better in such a scenario.

## Triple bottom line of sustainability

Sustainability can be considered the third front of 6G development, setting new demands. There is a long tradition of developing green radios, which has meant jointly considering both the energy and spectrum efficiency of networks to achieve sustainability (Zhang et al., 2019. The authors claim that in the future green radios should also comprise energy efficiency in forthcoming communication scenarios such as massive machine-type communications, have new optimisation frameworks based on machine learning and artificial intelligence, and introduce new hardware dynamics. For 6G, the integrated triple bottom line of sustainability, including social, economic, and environmental perspectives, has become a design criterion (Matinmikko-Blue et al., 2021; Uusitalo et al., 2021). The different elements of sustainability should be considered in parallel and as balanced and uncompromised for 6G. Environmental sustainability should be sought without sacrificing economic and societal progress; societal values should be sought without compromising economic and environmental sustainability; and finally, economic sustainability should be sought without causing negative societal or environmental consequences.

The UN SDGs have been adopted as the guideline for developing future 6G (Matinmikko-Blue et al., 2020), and they are reflected across the perspectives of integrated sustainability. Economic sustainability means focusing on the opportunities, value creation potential, and advantages of the developed technology that contribute to its scalability and replicability. In turn, economic resilience emerges as the combined effect of technology's scalability, replicability, and sustainability. Societal sustainability related to 6G means people can participate and act in society in a new and beneficial way, provided it is affordable, and if they choose to use it or opt out if required. Finally, environmental sustainability will extend beyond resource efficiency to cover circularity and zero-emission aims (Matinmikko-Blue et al., 2021).

Although 6G is not yet directly within the European emission trading system or under specific $CO_2$ taxation, it is envisioned that such an arrangement will spread to new sectors in the future. Future 5G and 6G will be directly influenced by the need to decrease emissions of greenhouse gases, including $CO_2$, and the harmful environmental impacts of materials used in manufacturing the necessary hardware. The new growth opportunity of 5G and 6G is envisioned in the various digitalising industry verticals that are increasingly being brought to the European Green Deal domain or under different environmental regulations. Mobile communications technologies are expected to converge and merge with other technologies and platforms. They jointly contribute to the development in which the 5G and 6G technologies will become sustainability-regulated and eventually placed within the European emission trading system. A good example of this is the local and private networks that are owned and operated by stakeholders that are already within the emission trading system.

### Trustworthiness: privacy, security, and safety of users

The fourth front for European 6G development and deployment concerns users' privacy, security, and safety. The developers of 6G envision local trust zones (Hexa-X, 2021), but more widely, the question concerns the built-in trustworthiness of 6G in general (Ylianttila et al., 2020). As 6G becomes intertwined with all the functions of everyday life, trustworthiness will become a necessity. The characteristics of trustworthiness – comprising security, privacy, availability, resilience, and compliance with ethical frameworks – are forecast to become fundamental new requirements for 6G. Physical security and safety can be seen as consequences of trustworthiness, because many digital systems such as autonomous vehicles depend on mobile communications.

According to Hexa-X (2021), to achieve trustworthiness, security considerations need to cover all aspects of cybersecurity, including 'resilience against attacks, preservation of privacy, and ethical, Several ground-breaking capabilities of 6G will make it essential for modern societies in the 2030

safe application of automation to network operations and applications'. To make 6G trustworthy, deep interaction between academia, verticals, and the authorities is required. However, trustworthiness involves more than just privacy, security, and safety: the European framework should consider ethical and regulatory demands and values in a non-biased and inclusive way, while fulfilling the demands for social, economic, and environmental sustainability and resilience.

### National and European sovereignty

The fifth front concerns the combining of national and European sovereignty. Moerel and Timmers (2021: 5) posit that 'digital technologies have become the battleground for the competition for global leadership and are leading to ever-increasing geopolitical tensions'. In recent years, phenomena such as trade wars, cyber espionage, disinformation, threats, and sanctions (Robles-Carrillo, 2021), dependence on foreign suppliers, data colonialism via platforms, technological vulnerabilities (also related to foreign suppliers), and risks to the economy, society, and democracy (Timmers, 2020) have started to appear in public discussion. Regarding 6G in general, Timmers (2020) argues that without solving the sovereignty issues of 5G, no global 6G will emerge. Compartmented innovation ecosystems, techno-nationalism, and market protection are already a fact in 5G, and there are no expectations that these will change for 6G.

Many EU Member States recognise the need for sovereignty and strategic autonomy, but national action requires EU-level coordination in many fields of society, which is not only a practical but also a legal-political challenge (Moerel & Timmers, 2021). The EU has identified that the main threats to 5G are those related to confidentiality, availability, and integrity (Robles-Carrillo, 2021). It is easy to believe that the same threats will also be faced in the future next-generation networks. Fundamentally, digital sovereignty relates to the control of data, software and algorithms, standards and protocols, (computing) processes, hardware and equipment, services, and infrastructures (Floridi, 2020). Sovereignty thus embeds the concept of ownership regarding strategic assets such as data, algorithms, and critical infrastructures. Thus, digital sovereignty concerns governments, firms, and research institutions active in the digital field, closing the loop to our first front, competitive innovation policies. Without sovereignty, competitive innovation policies are impossible. It can also be observed that the need for sovereignty may influence the future regulatory landscape, as well as the relationships between governments and firms.

## CONCLUDING REMARKS

In the previous section, the five fronts of the European action plan for 6G were discussed as distinct and independent of each other. This is not the case: the five fronts are deeply intertwined in practice at the national and European levels and are mutually dependent. The first front, innovation policies, is the fundamental enabler required to benefit from innovation; the second, values-based regulations, delimits the market actors' opportunistic or abusive market behaviour. The two first fronts are directly related to intellectual property development, the complementarity of the developed technological solutions, and the ability to capture profits from 6G innovation. If the first two fronts are considered push factors for future 6G, the third front, triple bottom-line sustainability, is a genuine pull factor, setting new demands for developing future 6G to combat climate change and environmental pollution. The fourth and fifth fronts, trustworthy 6G and sovereignty, comprise push and pull factors, closing the loop to innovation policy and competitiveness. These fronts are also directly related to standardisation. It may also be concluded that the importance of trustworthiness and sovereignty should not be undermined; they are fundamental requirements for the legitimacy and competitiveness of European 6G.

On all five fronts discussed, the EU should address *ex ante* and *ex post* mechanisms in its action plan: *ex ante* when 6G is developed and *ex post* when it is deployed. It appears that digitalisation – and 6G as part of it – cannot be stopped and is becoming a ubiquitous part of our lives. 6G has already become one of the battlefields of global competition: the EU's future competitiveness requires immediate action.

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### NOTE

1. See https://digital-strategy.ec.europa.eu/en/policies/5g-action-plan.

### REFERENCES

Ahokangas, P., Matinmikko-Blue, M., Yrjölä, S., & Hämmäinen, H. (2021). 'Platform Configurations for Local and Private 5G Networks in Complex Industrial Multi-Stakeholder Ecosystems'. *Telecommunications Policy*, 45(5), 102128.

Bajpai, P. (2021). 'The Race Towards 6G'. https://www.nasdaq.com/articles/the-race-towards-6g-2021-02-18. Accessed 20 February 2022.

Cave, M., Genakos, C., & Valletti, T. (2019). 'The European Framework for Regulating Telecommunications: A 25-Year Appraisal'. *Review of Industrial Organization*, 55(1), 47–62.

China's IMT-2030 (6G) Promotion Group. (2021). '6G White Paper on 6G Vision and Candidate Technologies'. http://www.caict.ac.cn/english/news/202106/t20210608_378637.html. Accessed 25 May 2022.

Cioffi, J.W., Kenney, M.F., & Zysman, J. (2022). 'Platform Power and Regulatory Politics: Polanyi for the Twenty-First Century'. *New Political Economy*, 27(1), 1–17.

Feijóo, C., Kwon, Y., Bauer, J. M., Bohlin, E., Howell, B., Jain, R., . . . & Xia, J. (2020). 'Harnessing Artificial Intelligence (AI) to Increase Wellbeing for All: The Case for a New Technology Diplomacy'. *Telecommunications Policy*, 44(6), 101988.

Floridi, L. (2020). 'The Fight for Digital Sovereignty: What It Is, and Why It Matters, Especially for the EU'. *Philosophy & Technology*, 33(3), 369–378.

Hexa-X. (2021). 'Deliverable D1.2 Expanded 6G Vision, Use Cases And Societal Values – Including Aspects of Sustainability, Security and Spectrum'. https://hexa-x.eu/wp-content/uploads/2021/05/Hexa-X_D1.2.pdf. Accessed 20 February 2022.

Kaska, K., Beckvard, H., & Minárik, T. (2019). 'Huawei, 5G and China as a Security Threat'. NATO Cooperative Cyber Defence Center for Excellence (CCDCOE), 28.

Latva-Aho, M., & Leppänen, K. (2019). 'Key Drivers and Research Challenges for 6G Ubiquitous Wireless Intelligence' [White Paper]. Oulu, Finland: 6G Flagship.

Matinmikko-Blue, M., Aalto, S., Asghar, M.I., Berndt, H., Chen, Y., Dixit, S., . . . & Ziegler, V. (2020). 'White Paper on 6G Drivers and the UN SDGs'. arXiv preprint arXiv:2004.14695.

Matinmikko, M., Latva-aho, M., Ahokangas, P., & Seppänen, V. (2018). 'On Regulations for 5G: Micro Licensing for Locally Operated Networks'. *Telecommunications Policy*, 42(8), 622–635.

Matinmikko-Blue, M., Yrjölä, S., Ahokangas, P., Ojutkangas, K., & Rossi, E. (2021). '6G and the UN SDGs: Where Is the Connection?' *Wireless Personal Communications*, 121(2), 1361–1362.

Moerel, L., & Timmers, P. (2021). 'Reflections on Digital Sovereignty'. EU Cyber Direct, Research in Focus series.

Robles-Carrillo, M. (2021). 'European Union Policy on 5G: Context, Scope and Limits'. *Telecommunications Policy*, 45(8), 102216.

Serentschy, G. (2021). 'The Regulatory Journey from a European Perspective'. https://www.serentschy.com/the-regulatory-journey-from-a-european-perspective/. Accessed 20 February 2022.

Teece, D. J. (2018). 'Profiting from Innovation in the Digital Economy: Enabling Technologies, Standards, and Licensing

Models in the Wireless World'. *Research Policy*, 47(8), 1367–1387.
Timmers, P. (2020). 'There Will Be No Global 6G Unless We Resolve Sovereignty Concerns in 5G Governance'. *Nature Electronics*, 3(1), 10–12.
Uusitalo, M.A., Rugeland, P., Boldi, M.R., Strinati, E.C., Demestichas, P., Ericson, M., . . . & Zou, Y. (2021). '6G Vision, Value, Use Cases and Technologies from European 6G Flagship Project Hexa-X'. *IEEE Access*, 9, 160004–160020.
Van Duijvenvoorde, G.P. (2020). 'Towards Implementation of the European Union Telecom Code: Ex Ante Reflections'. *Computer and Telecommunications Law Review*, 26(7), 205–215.
Ylianttila, M., Kantola, R., Gurtov, A., Mucchi, L., Oppermann, I., Yan, Z., . . . & Röning, J. (2020). '6G White Paper: Research Challenges for Trust, Security and Privacy'. arXiv preprint arXiv:2004.11665.
Yrjölä, S., Ahokangas, P., & Matinmikko-Blue, M. (2020). 'Sustainability as a Challenge and Driver for Novel Ecosystemic 6G Business Scenarios'. *Sustainability*, 12(21), 8951.
Yrjölä, S., Ahokangas, P., Arslan, A., Matinmikko-Blue, M., Golgeci, I., & Tarba, S. (2021). 'Artificial Intelligence in the Telecommunication Sector: Exploratory Analysis of 6G's Potential for Organizational Agility'. In V. Ratten (ed.), *Entrepreneurial Connectivity*, pp. 63–81. Singapore: Springer.
Yrjölä, S., Ahokangas, P. & Matinmikko-Blue, M. (2022a). 'Value Creation and Capture from Technology Innovation in the 6G Era'. *IEEE Access*, 10, 16299–16319.
Yrjölä, S., Ahokangas, P. & Matinmikko-Blue, M. (2022b). 'Visions for 6G Futures: A Causal Layered Analysis'. Paper presented at EUCNC / 6G Summit, June 7–10, Grenoble, France.
Zhang, S., Xu, S., Li, G. Y., & Ayanoglu, E. (2019). 'First 20 Years of Green Radios'. *IEEE Transactions on Green Communications and Networking*, 4(1), 1–15.

# 5G and the European Competitiveness Challenge: The Case for Demand-Side Innovation Policies


## Maria Alessandra Rossi



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**ABSTRACT**

**5G shares many features of general-purpose technologies (GPTs). Relative to previous GPTs, such as 'first wave' information and communication technologies, it may have deeper positive effects in terms of improvement of EU productivity performance. Yet it poses greater challenges. In this chapter, insights from the EU competitiveness debate are used to shed some light on the nature of these opportunities and challenges. The discussion points to the need to complement supply-side efforts at an initial stage at speeding up network deployment with demand-side innovation policies, that is, technology diffusion policies that actively leverage the potential for novel collaborations in innovation along the many new 5G-connected digitalised value chains, and to the need for improved vertical and horizontal governance of EU policies in this domain.**



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### 1. INTRODUCTION

5G promises to be much more than a simple evolutive step of mobile connectivity. Together with technologies such as artificial intelligence, robotics, biotech, and the Internet of Things (IoT), it holds the potential to transform not only production, but also social life and people's interactions with cities and places. 5G may possibly become the connectivity tissue that contributes to a trend towards blurring boundaries between the physical, digital, and even biological worlds, although much uncertainty on the overall extent of its impact reigns. In this process of (potentially) very pervasive change, many opportunities for improving the European Union's competitiveness may emerge. This was recognised early on by the European Commission, which has launched several initiatives that explicitly recognise the role 5G may play in enhancing productivity and innovation of European industries (including the latest EU Digital Decade policy initiative).[1]

In recent decades, however, Europe has had a very poor track record in seizing technological opportunities offered by digital technologies. Comparative data on labour productivity growth for the United States and for ten Western European nations over the period 1975–2015 (Gordon & Sayed, 2020) clearly shows that Europe missed the first information and communication technology (ICT) revolution: while the US experienced a significant ICT-led acceleration of productivity in the period 1995–2005, Western European nations did not, and productivity performance further worsened (this time on both sides of the Atlantic) in the period 2005–2015, when additional benefits from digitalisation could have been expected. Opportunities from 5G may be even harder to access for European countries than previous generations of communication technologies because the broader scope of transformation that may be associated with 5G requires the coordination of many more resources, knowledge bases, economic actors, and industrial assets than that required to fully profit from traditional ICT technologies.

This chapter discusses how 5G and related technologies may impact EU productivity performance in the light of insights from the EU competitiveness debate. It considers some of the key teachings from recent research jointly with the prospective (uncertain) features of 5G-based technological change to draw some implications for European policies. The analysis suggests that it is time for at least two changes in the European policy approach to 5G and to digital business transformation more generally. Firstly, the policy focus should expand early on beyond deployment of infrastructures and coverage, to encompass much more convincingly than is presently the case the issue of technology adoption, with particular emphasis on the demand-side innovation that adoption may bring about. Secondly, to pursue this end, much more attention should be devoted to improving both the horizontal and the vertical governance of policy interventions in this domain.

## 2. WHAT WE KNOW ABOUT EU COMPETITIVENESS

In the past decade, the debate on the sources and characteristics of aggregate productivity at the global level has greatly intensified, in parallel with the productivity slowdown in many OECD countries. The lack of sustained growth both in the period preceding the 2008 financial crisis and in subsequent years has triggered reflections on the possible existence of structural obstacles to continued growth. To some extent, the debate has revolved around the question of whether the size of the technological opportunities offered by the most recent technological wave (associated with ICT) is inherently smaller than that offered by previous pivotal technologies such as the steam engine and electrification. Technological 'pessimists' view the decline in productivity as permanent and linked to diminishing returns in ICT (e.g., Gordon, 2012), while technological 'optimists' believe the ICT revolution has still to bring about its full effects (e.g., Brynjolfsson & McAfee, 2012; Mokyr, 2014).

The relative merits of pessimists' and optimists' views are hard to assess empirically at this stage, as they very much depend on the future evolution of ICT technologies. However, the debate has offered the opportunity to clarify aspects of national productivity that are relevant beyond the controversy. To simplify, aggregate productivity is influenced by two main elements, which may be associated with different policy levers. The first element is firms' incentives to make investments known for enhancing productivity: primarily investments in tangible and intangible capital, and research and development (R&D) investments. More recently, the importance of mechanisms of reallocation of productive factors (labour and capital) has been increasingly emphasised. These mechanisms influence particularly the ability of the most productive firms in an economy to enlarge their size, which is a key driver of aggregate productivity.

Studies considering both of these elements together have brought attention to the fact that national economic performance is largely determined by the productivity of 'frontier' firms, that is, those with the highest productivity within each industry, rather than by industrial specialisation (Bartelsman, Haltiwanger, & Scarpetta, 2013; Hsieh

> 5G may become the connectivity tissue . . . blurring boundaries between the physical, digital, and even biological worlds

& Klenow, 2009). According to some estimates, the performance of the 1–5 per cent of firms with the highest productivity accounts for 70–90 per cent of growth in value added, exports, or foreign direct investment (Mayer & Ottaviano, 2008; Lopez-Garcia, Di Mauro, & the CompNet Task Force, 2015). This suggests that growth may be a matter of 'idiosyncratic growth episodes taking place within specific countries, regions or cities' (Altomonte & Békés, 2016). Moreover, it has been shown that the gap between frontier firms and laggards has widened with time, presumably due to ineffective technological diffusion. Andrews, Criscuolo, and Gal (2015) show that, while international diffusion of technologies has accelerated, even freely accessible technologies may not spread easily within a country unless local frontier firms facilitate their introduction by adapting them to local conditions.

When looking specifically at European competitiveness, it emerges that each of the above elements plays a role in explaining the unimpressive growth performance of EU countries. European firms invest less than their US counterparts in intangibles (Haskel & Westlake, 2017) and more specifically in R&D (Van Ark, O'Mahony, & Timmer, 2008; Moncada-Paternò-Castello et al., 2010). Moreover, a recent European Investment Bank study has shown that this investment reluctance and the associated gap with respect to the US has been extended to tangibles (equipment and machinery) since the 2008 financial crisis (EIB, 2020). The same report highlights that the EU lags behind the US in terms of adoption of digital technologies. The gap is particularly evident for the service sector as compared with the manufacturing sector, whose digital adoption performance is more aligned with that of US firms, and in terms of technologies for IoT solutions, big data, and software development.

Gordon and Sayed (2020) propose, on the basis of an analysis of ten Western European countries, that sluggish EU productivity is more attributable to the structural failure of firms to make adequate use of the ICT investment that did occur than it is to the amount of investment per se. They find that the large differences in productivity growth rates on the two sides of the Atlantic over the period 1995–2005 can be explained only in relatively small part (around 20 per cent) by disparities in raw ICT investment. They attribute this finding to differences in institutional factors such as the nature and flexibility of labour, product, and capital markets, and they draw attention to the possibility that the incomplete nature of the EU internal market may have limited the scale of operation of firms in some key industries.

Finally, it is now well established that a fundamental divergence between the US and the EU resides in their respective ability to promote the growth of young innovative firms that are likely to position themselves at the global productivity frontier. This may be due to lower average rates of return to R&D (Cincera & Veugelers, 2014), or more generally to features of the institutional environment that discourage risk-taking and growth. Whatever the specific cause, the type of dynamic firm that has been found by the literature to be largely responsible for national growth finds it significantly more difficult to emerge and grow in the EU than in the US, especially in the digital sectors.

This short overview suggests at least two broad considerations that are relevant to the present discussion. The first is that the emphasis that EU institutions are currently placing on issues of digitalisation and business transformation appears well placed. Adoption of innovative technologies is certainly a key driver of productivity improvement

> Opportunities from 5G may be even harder to access for European countries than previous generations of communication technologies

and empirical evidence shows it is not occurring spontaneously to a desirable extent in the EU. This means that, prima facie, market and/or institutional failures may presumably justify policies targeted at 5G adoption by firms. Secondly, the adoption of 5G and related technologies appears particularly challenging for EU firms.

### 3. TECHNOLOGICAL OPPORTUNITIES OPENED UP BY 5G AND RELATED TECHNOLOGIES

To understand the contribution that 5G may make to addressing the European competitiveness challenge, it is useful to compare it to 'first wave' ICTs. Both ICTs and 5G share many features of general-purpose technologies (GPTs), akin to the steam engine and electricity (Prieger, 2020; Knieps & Bauer, 2021). In particular, they exhibit the combination of three features singled out in the standard definition of GPTs (Bresnahan & Trajtenberg, 1995): a technology (1) that is pervasive in its use; (2) that is capable of self-regeneration and of ongoing technical improvement; and (3) that enables further downstream innovation in application sectors. So-called innovational complementarities result from the combination of features (2) and (3) and indicate that innovations in the GPT raise the return to innovations in applications and vice versa. The process of co-invention of the basic technology and applications makes it possible to avoid diminishing returns and may generate sustained aggregate growth (Bresnahan, 2010). Thus, GPTs raise productivity by raising the performance of existing firms and sectors and by creating opportunities for new firms and sectors to develop through innovation.

However, as the above-mentioned Gordon–Brynjolfsson controversy suggests, the extent and timing of induced productivity improvements may differ across GPTs. Indeed, GPTs may have economy-wide impacts or they may affect more limited portions of the economy. They may spread more or less rapidly within and across different economic sectors and geographies. They may improve more or less markedly on previous technologies.

Relative to previous ICTs, 5G appears capable of being a driver of innovation in a much broader range of industries. The first ICT revolution has been, all in all, relatively limited in terms of its effects on downstream innovation (Bogers, Chesbrough, & Moedas, 2018). 5G, by contrast, may become the connectivity tissue that enables the development of innovations along a range of very different digitised value chains and in a plurality of industries such as automotive, manufacturing, healthcare, and media (often referred to as 'verticals'). 5G makes improvements in terms of performance with respect to previous connectivity solutions by reducing network latency and by increasing capacity and network efficiency (Qualcomm Technologies, 2019). As is discussed ever more frequently, in addition to enabling significant improvements in the performance of standard mobile communications, the extremely high speed, ultra-low latency, and massive capacity brought about by 5G may enable a wide range of new applications, including virtual reality, augmented reality, full industrial automation with real-time data synchronisation, fully autonomous vehicles, and robotic surgery.

The possibility of this extremely wide range of innovative applications derives from a remarkable shift in network architecture that makes 5G as a common input particularly flexible and capable of adaptation to heterogeneous use cases. Differently from previous generations of mobile connectivity, in 5G networks, services are virtualised and can be provided independently from the underlying physical network, so that they may cater to different uses and may be combined on demand and in real time, to offer services on the fly. Thus, the key defining aspect of 5G is the possibility it opens up for creative recombination of assets and business models, and therefore for further innovation, through its flexibility and adaptability. Importantly, these opportunities arise for both large and small firms and may thus offer a chance of growth for small and medium-sized enterprises (EIB, 2021).

The materialisation of these innovation opportunities, and of the associated productivity improvements, should not be taken for granted, however. For these opportunities to come about, incentives to invest both in the common input and in applications must be present. As in any other context where there are important externalities, this raises a problem of coordination, as the returns from improving the common input are higher in the presence of investments in applications and vice versa. The rate of technological advancement of the cluster of 5G technologies and applications as well as the rate of its diffusion throughout the economy will depend on potential adopters'/innovators' expectations about the benefits of this technology.

Coordination problems emerge for any GPT and, more generally, for any platform technology (Bauer & Bohlin, 2021). One notable feature specific to 5G may be that the variety of forms of knowledge needed for successful innovation appears much broader than has been the case with previous GPTs. Because it spans very diverse industries, 5G-related innovation requires significant effort in overcoming problems of communication across heterogeneous environments and business cultures, and in combining different forms of knowledge and information. In particular, 5G innovation requires a very effective integration of science and technology or, in other words, of top-down and bottom-up knowledge and information. Developing applications that use 5G as well as adapting the common input to the different 'verticals' may thus turn out to be particularly challenging.

In sum, looking at 5G through the GPT lens suggests that the positive impact on overall European economic performance associated with 5G depends on firms' ability to combine relevant knowledge and information and on their incentives to invest in adoption and further innovation. The existence of positive feedback loops linking core technologies and applications entails that, once coordination problems are overcome, 5G may become an effective engine of growth, but also that the path towards these outcomes may be particularly difficult to navigate.

## 4. CHALLENGES FOR EU POLICYMAKING

EU institutions may have never placed as much emphasis on technology diffusion as is presently the case. 2030 targets in terms of coverage of advanced connectivity infrastructures, including coverage of all populated areas by 5G, have been set at the EU level, and national policies adopted in the context of the Resilience and Recovery Facility (RRF) will contribute to their pursuit.[2] The digital transformation of businesses has become particularly salient in the EU policy discourse and is also articulated in terms of targets set by the Digital Decade Decision. Still, the preceding discussion suggests that a broader reflection on the overall approach to and objectives of technology diffusion policies should be undertaken sooner rather than later.

Investment in 5G network deployment is an obvious precondition of the materialisation of productivity benefits from this technology. Moreover, horizontal policies aimed at increasing the interest and ability of European firms to interact with 5G-related technological solutions may certainly contribute to increased productivity. The preceding paragraphs highlight, however, that the biggest opportunity from adoption of 5G comes from its potential impact on innovation opportunities. This suggests a rationale for introducing policies that move from the premise that diffusion is important not only for its direct effects in terms of productivity improvement, but also as a driver of further innovation. Thus, there is a need not only for standard demand-side technology diffusion policies but also for demand-side innovation policies, that is, policies that actively leverage the potential for novel collaborations in innovation along the many new 5G-connected digitalised value chains and promote cross-fertilisation across firms and technologies, as enabled by 5G.[3]

This is no easy task for many reasons, starting from the fact that diffusion policies have not been fully explored and are certainly not fully understood in terms of their effects (Caiazza, 2016; Edler, 2016). Yet some broad insights may come from the above discussion.

Much of the positive impact on productivity of the diffusion of new technologies is mediated by 'frontier firms'. Thus, the issue of promoting diffusion is strictly linked to the ability of regions and local territories to stimulate the emergence and growth of these firms. This, in turn, in addition to the usual suspects (easy access to finance and an environment that does not discourage risk-taking) requires bottom-up policies that are able to take into account local conditions. Along these lines, Ketels and Porter (2021) have argued that a major limitation of EU action in the realm of competitiveness has been the failure to evolve from a model focused on harmonisation and removing barriers to market integration, to a model whereby policy interventions need to be location-specific to account for the fact that competitiveness is increasingly driven by microeconomic assets and capabilities.

While the perspective offered by Ketels and Porter does capture a well-articulated need for an evolution of EU competitiveness policies, the traditional EU role of coordination, harmonisation, and promotion of market integration remains very important to reap the productivity benefits of 5G technologies. Scale of operation is an important driver of incentives to develop both 5G technologies and applications, thus coordinated action at the EU level, for instance in terms of standardisation activities and of harmonisation in the implementation of technology diffusion policies, is particularly opportune. Moreover, the effectiveness of any policy focusing on technology adoption necessarily benefits from coordination. Since adoption normally involves significant demand externalities, coordination may help increase the value of adopting any given technological solution or reduce its cost for any potential adopter.

There is therefore a tension in designing the vertical governance of 5G-related digitalisation and diffusion policies. On the one hand, the fact that the EU can only support Member States' policies in this domain and not devise centralised solutions is consistent with the need for location-specific measures. On the other hand, EU-level coordination is key. Better and more creative forms of vertical coordination between EU-level and national policies are certainly needed, especially at a time when the amount of resources available to the pursuit of ambitious digitalisation objectives has finally become sufficient to generate a material impact on the European economy. A delicate balance needs to be struck between tailoring policies to local

5G requires the coordination of many more resources, knowledge bases, economic actors, and industrial assets

conditions and ensuring enough convergence of Member States' approaches to create EU-wide market demand for 5G-related goods and services.

More effective coordination of different policies is also clearly needed. One key area of attention, in the light of what has already been discussed, is the integration of science and technology policies. In this regard, the European Court of Auditors (2020: 29), in its analysis of the effectiveness of EU digitalisation initiatives, has proposed a case study in Poland to warn that scientific projects financed through EU funds may fail to constitute a useful input for market applications because the lack of coordination between funding of scientific research and subsequent funding of its implementation may prevent application on an adequate scale.

Finally, it is worth calling attention to some examples of policies that may affect innovation in the 5G GPT cluster beyond the most traditional financial incentive tools such as subsidies, grants, and tax credits (which are, of course, to be welcomed) and beyond awareness measures. Support to initiatives that maximise openness at the level of network infrastructures and interfaces such as Open RAN (radio access networks) would be coherent with an open innovation approach that maximises the potential for complementary innovation. In addition, it may help to address very salient security issues. Moreover, a revision of network neutrality policies may become opportune, as the latter may affect the ability of different players along the 5G value chain to reach value-enhancing innovation agreements (Rossi, 2021). Lastly, the Chinese experience shows that public procurement may play a significant role in guaranteeing the scale needed to justify innovation investments (Brake, 2020). While an exact replication of the Chinese approach is obviously not an option, use of the tool of public procurement as a source of demand for innovative digital solutions can certainly be improved.

## 5. CONCLUSIONS

Enhancing European competitiveness has been increasingly perceived and described as a challenge. Technological evolution, with the emergence of 5G and related technologies, may offer the opportunity for a sizeable change in aggregate productivity. However, reaping technological opportunities is even harder for European firms than it was in the last technological wave, which Europe largely missed out on. It is also notable that the 5G cluster of technologies may make it possible to increase productivity while incorporating concerns for the environment – a societal challenge that we are now aware any discourse on competitiveness should address.

Productivity improvements depend heavily on technology diffusion. While recently the EU has been doing much more than it did in the past, a shift of focus from diffusion per se to diffusion as a tool to facilitate further innovation is in order. Better vertical and horizontal governance of digitalisation policies, as well as more convincing open innovation, network neutrality, and public procurement policies, may go a long way towards enhancing the chances of adequately exploiting technological opportunities to address the EU competitiveness challenge.

### NOTES

1. https://digital-strategy.ec.europa.eu/en/library/proposal-decision-establishing-2030-policy-programme-path-digital-decade. Other important policies are the 2016 5G Action Plan, initiatives in the realm of spectrum assignment, and the 'Connectivity Toolbox' – a common set of best practices to speed up very high-capacity network investment, 5G included.

2. https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en.
3. We follow Edler's (2016; italics original) definition of *demand-side innovation policy* as 'all public action to *induce* innovation and/or speed up the *diffusion* of innovation through:

- *increasing the demand* for *innovation* (i.e. the willingness and ability to buy and use an innovation);
- *defining new functional requirements for products and services*; and/or
- *improving user involvement in innovation production (user-driven).*'

However, the focus of this chapter is restricted to industrial demand, rather than user demand.

### REFERENCES


Altomonte, C. & Békés, G. (2016). 'The Knowns and Unknowns of the European Competitiveness Debate'. https://www.bruegel.org/2016/04/the-knowns-and-unknowns-of-the-european-competitiveness-debate.

Andrews, D., Criscuolo, C., & Gal, P.N. (2015). 'Frontier Firms, Technology Diffusion and Public Policy: Micro Evidence from OECD Countries'. OECD Productivity Working Papers 2. Paris: OECD.

Bartelsman, E., Haltiwanger, J., & Scarpetta, S. (2013). 'Cross-Country Differences in Productivity: The Role of Allocation and Selection'. *American Economic Review*, 103(1), 305–334. https://doi.org/10.1257/aer.103.1.305.

Bauer, J.M. & Bohlin, E. (2021). 'Regulation and Innovation in 5G Markets'. *Telecommunications Policy*, 46(4), 102260. https://doi.org/10.1016/j.telpol.2021.102260.

Bogers, M., Chesbrough, H., & Moedas, C. (2018). 'Open Innovation: Research, Practices, and Policies'. *California Management Review*, 60(2), 5–16. https://doi.org/10.1177/0008125617745086.

Brake, D. (2020). 'A U.S. National Strategy for 5G and Wireless Innovation'. Washington, DC: Information Technology and Innovation Foundation.

Bresnahan, T. (2010). 'General Purpose Technologies'. In Bronwyn H. Hall and Nathan Rosenberg (eds.), *Handbook of the Economics of Innovation*, vol. 2, pp. 761–791. Amsterdam: North-Holland.

Bresnahan, T.F. & Trajtenberg, M. (1995). 'General Purpose Technologies "Engines of Growth"?' *Journal of Econometrics*, 65(1), 83–108. https://doi.org/10.1016/0304-4076(94)01598-t.

Brynjolfsson, E. & McAfee, A. (2012). *Race Against the Machine: How the Digital Revolution Is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy.* Digital Frontier Press.

Caiazza, R. (2016). 'A Cross-National Analysis of Policies Affecting Innovation Diffusion'. *The Journal of Technology Transfer*, 41(6), 1406–1419.

Cincera, M. & Veugelers, R. (2014). 'Differences in the Rates of Return to R&D for European and US Young Leading R&D Firms'. *Research Policy* 43(8), 1413–1421.

Edler, J. (2016). 'The Impact of Policy Measures to Stimulate Private Demand for Innovation'. In J. Edler, P. Cunningham, A. Gök, & P. Shapira (eds), *Handbook of Innovation Policy Impact*, pp. 318–354. Cheltenham: Edward Elgar.

European Court of Auditors. (2020). 'Digitising European Industry: An Ambitious Initiative Whose Success Depends on the Continued Commitment of the EU, Governments and Businesses'. Special Report no. 19.

EIB (European Investment Bank). (2020). 'Who Is Prepared for the New Digital Age? Evidence from the EIB Investment Survey'. Luxembourg: European Investment Bank. https://doi.org/10.2867/03951.

EIB (European Investment Bank). (2021). 'Accelerating the 5G Transition in Europe: How to Boost Investments in Transformative 5G Solutions'. Luxembourg: European Investment Bank. https://doi.org/10.2867/252427.

Gordon, R. (2012). 'Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds'. Cambridge, MA: NBER Working Papers, no. 18315.

Gordon, R.J. & Sayed, H. (2020). 'Transatlantic Technologies: The Role of ICT on the Evolution of U.S. and European Productivity Growth'. *International Productivity Monitor*, 38, 50–80.

Haskel, J. & Westlake, S. (2017). *Capitalism Without Capital: The Rise of the Intangible Economy*. Princeton, NJ: Princeton University Press.

Hsieh, C-.T. & Klenow, P. (2009). 'Misallocation and Manufacturing Productivity in China and India'. *Quarterly Journal of Economics*, 124(4), 1403–1448.

Ketels, C. & Porter, M.E. (2021). 'Rethinking the Role of the EU in Enhancing European Competitiveness'. *Competitiveness Review*, 31(2), 189–207. https://doi.org/10.1108/CR-08-2020-0100.

Knieps, G., & Bauer, J.M. (2021). 'Internet of Things and 5G Localization'. Working Paper 02-21. East Lansing, MI: Quello Center for Media and Information Policy.

Lopez-Garcia, P., Di Mauro, F., & the CompNet Task Force. (2015). 'Assessing European Competitiveness: The New CompNet Micro-Based Database'. Working Paper Research 279, National Bank of Belgium.

Mayer, T., & Ottaviano, G.I.P. (2008). The Happy Few: The Internationalisation of European Firms. *Intereconomics*, 43, 135–148. https://doi.org/10.1007/s10272-008-0247-x.

Mokyr, J. (2014). 'Secular Stagnation? Not in Your Life'. *Geneva Reports on the World Economy*, August, 83–89.
Moncada-Paternò-Castello, P., Ciupagea, C., Smith, K., Tübke, A., & Tubbs, M. (2010). 'Does Europe Perform Too Little Corporate R&D? A Comparison of EU and Non-EU Corporate R&D Performance'. *Research Policy*, 39, 523–536.
Prieger, J.E. (2020). 'An Economic Analysis of 5G Wireless Deployment: Impact on the U.S. and Local Economies'. ACT/The App Association. https://actonline.org/wp-content/uploads/ACT-Report-An-Economic-Analysis-of-5G-FINAL.pdf.
Qualcomm Technologies. (2019). 'Everything you need to know about 5G'. https://www.qualcomm.com/invention/5g/what-is-5g.
Rossi, M.A. (2021). 'The Advent of 5G and the Non-Discrimination Principle'. *Telecommunications Policy*, 46(4), 102279. https://doi.org/10.1016/j.telpol.2021.102279.
Van Ark, B., O'Mahony, M., & Timmer, M.P. (2008). 'The Productivity Gap Between Europe and the United States: Trends and Causes'. *Journal of Economic Perspectives*, 22(1), 25–44.

Part 2

# Specific Policy and Business Challenges

# The Challenge for Mobile Operators to Create Value with 5G

## Jason Whalley

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**ABSTRACT**

**5G is a transformational technology. Through its widespread adoption, 5G promises to generate significant economic value and create countless jobs. But it will not be easy for mobile operators to capitalise on this opportunity. 5G will further complicate the sector's value chain and encourage the presence of many more actors within the industry, potentially marginalising the role played by mobile operators in the more lucrative areas where it will be adopted.**

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### 5G CREATES VALUE

5G is often framed as creating value. One frequently cited report suggests that by 2035 the global 5G value chain will contribute $3.6 trillion in economic output and support over 22 million jobs (IHS Markit, 2019). Furthermore, the same report predicts that between 2020 and 2035 5G will contribute $2.1 trillion to real global GDP growth. Reflecting the role of 5G as a general-purpose technology, which enables it to support a wide array of uses, these figures were updated just a year later to $3.8 trillion and $2.3 trillion respectively (IHS & OMDIA, 2020).

Equally large figures can be found in other reports. According to PWC (2021), which analysed the use of 5G in five sectors, 5G will boost global GDP by over $1.3 trillion by 2030. Another estimate, which looks at the use of 5G more broadly, suggests it will add €2.2 trillion to the European Union's economy between 2020 and 2030 (European Commission, 2020), while GSMA (2021a) proposes it will add €600 billion in total economic value over the same period. While these figures differ in what they are attempting to estimate, it is clear that a consensus is emerging around the scale of the economic contribution of 5G: quite simply, it will be large.

This is also evident in those studies examining the impact of 5G at the national level. OMDIA (2021) examined the impact of 5G in five European markets – Belgium, France, Poland, Romania, and Spain – and found that it would support €407 billion in sales and over one million jobs. Another report, also commissioned by a mobile operator, suggested that the economic value of 5G would soon overtake that of fibre in the United Kingdom ($O_2$, 2017). 5G would create value added of £7 billion by 2026, with improvements in supply chains contributing another £3 billion.

The scale of the economic contribution of 5G reflects its ability to be used in many different contexts. The use cases identified are numerous and varied. Analysis from both the GSMA (2021a) and PWC (2021) draws attention to the use of 5G within manufacturing. While GSMA (2021a) notes that 'services' is another key area where 5G will be used, PWC (2021) highlights utilities and healthcare as sectors where the economic impact of 5G will be significant. Manufacturing and healthcare are also among the six sectors where use cases were identified by Deloitte (2018), with the others being transport, media and entertainment, public services and utilities, and agriculture. Although a narrower set of industries are discussed by Grijpink et al. (2020), the four industries they discuss – mobility, healthcare, manufacturing, and retail – are estimated to increase global GDP by between $1.2 trillion and $2 trillion by 2030.

In each of the five countries examined by OMDIA (2021), manufacturing is the sector where 5G-enabled sales are forecast to be the largest by 2030. With the exception of France, the use case for each country described by the report is outside of manufacturing – the Romanian use case is smart agriculture, while asset tracking is the Belgian example. Use cases from the transportation and manufacturing sectors are prominent among those identified by the World Economic Forum (WEF, 2020), accounting for two-thirds of the 40 included in their analysis. The manufacturing sector will benefit through 5G enabling predictive intelligence, as well as improved workplace safety and operational effectiveness (WEF, 2020). The 21 use cases included in IHS Markit (2019) are grouped into three broad areas: enhanced mobile broadband (eight use cases), Internet of Things (IoT) (eight) and mission-critical services (five). Interestingly, manufacturing is only mentioned once – industrial automation – among the case studies included in WEF (2020), though arguably the sector would benefit from other use cases such as fixed wireless broadband deployment or remote monitoring and asset tracking. Other use cases include education (illustrating enhanced mobile broadband), smart homes (massive IoT) and drones (mission-critical services).

## EVER MORE COMPLEX VALUE CHAINS

Technological change and liberalisation have changed the mobile telecommunications industry. Over time, the number of services has increased and the value chain has become more complex. The advent of 2G in the early 1990s was associated with a limited number of services (that is, voice and data) (IDATE, 2019) but increasing diversity in terms of network equipment and devices, fuelling in the process the growth of manufacturing companies such as Nokia (Steinbock, 2002, 2010). The emergence of 3G around the turn of the millennium furthered the increasing complexity of the mobile telecommunications value chain (Maitland, Bauer, & Westerveld, 2002; Sabat, 2002), widening the array of services available to end users.

Regardless of whether the term 'value network' (Li & Whalley, 2002) or 'ecosystem' (Fransman, 2010) is used to describe the resulting combination of actors to provide mobile communication services, there is a common characteristic: namely, the increased number of actors that collectively deliver services to the end user. It is worth noting, however, that while Li and Whalley (2002) draw attention to the increased number and diversity of actors in one particular area, namely services, Fransman (2010) highlights these changes more broadly across the whole telecommunications industry.

Both these trends will continue with 5G, albeit more extensively than was previously the case. One driver of this increased complexity is the use cases noted above. Many of the use cases can be found within a vertical, which are industries such as automotive, healthcare, and media and entertainment, that will use 5G to deliver services to their own customers (Curwen & Whalley, 2021). Within these industries, companies could partner with mobile operators to provide their services, limiting the complexity within the value chain. Alternatively, companies within the vertical industries could partner with solution providers or consultancy companies to offer their services, thereby adding to the complexity of the sector.

Local 5G licences will also play a role in furthering the mobile sector's complexity. These licences have the potential to create new types of operators (Ahokangas et al., 2019; Matinmikko et al., 2018). Not only do the ecosystems of the three different types of operators identified by Matinmikko et al. (2018) differ in their structural complexity, arguably being more complex than the ecosystems surrounding mobile operators today, but they also vary in their geographical scope. The emergence of local licences marks the end of a mobile telecommunications industry composed of a relatively small number of nationally oriented mobile operators; instead, through 5G local licences, the future structure of the sector will combine a handful of nationally focused mobile operators with a potentially large number of local ones, the vast majority of which will not be mobile operators as we understand them today.

Vertical industries can, of course, utilise local licences. 5G could be used to provide high-quality audio streaming or video content from a concert, or to enable the automation of a factory (Guirao et al., 2017). Not only does the provision of 5G services through a local licence further complicate the value chain through introducing new actors such as the owner of the concert venue or factory, but it also raises the prospect of whatever services are provided being limited temporally. A local licence to provide 5G-enabled services at a concert or large sporting occasion may be limited to just a specific (time-limited) event, whereas one awarded to a manufacturing company to assist with the automation of its factory will operate over the longer term.

## FINDING VALUE IN AN INCREASINGLY COMPLEX INDUSTRY

The increased complexity of the mobile telecommunications value chain is the inevitable consequence of the transformational role of 5G. 5G will be used in many different ways across a wide range of socio-economic activities. This is evident in the use cases noted above, with the commonly mentioned verticals being significant industries in their own right. They are also sources of revenue for mobile operators – these industries use the services and connectivity provided by mobile operators in their own operations. But with 5G, mobile operators may be sidelined: a sports venue or concert hall could use a local licence to develop their own infrastructure, for example, while a factory could instal its own network to improve its operational efficiency.

There is, therefore, a danger that mobile operators will miss out on the commercial opportunities emanating from 5G. This would be worrying in the sense that it would perpetuate their general failure to capitalise on the value created by the digital economy over the last 20 years or so. Arthur D. Little (2022) vividly illustrates how revenues across the global digital ecosystem have grown, with Internet

> The manufacturing sector will benefit through 5G-enabling predictive intelligence, as well as improved workplace safety and operational effectiveness

companies (for example, Amazon, Google) displaying an annual growth rate between 2011 and 2020 (inclusive) of 26 per cent. In contrast, the revenues of telecommunications companies (for example, AT&T, Deutsche Telekom) grew annually by just 4 per cent over the same period. Given these very different rates of growth, it is no surprise that few mobile operators can be found among the world's most valuable companies (Curwen & Whalley, 2010). While Curwen, Sadowski and Whalley (2015) highlight the declining number of European technology companies among the world's most valuable companies, it is worth noting that telecommunications companies are around half of these companies. However, European telecommunications companies have a market capitalisation that is considerably lower than their US-based counterparts: Deutsche Telekom, Europe's most valuable operator in August 2020, was worth less than half of AT&T and just under a third of Verizon (ETNO, 2022a).

5G and the IoT are often linked together. The forecasts that have been made – for example, 24 billion connections and global revenues of over $900 billion by 2025 (GSMA, 2021b) – suggest an attractive market, and one that has been targeted by mobile operators around the globe. Vodafone, for example, reported that its IoT revenues for calendar year 2020 were €800 million (Vodafone, 2021). While this figure is small compared with what the company generates from other activities – mobile generated €5.9 billion in revenues over the same period from businesses – it is worth remembering that Vodafone forecasts that the IoT will grow considerably faster than the mobile market and that the two will be more or less the same size within the space of just a couple of years.

While the IoT may eventually generate large revenues, mobile operators are rolling out their 5G infrastructure today. The sums involved are considerable. One forecast suggests that globally mobile operators will invest over $1 trillion in their networks between 2019 and 2025 (Iacopine et al., 2020), while another report states that $510 billion will be spent on 5G between 2022 and 2025 (Mobile World Live, 2022). ETNO (2022b) states that European operators will need to spend €150 billion to make 5G widely available. While this sum is large, it may not be enough: IDATE (2019) has highlighted the investment gap between the United States and the European Union, with the former spending twice as much as the latter.

It has been argued that, as operators invest in their networks, expanding capacity and rolling out 5G, costs will increase (Grijpink et al., 2018). This underlines the need for mobile operators to both find lucrative sources of revenue and ensure they are not sidelined by new actors entering the value chain. The marginalisation of mobile operators will reduce their ability to generate (multiple) revenue streams that would justify their considerable 5G investments. Mobile operators could mitigate this marginalisation through engaging in partnerships (Harrowell, Talmesio, & Kirchheimer, 2020; Leong, 2019, PWC, 2019) with companies in the industries where 5G will be extensively used as well as other technology companies (for example, those providing cloud services, equipment vendors). One advantage of such a strategy is that it will help mobile operators better understand the needs of customers, something it has been suggested that they struggle with (Harrowell, Talmesio, & Kirchheimer, 2020). However, within these partnerships, mobile operators need to carefully position themselves, constructing an ecosystem to create value where they are at the heart of developments without distancing themselves from the various industries

Local 5G licences will also play a role in furthering the mobile sector's complexity

where 5G will be pivotal to value creation. Through such an approach, mobile operators may be able to reverse their overshadowing in the value chain that occurred with 4G (Grijpink et al., 2021).

## CONCLUSION

5G is a transformational technology. The changes it will bring about are widespread, creating many new opportunities and substantial value across vast swathes of the global economy. Integral to these new opportunities and value creation will be the use of 5G in verticals, where industries will use 5G to deliver their own products and services. This is both an opportunity and a challenge for mobile operators; the widespread use of 5G will create new markets for mobile operators to enter, but these markets are complex, dynamic, and composed of many different companies. The challenge for mobile operators is how to benefit from the transformational impact that 5G will have and thus avoid being sidelined by other companies who then go on to capture a greater share of the value that it creates.

### REFERENCES


Ahokangas, P., Matinmikko-Blue, M., Yrjölä, S., Seppänen, V., Hämmäinen, H., Jurva, R. & Latva-aho, M. (2019). 'Business Models for Local 5G Micro Operators'. *IEEE Transactions on Cognitive Communications and Networking*, 5 (3), 730–740.

Arthur D Little. (2022). 'French Telecoms Economics 2021'. 3 January. https://www.fftelecoms.org/en/studies-publications/2021-french-telecoms-economics-report/

Curwen, P., Sadowski, B., & Whalley, J. (2015). 'Where Are the Europeans? A Longitudinal Analysis of the World's Largest TMT Companies'. *Digital Policy, Regulation & Governance*, 17 (5), 1–19.

Curwen, P. & Whalley, J. (2010). 'Mobile Operators in the New Millennium: Retrospect and Prospect'. *info*, 12 (3), 30–45.

Curwen, P. & Whalley, J. (2021). *Understanding 5G Mobile Networks: A Multidisciplinary Primer*. Bradford: Emerald.

Deloitte. (2018). 'The Impacts of Mobile Broadband and 5G: A Literature Review for DCMS'. June. London: Deloitte.

ETNO (European Telecommunications Network Operators' Association). (2022a). 'State of Digital Communications'. Report prepared by Analysys Mason for European Telecommunications Network Operators Association. https://etno.eu/library/reports/104-state-of-digi-2022.html

ETNO (European Telecommunications Network Operators' Association). (2022b). 'Connectivity and Beyond: How Telcos Can Accelerate a Digital Future for All'. February. https://etno.eu/library/reports/96-connectivity-and-beyond.html

European Commission. (2020). *Shaping the Digital Transformation in Europe*. Directorate-General for Communications Networks, Content and Technology, September. https://digital-strategy.ec.europa.eu/en/library/shaping-digital-transformation-europe

Fransman, M. (2010). *The New ICT Ecosystem: Implications for Policy and Regulation*. Cambridge: Cambridge University Press.

Grijpink, F., Menard, A., Sigurdsson, H., & Vucevic, N. (2018). 'The Road to 5G: The Inevitable Growth of Infrastructure Cost'. McKinsey & Company, February. https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/the-road-to-5g-the-inevitable-growth-of-infrastructure-cost

Grijpink, F., Kutcher, E., Menard, A., Ramaswamy, S., Schiavotto, D., Manyika, J., Chui, M., Hamill, R., & Okan, E. (2020). 'Connected World. An Evolution in Connectivity beyond the 5G Revolution'. McKinsey & Company, February. https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/connected-world-an-evolution-in-connectivity-beyond-the-5g-revolution

Grijpink, F., Larsson, J., Menard, A., & Pell, K. (2021). 'Unlocking the Value of 5G in the B2C Marketplace'. McKinsey & Company, November. https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/unlocking-the-value-of-5g-in-the-b2c-marketplace

GSMA. (2021a). The Mobile Economy: Europe 2021'. https://www.gsma.com/mobileeconomy/europe/

GSMA. (2021b). 'The Mobile Economy 2021'. https://www.gsma.com/mobileeconomy/wp-content/uploads/2021/07/GSMA_MobileEconomy2021_3.pdf

Guirao, M.D.P., Wilzek, A., Schmidt, A., Septinus, K., & Thein, C. (2017). 'Locally and Temporally Shared Spectrum as Opportunity for Vertical Sectors in 5G'. *IEEE Network*, 31(6), 24–31.

Harrowell, A., Talmesio, D., & Kirchheimer, E. (2020). 'Industries and Enterprises Are Ready to Reap the Benefits of 5G'. *Beyond Now*, report prepared by OMDIA. www.beyondnow.com

Iacopine, P., Jarich, P., Hatt, T., & Zhong, Y. (2020). 'The 5G Era For Operators: Investing In Core Networks, Capturing B2B

Opportunities'. https://data.gsmaintelligence.com/research/research/research-2020/the-5g-era-for-operators-investing-in-core-networks-capturing-b2b-opportunities
IDATE. (2019). *Digiworld Yearbook: The Challenges of the Digital World 2019*. Montpellier: IDATE
IHS Markit. (2019). 'The 5G Economy: How will 5G contribute to the global economy'. November. https://ihsmarkit.com
IHS Markit & OMDIA. (2020). 'The 5G Economy in a Post-COVID-19 Era: The Role of 5G in a Post-Pandemic World Economy'. November, report prepared for Qualcomm Technologies. www.qualcomm.com
Leong, C.H. (2019). 'Why Partnerships Will Be Key to the 5G Future'. August. https://home.kpmg/uk/en/home/insights/2019/08/why-partnerships-will-be-key-to-the-5g-future.html
Li, F. & Whalley, J. (2002). 'Deconstruction of the Telecommunications Industry: From Value Chains to Value Networks'. *Telecommunications Policy*, 26 (9–10), 451–472.
Maitland, C.F., Bauer, J.M., & Westerveld, R. (2002). 'The European Market for Mobile Data: Evolving Value Chains and Industry Structures'. *Telecommunications Policy*, 26 (9–10), 485–504.
Matinmikko, M., Latva-aho, M., Ahokangas, P., & Seppänen, V. (2018). 'On Regulations for 5G: Micro Licensing for Locally Operated Networks'. *Telecommunications Policy*, 42 (8), 622–635.
Mobile World Live. (2022). 'Mobile Operators Face $600b Capex by 2025'. 27 February. https://www.mobileworldlive.com/featured-content/top-three/mobile-operators-face-600b-capex-by-2025
OMDIA. (2021). '5G Impact 2030'. Report commissioned for Orange. https://omdia.tech.informa.com/commissioned-research/articles/5g-impact-2030
$O_2$. (2017). 'Press Release: UK 5G infrastructure to outstrip economic benefits of fibre broadband by 2026'. 16 February. https://theonepoint.co.uk/news/post/5g-infrastructure-to-exceed-fibre-broadband
PWC. (2019). 'The Great Potential of 5G Ecosystems: Capturing the Full Potential of 5G by Embracing Industry Convergence'. February. https://www.pwc.nl/nl/assets/documents/the-great-potential-of-5G-ecosystems.pdf
PWC. (2021). 'The Global Economic Impact of 5G: Powering Your Tomorrow'. https://www.pwc.com/gx/en/tmt/5g/global-economic-impact-5g.pdf
Sabat, H.K. (2002). 'The Evolving Mobile Wireless Value Chain and Market Structure'. *Telecommunications Policy*, 26 (9–10), 505–535.
Steinbock, D. (2002). 'Wireless R&D – From Domestication to Globalisation'. *info*, 4 (6), 27–49.
Steinbock, D. (2010). *Winning Across Global Markets: How Nokia Creates Strategic Advantage in a Fast-Changing World*. San Francisco, CA: Jossey-Bass.
Vodafone. (2021). 'Vodafone Business Investor Briefing'. March. https://investors.vodafone.com/sites/vodafone-ir/files/vodafone/vodafone-business-investor-briefing/vodafone-business-investor-briefing.pdf
WEF (World Economic Forum). (2020). 'The Impact of 5G: Creating New Value Across Industries and Society'. January. https://www.weforum.org/whitepapers/the-impact-of-5g-creating-new-value-across-industries-and-society/

# Leadership with 5G in Europe: The Benefits of Open Networks

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**ABSTRACT**

**This chapter provides recommendations on how the European Union may assume a leadership role with 5G based on an analysis of the regional and global success of 2G-GSM. It builds on the benefits of openness through standards, interfaces, protocols, application platforms, and application programming interfaces. It identifies 5G wholesale access as a critical enabler for building market momentum, an essential ingredient for achieving leadership. The review of the economic literature on wholesale access and the historical record suggests that leadership with 5G and potentially 6G will only be realised through policy action.**

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**INTRODUCTION**

In 2015, as the next generation of mobile communications took shape in the standardisation arena and was scheduled to be introduced in 2020, a call for a leadership role with 5G in Europe could be heard in Brussels. This call was inspired by the European and subsequent global success of 2G GSM in the 1990s. The GSM project remains an excellent example of how a 'single market' was created within the European Union.

How, then, can a leadership role with 5G in Europe be shaped and what might that leadership role entail? The call for leadership triggered a study of the successes and failures of successive generations of mobile technology since the introduction of 1G in the early 1980s. For an appreciation of what it takes to adopt a leadership role, the findings of this study are summarised in the following section.[1] As the first window of opportunity to assume a leadership role has passed, that is, at the introduction of 5G, this chapter explores in the subsequent sections the remaining opportunities available for leadership with 5G.

**FROM 1G TO 5G – SUCCESSES AND FAILURES**

The introduction of cellular mobile technology in the early 1980s led to a fragmented industry with each major country having its own standard, its own supplier, and its own mobile network operator (MNO). Only in the Nordic countries did collaboration lead to a common and open standard, which was also adopted by the Netherlands, Belgium, and Luxembourg. Typically, the fixed line operator was licensed by the national government to use the radio frequency band destined for cellular mobile communication. As such, the incumbent became the monopoly provider of wireless telephony. At that time it was primarily used by businesses and travelling salesmen, as analogue phones were expensive and luggable. Travelling across Europe and staying connected required a boot full of different car phones and a subscription in each country that was visited.

The rapid growth and impending capacity limitations of the mobile network led to the initiative for a next generation of cellular technology. This became the first digital generation, with a 'handy' aimed at the mass consumer market introduced in 1990. The creation of a European standard, the adoption thereof, and the alignment of all stakeholders involved constituted the start of the success story.

The introduction of a second operator in each country and the rapid uptake of GSM by the entrants led to rapid adoption of the new technology. The success in Europe was followed by worldwide success. In 2015, 25 years after its launch, 2G-GSM reached its peak in deployment with 3.8 billion users served by 700 operators in 219 countries and territories. The runner up was 2G-CDMA with 374 million users, a US-based development.

In the year 2000, 3G was launched, with the United States and South East Asia taking the lead. The launch coincided with the peak of the telecom–Internet bubble (Lemstra, 2006). Competition was stimulated using auctions to obtain the right to use the new (higher) radio frequency bands. The high expectations at the peak of the dot.com bubble led to very high auction fees. The UK auction held at the peak of the bubble resulted in a fee equivalent to US$650 per inhabitant. The collapse of the bubble delayed the roll-out and uptake of 3G. Its momentum started to build following the introduction of the smartphone in 2007.

The next generation, 4G, was the first All-IP technology in support of the mobile Internet. Hence, legacy constraints were removed, and the first global standard could be created. The deployment of 4G at the end of the fourth quarter of 2021 stood at 6.6 billion mobile broadband users worldwide, making it the most successful mobile generation to date in terms of deployment and take-up.[2]

### THE CONDITIONS FOR A LEADERSHIP ROLE TO BE REALISED

With the ten-year upgrade cycle of mobile technology having been well established, the requirements for 5G were developed at the beginning of the previous decade. With the shaping of the 5G architecture under way in the middle of the decade, the political desire to assume a leadership role with 5G in Europe arose. With the recognition that, after the success of 2G-GSM, the United States and Asia had become the leading regions in the adoption of 3G and 4G, the question was how to re-assume leadership with 5G in Europe.

An assessment of the success of GSM concluded that it was the result of 'the stakeholders providing the conditions for market momentum to build and be maintained' (Lemstra, 2018: 591). The conditions included (1) the creation of an open standard that was adopted by all mobile operators in the region; (2) the allocation of the same radio frequency band across Europe, timely national assignments, and reserving this band exclusively for GSM; (3) the alignment of the roll-out plans of operators in terms of timing and services to be offered; and (4) the introduction of compelling new services for end users. The latter included the introduction of the 'handy', enabling the opening up of the mass consumer market for mobile telephony. Finally, a further condition was (5) the introduction of competition, that is, a second operator in each national market accelerating the GSM infrastructure roll-out.

The GSM project remains an excellent example of how a 'single market' was created within the EU

### A LEADERSHIP ROLE WITH 5G

While these conditions applied to the introduction of the following generations of mobile technology in general, they played out differently at the launch of 5G. With 4G a first global standard was introduced, which changed the structure of the market from three regions into one global market. Hence, there will be no geographical expansion of the market with 5G, which is an important component in building momentum, as it increases the economies of scale for the equipment suppliers. Moreover, the radio spectrum regulations were changed, ensuring that allocations and assignments are made 'technology neutral', thus giving mobile operators maximum freedom in the use of their radio spectrum usage rights. Moreover, existing rights were adapted and made neutral, and as soon as repurposed, old bands and new bands became available and were typically auctioned off and not reserved for a new round every ten years. Nonetheless, the need for higher data rates has led to the need to open up higher frequency bands. For 5G, these are the 3.5 GHz band and the 26–28 GHz band. National governments have been auctioning these bands according to their own timetables, which in some cases have been negatively affected by the COVID-19 pandemic. As the mobile services market is well established and competitive, there is no need for policy intervention or regulation; hence, the roll-out initiatives have been limited to recommendations as part of the EU 5G Action Plan.[3] The level of competition appears to settle around three to four main players in each national market. Although governments aim to introduce new players through spectrum caps and spectrum reservations as part of the auction process, typically consolidation of mobile operators takes place in between auctions.

Hence, for the introduction of 5G most of the conditions that were instrumental for the success of 2G-GSM do not apply. Thus, leadership with 5G was not taken up at the time of its introduction. Does that mean there is no longer an opportunity to assume a leadership role with 5G in Europe? The answer is no. What remains to be done is the introduction of new and enhanced services for the so-called industry verticals and the use of application programming interfaces (APIs) to enable these services. This constitutes the opening up of new markets, the most important factor that remains for building momentum.

### WHAT MAKES 5G DIFFERENT

The 5G architecture is fundamentally different from its predecessors in the sense that it has incorporated the notion of virtualisation as we know it from the information technology (IT) domain, essentially the paradigm of cloud-based services. 5G architecture is based on software-defined networking and network function virtualisation.[4] This enables the tailoring of services to specific groups of end users or industry verticals. These services can be separated from each other through network slicing, thus providing different classes of services to each. These include 'mission critical' for emergency services, such as the police, fire brigade, and ambulances; 'business critical' for operators of critical infrastructures, railways, airports, and seaports, as well as major industrial entities; and the 'normal' services bundle we associate with broadband services for consumers.

Providing this broad range of services requires mobile operators to understand the needs and requirements of these new market segments and new business customers. As such, they may benefit from having built up experience by linking

Information Technology services with their traditional Communication Technology services in recent years. However, their ability to diversify and shape tailored services may be limited as operators downsized and refocused on core business in the aftermath of the telecom–Internet bubble. For example, some Tier 2/3 operators have outsourced their once leading research activities.

Deep insights into the needs and requirements of verticals resides within the verticals themselves and in the specialised IT-services firms that support them. To effectively open up these markets, the telcos need to open up their networks for these verticals to become virtual mobile network operators (VMNOs) (Lemstra, 2018). However, opening up the network is counter-intuitive for MNOs. Recall the so-called walled gardens that mobile operators created at the time that mobile Internet access was first offered. Moreover, Steve Jobs, at the launch of the Apple App Store, restricted access to apps developed by Apple engineers, arguably to secure the quality of the apps being offered. Within two weeks he realised that an open App Store would be much more attractive . . . and the rest is history.

Before exploring in more detail openness in relation to mobile networks and to 5G, let's first review the notion of openness in general and identify its benefits.

## THE BENEFITS OF OPENNESS IN GENERAL

One of the early and most impressive examples of the benefits of openness, in terms of an open standard, is related to complementarity between the LP music record and the vinyl record player, introduced in the late 1940s (DMS, 2017). The recording and the replay method had to be compatible, and the sales success of the player was directly linked to the portfolio of recorded music that was made available using the specific recording method. Industry battles have been fought over subsequent generations, such as the audio cassette, the CD, and the blue ray disc. Success has typically been determined by the portfolio of popular music that was made available using the specific standard. The result has been that two complementary types of industries could flourish simultaneously, focusing on their specific skills and capabilities. Philips Electronics and Sony are typical examples.

A more recent and even more compelling example of the benefits of openness is the Internet, which was introduced to the general public in the late 1980s. Through the universal adoption of the TCP/IP protocol stack by new Internet service providers (ISPs), a global network-of-networks was created. It should be noted that the early connectivity was enabled by the global reach of the telephone network, providing access to customer premises and the international backbone connectivity. The first major application supported by the Internet was the World Wide Web, invented by Tim Berners-Lee at the CERN research facilities in Geneva in 1990.

Returning to the music industry, the introduction of the iTunes store and the iPod by Apple in 2001 disrupted the music industry and established a new business model for the distribution of music, with the Internet providing the distribution network. This was followed by music streaming services such as Spotify, introduced in 2006.

The Apple iOS App Store was launched in 2008 with 500 apps. As of 2022, 1.85 million different apps are available for users to download. Android users have an even wider choice, with 2.56 million different apps available through the Google Play Store.[5] Hence, an open infrastructure supports innovation-on-top.

## OPENNESS IN MOBILE NETWORKS

Let's return to openness in public mobile networks.

With the introduction of 2G-GSM, two aspects of openness were introduced to the market. The GSM standard developed by the European Telecommunications Standards Institute (ETSI) includes an open interface between the mobile core and the radio access network, the so-called A-interface. This facilitated the development of a competitive equipment market, with multiple providers of the core and base station equipment, such as Ericsson, Nokia, Siemens, and SEL, and base station only providers, including AEG/Telefunken, Bosch, Matra, Philips (PKI and TRT), and TeKaDe. Note that the market for terminals was liberalised in the late 1980s.[6] For GSM that implied an open and standardised device interface. Nonetheless, Nokia and Ericsson became the main suppliers of the handy, with other vendors taking smaller shares. Philips also entered the market but did not create a breakthrough. All in all, the 2G-GSM equipment market was highly diverse and competitive.

Next to open standards, the mobile network was also opened up for alternative operators, the so-called mobile virtual network operators (MVNOs).[7] An MVNO negotiates with an MNO to obtain access to network services at wholesale rates and sets its own retail prices. An MVNO provides, as a minimum – 'thin' – MVNO, its own marketing and sales, customer services, and billing support systems. Full MVNOs also provide their own network core, including switching functions, and rely on the MNO only for access to the radio network. An MVNO typically addresses a specific (niche) market segment, such as a diaspora, specific consumer or business groups, and so forth. Although wholesale rates will be lower than retail rates and thus MNOs will see lower margins on this part of their business, MVNOs can broaden and deepen the market, which is difficult for the MNO to achieve as a generalist. Therefore, both MNOs and MVNOs typically benefit. Some MVNOs operate across multiple countries and provide uniform services for their clients. A typical example is France-based Transatel, which provides services such as fleet and asset tracking, vehicle telematics, smart metering, entertainment, and telehealth, including support for machine-to-machine communication and Internet of Things.[8]

However, despite the benefits, in Europe the success of the MVNO business model is mixed. In the United Kingdom the MVNO model is very successful, with examples such as Virgin Mobile, and main street brands such as Tesco Mobile. MVNOeurope, the industry organisation, claims that MVNOs represent approximately 10 per cent of all SIM cards issued in the EU. It appears that in some countries the wholesale model is not supported by the MNOs or is not supported by national regulation.[9] For MVNOs that operate internationally, such as Transatel, this means they cannot provide their services uniformly across the EU, which in turn hinders European and other companies' ability to provide their end-user services uniformly and through one operator in all Member States. In some cases, underutilisation of radio spectrum assets has encouraged MNOs to provide MVNO access.[10] In some countries spectrum access rights have been made conditional on providing wholesale access, most recently in France and the Czech Republic for access rights to the 5G spectrum.

As enabling the vertical industries across the board is a main objective for 5G, providing virtual access is essential.

In 2015, 25 years after its launch, 2G-GSM reached its peak in deployment with 3.8 billion users

### THE LEADERSHIP OPPORTUNITY WITH 5G IN EUROPE

As already mentioned, the virtualised architecture of 5G provides for the tailoring of mobile services to the needs of diverse user groups, including industry verticals and public organisations. This is a first within the mobile industry and thus allows for 'market momentum to be built and maintained'. It represents new value-added business opportunities for MNOs, which may relieve some of the pressure on margins resulting from the highly competitive mass consumer market. When combined with the transition to Industry 4.0, the new mobile communications technology co-enables the digital transformation of industry and society at large. As such it enables economic growth and the success of EU-based companies operating in global markets.

Realising this potential is not trivial: the requirements and needs of the verticals are very diverse and the deep knowledge that is required resides not within the MNOs but in the industries themselves. Moreover, the three to five MNOs in each country will be unable to serve the many different verticals and competing firms within these verticals simultaneously. Here, the virtualised architecture of 5G provides for APIs to configure tailored services. Today, these APIs are used by the MNOs to configure these services; however, in order to build market momentum, these APIs need to be opened up to professionals within the industry verticals to shape their own services.[11] The verticals then become VMNOs using the 5G infrastructure of the MNO. Moreover, the current MVNOs can continue their 4G business into the 5G era as VMNOs and broaden their services portfolios.

### POLICY AND REGULATORY INTERVENTION

This is the leadership opportunity with 5G that remains available. In the recommendations of the study we concluded that these new capabilities are truly innovative. Time is required to learn about these new capabilities and to determine how the theoretical use cases that have shaped the 5G architecture can be translated into actual use cases deployed in the field. Hence, the stakeholders should be allowed to learn and apply their findings. Does that mean one has to wait and see whether MNOs are inclined to open up the APIs to the new VMNOs? Not necessarily.

Economic theory suggests that MNOs in competitive markets will be likely to provide wholesale access if VMNOs are providing services that are different from those provided by the MNOs (see, e.g., Dippon & Banerjee, 2006; Ordover & Shaffer, 2006; Dewenter & Haucap, 2007; Bourreau et al., 2011). If the MNOs stay focused on the mass consumer broadband market, this will be the case. However, if MNOs choose to pursue the new opportunities offered by the vertical industries, which we should expect, this will only be the case if the MNOs and VMNOs serve different verticals. In practice this is difficult to arrange, and moreover it would hamper competition. Furthermore, the historical record on openness by MNOs is not encouraging. So, if competitive markets do not deliver on the desired goal, is that the end of the road? Certainly not.

As the institutional economist Groenewegen has observed, it means shifting from a pure 'regulatory state' role, where the outcome is the result of competitive markets, to a more 'developmental state' role, where policymakers provide a vision of the future they wish to realise (Lemstra & Groenewegen, 2009). The first step in the realisation of the vision is informing the market actors on the objective to

## The deployment of 4G at the end of the fourth quarter of 2021 stood at 6.6 billion mobile broadband users worldwide

be realised. If the market fails to deliver, further action can be taken in terms of stimulating certain developments by, for example, bringing the actors involved together to share the vision, to resolve any information asymmetry, and to provide a layout of the desired next steps in the collaboration necessary between MNOs and the vertical industries as VMNOs. This closely links with the other issue that needs to be resolved to enable leadership with 5G.

Delivering success does not depend only on the MNOs opening up the 5G networks; it appears that not all industries are fully aware yet of the capabilities that 5G offers. A salient anecdotal example is the case of eHealth in the Netherlands. In 2016, when the 'leadership' study was conducted, an exploration was started to obtain insight into the potential use cases of 5G.[12] Meetings were held with representatives of the information and communication technology departments of two academic hospitals in the Netherlands. It appeared that the pager was still considered the most trustworthy device for internal communication. The telecom experts in the room had to remind the audience that a pager does not have a return channel, thus there is no confirmation of whether a message has been received properly or not. A representative of T-Mobile demonstrated how the function of a pager could be readily emulated by a 4G smartphone. This anecdotal case shows that general awareness of the capabilities of mobile technology cannot be assumed, not even five years after its introduction.

This research into 5G use cases is ongoing at the Nyenrode Business University through Master's thesis projects and Executive MBA Module Paper projects. The eHealth use case is most likely the most complex of all use cases, as the decision-making unit involves the patient adopting an eHealth device; the doctor prescribing the service; the mobile operator ensuring high-quality service (e.g. for real-time heart rate monitoring); the medical profession taking responsibility for including the service in their treatment plan; the hospital director approving the related IT investment; and the insurance company reimbursing the costs. Moreover, the system appears to have perverse incentives, as savings obtained through the application of new technologies implies a reduction in doctors' income. Hence, it should not come as a surprise that adoption of the eHealth case has been slow despite many smart devices and applications being introduced in the market and many trials having been executed.

The analysis of this use case suggests that 'institutional' buying requires special attention for 5G to be able to provide its benefits. An approach that might facilitate the process is to assure that 'use case approval' is realised in an academic hospital with the appropriate research facilities, skilled staff, and stakeholder relations. Once the use case is 'foolproof' it can be introduced smoothly into the practice of general hospitals – a typical case of separating 'exploration' from 'exploitation' activities, a well-known approach from the business strategy literature (see, e.g., De Wit, 2020).

The autonomous driving use case is complex because of its dependence on two independent innovation trajectories. The smart building case features a long construction cycle and different user groups. The smart factory typically depends on private 5G solutions for which radio spectrum access needs to be provided.

Realising leadership with 5G in Europe thus implies actions on multiple fronts. All industries, and all private and public entities that might benefit, should be made aware of what 5G opportunities are in the offering and how they may be deployed to their benefit. To build market momentum, all stakeholders must be aligned in the private sector and at all levels of government. The Members of the European Parliament are ideally positioned to initiate and coordinate this policy action. The creation of the 5G Infographic to inform the general public is a great first step.[13] The next step should be to make industry policy driven by 5G and Industry 4.0, enabling all verticals to benefit from the new technological capabilities that 5G provides. In the process the leadership role with 5G in the European Union will be shaped and may be continued in the shaping of 6G.


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## NOTES

**1**. For the original study conducted for CERRE (Centre on Regulation in Europe), see https://cerre.eu/wp-content/uploads/2020/06/170330_CERRE_5GReport_Final.pdf. For the subsequent academic paper, see Lemstra (2018). For the use of this study in the contribution to the 5G Infographic of the European Parliament, see https://map.sciencemediahub.eu/5g.

**2**. See GSA, 'Evolution of LTE to 5G. January 2022. https://gsacom.com/paper/evolution-lte-5g-may2019/

**3**. See https://digital-strategy.ec.europa.eu/en/policies/5g-action-plan.

**4**. Note that the role of open interfaces between the core network and the radio access network (RAN) established as part of 2G-GSM has continued through 3G and 4G into 5G. Next to the backhaul interface, 3GPP has also standardised the midhaul interface for 5G. Recent initiatives within the industry are aimed at standardising the fronthaul interface. For an assessment of these Open RAN initiatives, see the upcoming CERRE report 'Open RAN and the Future of Innovation in Telecoms'. Note: the 3GPP is the standards body responsible for the standardisation of 5G at the global level.

**5**. See Business of Apps, https://www.businessofapps.com/data/app-statistics/.

**6**. Commission Directive 88/301/EEC of 16 May 1988 on competition in the markets in telecommunications terminal equipment (OJ L 131 16.05.1988, p. 73, CELEX), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31988L0301.

**7**. For a review of the early developments of the MVNO business model, see Rasmussen (n.d.). See also Dewenter and Haucap (2007). MVNOs in Europe collaborate through their industry organisation MVNOeurope, http://mvnoeurope.eu/.

**8**. See Wikipedia, https://en.wikipedia.org/wiki/Transatel. Other examples include Cubic Telecom (B2C), Ventocom (B2C), and Enreach (B2B). Source: MVNO Europe, personal communication.

**9**. See MVNO Europe Response to BOR (20) 163 'Draft BEREC Work Programme 2021', https://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/9801-contribution-from-mvno-europe-to-the-pub_0.pdf.

**10**. See 'MVNOs: to regulate or not to regulate – that is the question', https:// https://www.mobiliseglobal.com/wp-content/uploads/2021/03/To-regulate-or-not-to-regulate-Mobilise-Whitepaper.pdf.

**11**. For a discussion of openness in relation to 5G, see for instance Nokia (n.d.).

**12**. The context for the meetings was the CognitiveRadioPlatform.NL, an informal community of interest on the topic of electronic communications initiated by Peter Anker, representative of the Ministry of Economic Affairs of the Netherlands; Koen Mioulet, entrepreneur/consultant on wireless technologies; Vic Hayes, former chair of IEEE 802.11 responsible for the standardisation of Wi-Fi; and the author of this chapter, at that time affiliated with TU-Delft, now Nyenrode Business University.

**13**. For the 5G Infographic of the European Parliament, see https://map.sciencemediahub.eu/5g.

#### REFERENCES


Bourreau, M., Hombert, J., Pouyet, J., & Schutz, N. (2011). 'Upstream Competition Between Vertically Integrated Firms'. *Journal of Industrial Economics*, 59(4), 677–713.

Dewenter, R. & Haucap, J. (2007). 'Incentives to License Virtual Mobile Network Operators (MVNOs)'. In J. Haucap & R. Dewenter (eds.), *Access Pricing: Theory and Practice*. Amsterdam: Elsevier.

De Wit, B. (2020). *Strategy: An International Perspective*. Andover, UK: Cengage Learning.

Dippon, C. & Banerjee, A. (2006). *Mobile Virtual Network Operators: Blessing or Curse? An Economic Evaluation of the MVNO Relationship with Mobile Network Operators*. White Plains, NY: NERA Economic Consulting.

DMS. (2017). 'Back in Time: A Brief History of the Vinyl Record'. DMS News Blog, 6 September. https://www.discmanufacturingservices.com/blog/post/back-in-time-a-brief-history-of-the-vinyl-record.

Lemstra, W. (2006). *The Internet Bubble and the Impact on the Development Path of the Telecommunication Sector*. Delft, The Netherlands: TUDelft.

Lemstra, W. (2018). 'Leadership with 5G in Europe: Two Contrasting Images of the Future, with Policy and Regulatory Implications'. *Telecommunications Policy*, 42, 587–611. https://www.sciencedirect.com/science/article/abs/pii/S0308596118300491.

Lemstra, W. & Groenewegen, J.P.M. (2009). 'Markets and Public Values: The Potential Effects of Private Equity Leveraged Buyouts on the Safeguarding of Public Values in the Telecommunications Sector'. Report for the Ministry of Economic Affairs of The Netherlands. TUDelft, The Netherlands:

Nokia. (n.d.). 'As 5G rolls out, a more open business model could spark a wave of customer-centric innovation in the telecom industry'. Nokia Newsletter. https://www.nokia.com/networks/insights/openness-drives-innovation.

Ordover, J. & Shaffer, G. (2006). 'Wholesale Access in Multi-Firm Markets: When Is It Profitable to Supply a Competitor?' The Bradley Policy Research Centre Working Paper No. FR 06-08. Rochester, NY: William E. Simon Graduate School of Business Administration.

Rasmussen, A. (n.d.). 'History of MVNO'. Yozzo. https://www.yozzo.com/mvno-academy/the-history-of-mvno/.

# Net Neutrality, Network Slicing, and the Deployment of 5G and 6G

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**ABSTRACT**

**The deployment of 5G and 6G may depend on a new business model known as *network slicing*, which allocates different levels of shared components to different business verticals as needed. This chapter examines network slicing's compatibility with European net neutrality regulation. It explores how categorical rules erected in a prior context are often poorly suited to accommodating new business and technological approaches and how artificial distinctions between technical and business justifications can bar innovations that would benefit consumers. The result is a useful case study of the impact that categorical regulation can have on innovation.**

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## INTRODUCTION

Smartphones and the networks that connect them are universally regarded as among the most significant advances of the twenty-first century. These technologies have enabled people to access an unprecedented scale and scope of functionality through devices carried in the palms of their hands. Successive generations of mobile broadband technologies have transformed almost every aspect of human life and in the process have become critical drivers of economic growth, innovation, and personal empowerment.

European countries were among the global leaders in 3G wireless technologies but lagged behind key countries in Asia and North America in 4G deployments. The shift in focus toward the current buildout of 5G and emerging prospect of 6G have placed a renewed emphasis on positioning Europe to ensure that its citizens receive the greatest possible benefit from these innovations.

Industry observers expect that 5G and 6G technologies will be built around business models that are quite different from those used to support the deployment of previous mobile broadband generations. Rather than focusing primarily on individual consumers, business customers are expected to serve as the primary source of revenue to recoup 5G investments, with devices often connecting to one another directly (machine-to-machine or M2M) instead of indirectly through base stations. The fact that the demands of different business segments are more heterogeneous than those of individual consumers means that these networks will need to be configurable to meet the disparate needs of particular business verticals. Moreover, the lower level of demand, particularly areas of lower population density, may require network resources to be shared across multiple

European countries were among the global leaders in 3G wireless technologies but lagged behind key countries in 4G deployments

networks rather than being devoted to a single provider.

These realities have led providers to explore deploying 5G around a new architectural approach known as *network slicing*, which permits multiple providers to requisition and assemble portions of different infrastructure components on a dynamic basis. In many ways, network slicing is a natural next step in the historical progression of the Internet towards shared infrastructure. Much of the Internet's initial success derives from its shift away from architectures that required that network capacity be dedicated to a single application delivered to a single user in favour of a design that allocates the same resources to multiple applications and users simultaneously. Cloud computing later showed how technologies can be *virtualised* by seamlessly enabling users to call upon shared storage and processing resources on an on-demand and pay-as-you-go basis. Network slicing extends these same principles of virtualisation and resource sharing beyond the machines attached to the edge of the network into the network itself.

One problem is that a business model that allows customers to construct a virtual network by purchasing higher or lower levels of individual resources customised to fit their particular needs bears a striking resemblance to the pay-for-play business models that are the target of the European Regulation mandating network neutrality, which prohibits network providers from favouring particular providers of content or application. The focus of this chapter is to identify the key interpretive issues that will determine whether courts will find network slicing compatible with the Regulation (for a preliminary analysis, see Yoo & Lambert, 2019). In the process, it underscores two key difficulties. First, it explores how categorical rules that were erected in a particular business environment are often poorly situated to accommodate new business models based around different paradigmatic principles. Second, it examines how the artificially strict dichotomy between technical and business justifications drawn by the Regulation prevents providers from implementing solutions that would benefit consumers. The result is a useful case study of the impact that categorical regulation can have on innovation.

## THE NET NEUTRALITY REGULATION

Article 3 of Regulation (EU) 2015/2120 lays out both the basic net neutrality mandate as well as two key exceptions. The primary liability provision appears in Paragraph 3, which states: 'Providers of internet access services shall treat all traffic equally, when providing internet access services, without discrimination, restriction or interference, and irrespective of the sender and receiver, the content accessed or distributed, the applications or services used or provided, or the terminal equipment used.'

Paragraph 3 immediately qualifies that obligation with what is commonly known as the exception *for reasonable traffic management measures*. Paragraph 5 lays out an additional exception for 'services other than internet access services', commonly known as *specialised services*. Network slicing's ability to comply with the Regulation will likely turn on whether its architecture falls within one of these two exceptions.

Any future decisions about network slicing's compatibility with net neutrality will be informed by recent judicial decisions interpretating these provisions. In addition, the Body of European Regulators of Electronic Communications (BEREC) has issued Guidelines (in 2016, revised in 2020) offering an interpretation of the Regulation that have drawn praise from the European Union (Regulation (EU) 2018/1971, Para. 3) and of which the EU has directed Member States to take 'utmost account' (Directive (EU) 2018/1972, Art. 10(2)).

### REASONABLE TRAFFIC MANAGEMENT MEASURES

The provision recognising the exception for reasonable traffic management measures (Art. 3, Para. 3) specifies that to qualify as reasonable, 'such measures . . . shall not be based on commercial considerations but on objectively different technical quality of service (QoS) requirements of specific categories of traffic'. Recital 9 offers 'latency, jitter, packet loss, and bandwidth' as examples of objective technical QoS standards.

BEREC's interpretation of these provisions suggests that network slicing is unlikely to fall within the exception for reasonable traffic management measures. Paragraph 63, which addresses what constitutes objectively different technical QoS requirements of traffic categories, echoes the regulatory language by indicating that '[t]raffic categories should typically be defined based on QoS requirements', such as 'latency, jitter, packet loss, and bandwidth'. Paragraph 66 further provides that such objectively different categories of traffic 'refer[] to an application layer protocol or generic application types (such as file sharing, VoIP or instant messaging)'. The type of service differentiation imagined by network slicing does not define the services it offers in terms of QoS requirements or application protocols or types. Instead, it offers the services provided by individual elements of its infrastructure to individual customers. This illustrates how using past definitions of quality as the basis for determining the reasonableness of traffic management measures can create complications for new approaches that address quality in different ways.

BEREC's interpretation of what constitutes being based on commercial considerations is similarly prohibitive. As an initial matter, under the Guidelines, national regulatory authorities (NRAs) do not have to prove that a practice is based on commercial considerations; it is sufficient to show that they are not supported by technical justifications. Moreover, Paragraph 68 of the Guidelines provides that an 'obvious example' of a traffic management measure based on commercial grounds is 'where an ISP [Internet service provider] charges for usage of different traffic categories or where the traffic management measure reflects the commercial interests of an ISP that offers certain applications or partners with a provider of certain applications'. Network slicing clearly envisions charging for usage of different elements, and it certainly envisions offering different services to different applications and verticals. As a result, network slicing is unlikely to fit within BEREC's interpretation of what constitutes a reasonable traffic management measure.

Recent decisions by the European Court of Justice reinforce the conclusion that network slicing is unlikely to fall within this exception. The Court's 2020 *Telenor Magyarország* decision arose from Telenor's programmes that generally slowed down users' traffic once they exceeded their 1 GB data limit but subjected six chat, four music streaming, and six radio applications to a 'zero tariff' that did not deduct traffic to those applications from customers' data limits and did not slow down traffic to those applications after they had surpassed their 1 GB data limit. The Court held that providing more favourable treatment to the applications covered by these zero tariff programmes violated the Regulation's prohibition against discriminating among different types of traffic. In addition, the Court concluded that the unequal treatment provided by these programmes did not appear to be based on objective technical differences and thus regarded them as being based on commercial considerations. The fact that this programme was embodied in a user agreement as envisioned by Article 2 of the Regulation did not affect the analysis.

The European Court of Justice relied on *Telenor Magyarország* in three decisions issued on the same day in 2021 invalidating two zero tariff programmes operated by Vodafone and one offered by Telekom Deutschland. Courts in Germany, Spain, and Sweden have followed suit in their own enforcement actions against zero tariff packages. At the same time, a Dutch court upheld a zero tariff programme offered by T-Mobile that offered the same treatment to all music services (BEREC, 2021: 57–59).

These judicial decisions reinforce the idea that courts are likely to regard programmes that provide a higher level of services to specific users or applications without according the same benefits to all similarly situated users or applications as being based on commercial rather than objective technical criteria and therefore not constituting reasonable traffic management measures. The Dutch decision raises the possibility that programmes that offer the same benefits to all applications belonging to the same class of applications might comply with the Regulation. Such a programme would bear little resemblance to network slicing, which envisions providing enhanced services to specific customers for a fee rather than offering them to an entire applications class.

## SPECIALISED SERVICES

Paragraph 5 of the Regulation lays out the exception for what are commonly known as *specialised services*, describing them as services that 'are optimised for specific content, applications or services, or a combination thereof, where the optimisation is necessary in order to meet requirements of the content, applications or services for a specific level of quality'. The BEREC Guidelines cite voice over LTE (VoLTE), linear broadcasting Internet protocol television (IPTV) services with specific QoS requirements, M2M services, and corporate customers using business services as examples of specialised services. The provision creating the exception further specifies that specialised services 'shall not be a replacement for internet access services and shall not be to the detriment of the availability of general quality internet access services for end-users'. Recital 16 recognises that there is a demand for specialised services and calls on NRAs to ensure that they are 'objectively necessary' and do not 'simply . . . grant[] general priority over comparable content, applications or services available via the internet access service and thereby circumvent[] the provisions regarding traffic management measures applicable to internet access services'.

If construed strictly, the exception for specialised services may be hard to reconcile with network slicing. As an initial matter, because network slicing is designed as a general platform capable of providing advanced services to a wide range of use cases, it cannot be said to meet the Regulation's provision limiting specialised services to those 'optimised for specific content, applications or services'. The fact that this phrase is immediately followed by 'or a combination thereof' arguably creates some room for interpretation, although network slicing is better described as a general platform that can support an arbitrary range of applications than as one optimised to support a specific combination of applications. Indeed, construing the provision

Business customers are expected to serve as the primary source of revenue to recoup 5G investments

as encompassing any combination of applications would drain this limitation of all meaning.

Even more problematic is the provision requiring that any optimisation built into specialised services be 'objectively necessary' to 'meet requirements of the content, applications or services for a specific level of quality'. The BEREC Guidelines require that the levels of quality used to measure objective necessity be defined in terms of 'standard parameters, such as speed, latency, and jitter' or using 'other quality parameters in novel network paradigms' that reflect as resource constraints, including 'limited processing power, battery lifetime . . . memory capacity . . . interference and security'. While the embrace of a broader range of standards is an improvement over the parallel provisions contained in the exception for reasonable traffic management measures, it is not clear whether even this more flexible language is broad enough to characterise the services provided by network slicing. The fact that the Supreme Administrative Court of Austria ruled that a video-on-demand service prioritised in the Internet access service bandwidth lacked the technical justification for prioritisation (while upholding a live linear IPTV service that shared bandwidth with Internet access service bandwidth) reinforces the need for clear technical justifications using established criteria.

The BEREC Guidelines underscore the need for technical and not just business justifications when they note that specialised services are permissible only when an NRA determines that they 'require[] a level of quality that cannot be assured over an [Internet access service]'. At the same time, the Guidelines candidly recognise that specialised services and Internet access services are inherently linked when they note that specialised services can be provided either through 'dedicated connectivity' or 'through a connection that is logically separated from the traffic of the [Internet access service] in order to assure these levels of quality'. This logical separation 'could be provided with fixed or dynamic or without reservation capacity for [Internet access service] and specialised services'. When specialised and Internet access services share capacity, whether on a fixed or dynamic basis, it is 'technically impossible to provide the specialised service in parallel to [Internet access service] without detriment to the end-user's [Internet access service] quality'. The Guidelines address this problem by requiring that NRAs not regard such detriment as prohibitive when an individual end user's use of specialised services affects the quality of only their own Internet access service and does not affect other parts of the network. This effectively treats each user as if it existed in isolation, when the resource sharing inherent in the Internet means that each user's conduct affects the service received by others.

## ANALYSIS AND CONCLUSION

The tension between network slicing and the Regulation created to enforce net neutrality reveals two basic problems. Firstly, the Regulation is based on the paradigmatic assumption that the network on the one hand and the content and applications travelling over the network on the other hand are conceptually distinct. Although that was true for much of the Internet's history, network slicing is based on a different approach which envisions that applications will interact with the network by reconfiguring it to meet their particular needs. Such selective invocation of higher and lower levels of resources on a case-by-case basis can be hard to square with a mandate for categorical non-discrimination.

Any future decisions about network slicing's compatibility with net neutrality will be informed by recent judicial decisions

Even more problematic is the Regulation's attempt to treat commercial and technical considerations as mutually exclusive alternatives. This is most evident in the language laying out the exception for reasonable traffic management measures, which treats any measure not shown to be justified by technical QoS as being motivated by commercial considerations. It is also implicit in the distinction drawn by the exception for specialised services between measures that are objectively necessary to provide a given level of QoS (as measured by technical standards) and those that are motivated by other (presumably business) concerns. The flaw in this argument is that technical issues can always be reframed as commercial considerations. For example, instead of applying reasonable traffic management measures or creating specialised services, network providers always have the option of addressing congestion or poor QoS by investing in more capacity. However, adding more capacity is expensive and will eventually render providing the service uneconomical. What seem to be technical limitations from one perspective are thus necessarily ultimately based on commercial considerations from another point of view. Whether a justification is based on technical or commercial considerations is therefore best viewed as a matter of degree. While this is more correctly viewed as a balance, the Regulation instead treats this as a dichotomous choice that determines whether a particular practice, such as network slicing, is permissible, which in turn has significant policy implications for how far the 5G network will reach and how quickly it will be deployed. The Guidelines are more candid in their recognition of the shortcomings of the supposed dichotomy between specialised services and Internet access services but still resolve them in a way that downplays the importance of commercial realities.

These insights underscore the extent to which rules that are stated in overly categorical terms and that take a sceptical view of commercial considerations can run afoul of the dynamic changes and economic realities that surround the deployment of any new technology. In so doing, they underscore the wisdom of the competition law principle counselling that per se prohibitions are appropriate only when courts and enforcement authorities have sufficient experience with a practice to be able to predict with confidence that it is so harmful and lacking in redeeming virtue that little would be lost by prohibiting it without conducting a case-by-case analysis of its overall effects (Yoo, 2008: 246–247). The analysis of how categorical net neutrality rules can adversely affect the deployment of 5G and 6G through network slicing exposes the important dynamics underlying this admonition.

This analysis argues in favour of regulating new technologies through the approach reflected in modern competition law, which examines the effects of particular conduct and prohibits only that conduct that is shown to harm consumers. Conversely, it argues against categorically prescribing conduct whose impact is not well understood, a cautionary note that applies to the deployment of all new technologies and not just 5G and 6G.

## REFERENCES


### Legislation

Regulation (EU) 2015/2120, 2015 O.J. (L 310) 1. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2120.

Regulation (EU) 2018/1971, 2018 O.J. (L 321) 1. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1971.

Directive (EU) 2018/1972, 2018 O.J. (L 321) 36. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972.

### Judicial Decisions

Joined Cases C-807/18 and C-39/19, *Telenor Magyarország Zrt v. Nemzeti Média- és Hírközlési Hatóság Elnöke*, ECLI:EU:C:2020:078 (15 September 2020). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:62018CJ0807.

Case C-854/19, *Vodafone GmbH v. Bundesrepublik Deutschland*, EU:C:2021:675 (2 September 2021). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:62019CJ0854.

Case C-5/20, *Bundesverband der Verbraucherzentralen und Verbraucherverbände v. Vodafone GmbH*, EU:C:2021:676 (2 September 2021). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:62020CJ0005.

Case C-34/20, *Telekom Deutschland GmbH v Bundesrepublik Deutschland*, EU:C:2021:677 (2 September 2021). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:62020CJ0034.

Verwaltungsgerichtshof [VwGH] 16 November 2021, No. 2020/03/0017 (Austria), https://www.ris.bka.gv.at/Dokumente/Vwgh/JWT_2020030017_20211116J00/JWT_2020030017_20211116J00.pdf.

### Other

BEREC (Body of European Regulators of Electronic Communications). (2016). 'BEREC Guidelines on the Implementation of the Implementation by National Regulators of European Net Neutrality Rules'. BoR (16) 127. https://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/6160-berec-guidelines-on-the-implementation-b_0.pdf.

BEREC (Body of European Regulators of Electronic Communications). (2020). 'BEREC Guidelines on the Implementation of the Open Internet Regulation'. BoR (20) 112. https://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/9277-berec-guidelines-on-the-implementation-o_0.pdf.

BEREC (Body of European Regulators of Electronic Communications). (2021). 'BEREC Report on the implementation of Regulation (EU) 2015/2120 and BEREC Open Internet Guidelines 2021'. BoR (21) 119. https://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/10034-berec-report-on-the-implementation-of-re_0.pdf.

Yoo, C.S. (2008). 'Network Neutrality, Consumers, and Innovation'. *University of Chicago Legal Forum*, 2008(1), 179–262. https://chicagounbound.uchicago.edu/cgi/viewcontent.cgi?article=1426&context=uclf.

Yoo, C.S. & Lambert, J. (2019). '5G and Net Neutrality'. In G. Knieps & V. Stocker (eds), *The Future of the Internet: Innovation, Integration and Sustainability*. Baden-Baden: Nomos.

# 5G and AI Convergence, and the Challenge of Regulating Smart Contracts

## William Lehr

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**ABSTRACT**

**We are in the early stages of integrating the real and digital (virtual) worlds. In the next wave of automation, information and communications technologies (ICTs) will augment and substitute for human action in a growing range of tasks across all aspects of our social and economic lives. This depends on the convergence of two essential ICT developments that previously have proceeded along parallel but largely separate paths: (1) the realisation of sufficiently capable 5G networked ICTs, and (2) the availability of suitably 'smart' software applications (also known as artificial intelligence, or AI). 5G/AI convergence will depend critically on the progress of yet another cluster of technologies: smart contracts (SCs) and the blockchain and cryptocurrency technologies with which they are associated. To avoid losing control of the accelerating 5G/AI convergence, policymakers need to engage now in developing coherent and coordinated strategies for regulating SCs and their role in shaping the future of automation.**

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### INTRODUCTION

We are in the beginning stages of what some have described as the Fourth Industrial Revolution – the integration of information and communications technologies (ICTs) into all economic and social activities, signalling the convergence of the real and digital (virtual) worlds and the next wave of automation.[1] This will depend on the convergence of two essential ICT-related developments: (1) the realisation of sufficiently capable digital connectivity infrastructure (also known as 5G); and (2) the availability of suitably 'smart' software applications (also known as artificial intelligence or AI). 'Smart' here refers to augmenting economic processes (decision-making, production, distribution, etc.) with ICTs, and visions of the potential are often characterised as 'smart-X', where the X may be replaced with transport systems, power grids, healthcare, buildings, cities, supply chains, government, and so forth.[2] Moreover, as explained herein, the convergence of 5G and AI and the real/virtual world convergence that it will enable will depend critically on the progress of smart contracts (SCs) and the blockchain and cryptocurrency technologies with which SCs are closely associated. SCs are an ICT technology for automating the economic and legal functionality of business agreements or contracts and hence have wide applicability across all realms of economic and social activity.[3]

The hype version of this real/virtual world convergence is being variously characterised as the Metaverse or Web3.0. Both refer to different aspects of the future Internet: the Metaverse refers to the creation of virtual reality digital worlds that are potentially as rich as the physical world and may augment or substitute for physical world activities,[4] whereas Web3.0 focuses on an Internet that the cryptocurrency/blockchain/SC infrastructure developments hope to deliver.[5] Although these are separable but co-dependent technological and market developments,[6] collectively they contribute to the excessive exuberance that recalls the dot.com boom, when believers in the promise of the World Wide Web ('Web') had got too far over their skis relative to the readiness of business processes and mobile broadband, resulting in the tech-market crash in March 2000 that helped drive a global financial downturn.[7] Although investors threw money at lots of silly ideas during the dot.com bubble, the fundamental belief in the future of the broadband Web was not misplaced – it was only premature and depended on advances in complementary developments that a decade later enabled Web2.0 to be realised. Before the business-to-consumer services that many dot .com ventures sought to promote could be economically viable, lots of business-to-business back-end processes and broadband infrastructure needed to be in place. This included the rise of cloud computing and the digital platform providers that are now ascendant and attracting so much antitrust attention from policymakers in the United States and European Union.[8]

Similar lessons apply in order to realise the promise of either the Metaverse or Web3.0 – namely that lots of co-dependent innovations spanning the realms of technology, business processes (and market structures), and regulatory policies are needed before we will be able to realise the promise of real/virtual world convergence. It is also possible that early investors and others sucked in by the hype may suffer losses, but in the case of real/virtual world convergence, the stakes are much greater than an economic depression due to the collapse of a financial bubble. What is at stake is who will control the future global economy – will it be humans or machines? Will power be concentrated or more equitably distributed? Will there be order or chaos?

Thus far, the evolution of our digital connectivity infrastructure and AI have progressed along mostly separate paths. Herein, I use '5G' as shorthand for the horizon vision of pervasive computing infrastructure that will deliver *always/everywhere connectivity to digital computing, storage, and communications resources for everything on demand*. The ability to connect 'everything' enables the Internet of Things, while 'on-demand access to computing, storage, and communications resources everywhere' anticipates mobile edge computing (embedded processors) and robust cloud computing infrastructures. Obviously, in such a world, the capability to be continuously and ubiquitously connected will necessitate *choices* about what connectivity is desired in what circumstances, elevating concerns about privacy, security, and data access policies.

True 5G as envisioned by the International Telecommunication Union (ITU) in 2015 does not yet exist anywhere and much of what is needed is still in the process of being standardised.[9] Whereas the transition to 4G, which began in 2010 and was mostly complete in the US and Europe by 2020, represented a watershed event in the progress of mobile broadband, the prospects for 5G are much more incremental – at least currently. Although mobile technologies have progressed through numerous generations since the 1980s at roughly decade-long intervals, the reason 4G is characterised as a watershed event is because it represented the true realisation of mobile broadband, heralding the convergence for the first time of the Internet (mass market access to networked data communications and computing services) and personalised, everywhere connectivity (mobile telephony). Arguably, the smartphone revolution, launched by the iPhone (which was a 3G device in June 2007 that relied on

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Wi-Fi for Internet connectivity), represented the true watershed event, but such distinctions are not important here and only serve to highlight the fact that multiple complementary developments are jointly necessary for progress. When true 5G capabilities become available – enabling not just enhanced mobile broadband (eMBB), but also massive machine type communications (mMTC) and ultra-reliable and low-latency communications (URLLC) – we will be much closer to realising the vision of pervasive computing articulated above.

Although the envisioned horizon is still years away even in advanced markets such as Europe, today's mostly 4G world is sufficiently developed so that we may regard ourselves as at the end of the beginning of realising the digital connectivity infrastructure (or networked ICTs) needed to support the next stage in real/virtual world convergence.

### ARTIFICIAL INTELLIGENCE AND 5G ENABLING THE FOURTH INDUSTRIAL REVOLUTION

AI is the horizon vision for ICTs capable of human intelligence, which, if achieved, would likely result rapidly in the realisation of super intelligence (Bostrom, 2014; Harari, 2017). As 5G is the end of the process for creating *networked ICTs*, AI is the end of the process for the *softwarisation of ICTs*. And just as today's version of 5G only hints at the ultimate goal, so today's AI is far from being able to replicate human intelligence. Nevertheless, the maturation and commercialisation of core AI technologies such as machine learning (ML), computer vision, natural language processing, robotics, and recommendation applications demonstrates the extensive range of human tasks that software ICT applications are already or will soon be capable of *automating* (i.e., augmenting or substituting for human factors of production).[10] Indeed, Frey and Osborne (2017) conclude that upwards of 47 per cent of US employment is at risk of automation. Softwarisation is the process by which ICT functionality moves from hardware to software and, by so doing, realises the economic efficiency benefits of accelerated innovation, customisation, and modularisation, which collectively facilitate *virtualisation* (which facilitates the commoditisation of factor inputs, unbundling, fungibility, and re-composability).[11] Networking the software applications makes them much more usable in many more contexts. It enables *delocalisation*, or the unbundling of economic functionality and control based on 'location' (either in geographic space or context, where the latter may be in time or some other dimension).[12]

What is new in the Fourth Industrial Revolution is that 5G and AI have sufficiently evolved to vastly expand their applicability across all sectors and realms of human activity, to do so at an accelerated pace, and to potentially cut humans out of the loop in an ever-wider range of economic activity – that is, they enable automation that risks being out of human control.[13] Taking humans out of the control loop is essential in some situations where human capabilities for real-time responsiveness are too limited (e.g., controlling uninhabited aerial vehicles, responding to cyberattacks). More generally, much of the process of automation has substituted ICTs for other forms of capital in production processes because the quality-adjusted cost of using ICTs is lower and substituting ICTs for human tasks results in productivity gains. These occur because robots are less expensive than human labour inputs, they offer improved reliability, and they facilitate the realisation of scale/scope economies via virtualisation and delocalisation. However, although such automation may be economically efficient, most of it is not essential. Human control is maintained by shifting it to another level (e.g., the design of the control software and the decision to launch the applications), but those stopgaps may be bypassed as the control systems and decision-making that govern their design may be automated, capabilities that general-knowledge, learning-enabled AI may become capable of in the not-too-distant future.

Realisation of only one of the visions would significantly reduce the transformative capability of the other.[14] The potential for both visions to now combine and merge is why some refer to this as the Fourth Industrial Revolution, even if the process for the Third Industrial Revolution remains a work in progress, as noted above. It is already the case that many economic activities are heavily automated and significantly under the control of software applications – and, in a rapidly growing range of business contexts, under the control of AI systems – but the ultimate control remains in human hands. The AI and other ICT automation (e.g., computer-controlled machines and robots) are not networked and capable of autonomous decision-making *yet*, and even when networked, their reach is limited by firewalls, sandboxes, and the limits of today's 5G infrastructure. Indeed, as the capabilities of our networked, softwarised ICTs improve and grow ever more complex, we find ourselves needing to rely on AI techniques to design and manage those applications. Although the focus here is on what the convergence of AI and 5G imply for the global economy, the progress of 5G itself depends on AI.[15]

## SMART CONTRACTS AS KEY ENABLING TECHNOLOGIES

Where do SCs (and blockchain and cryptocurrencies,[16] or Web3.0) fit into all this? They are key enabling technologies that have the potential to greatly accelerate the real/virtual world convergence enabled by the convergence of AI and 5G since SCs facilitate the linking and automated control of distributed, semi-autonomous ICT systems. And, by virtue of their design, control of the resulting complex systems may be decentralised, distributed, and potentially anonymous. For those concerned about the concentrated economic power of digital platform providers, pesky government regulators, or other transaction-cost-causing intermediaries, the potential for SCs to bypass those intermediaries is one of their key attractions. Of course, those same capabilities pose the risk of the loss of human control (or, if not human control, control by our designated regulatory authorities).

Although there are many good things that SCs can facilitate, much of the current demand driving volatile cryptocurrency valuations depends on grey (if not criminal) market activity, and many cybercrime exploits (fraud, data breaches, ransomware, etc.) can take advantage of SC tools.[17] Regulatory authorities are scrambling to put in place adequate policy frameworks to address the challenges posed by AI,[18] and more belatedly by SCs. With respect to the latter, much of the regulatory focus has been on fintech regulation of cryptocurrencies, but the current policy debates can best be characterised as chaotic.[19] On one side are proponents of the technology who generally favour more laissez-faire policies to avoid stifling key enabling technologies; on the other are those concerned with ensuring financial stability and fighting criminal activity (e.g., money laundering, fraud, terrorism, and other illegal activities); and in the middle are the vast majority of interested stakeholders (including the author of this chapter) who have yet to formulate firm ideas as to what ought to be done.

The multidisciplinary engagement of legal scholars, economists, technologists, and others on better understanding the potential role of SCs as a form of gate-keeping technology will have to be accelerated. How SCs evolve will influence our options for governing the future converged virtual/real digital economy that AI advances have the potential to deliver. Economists have already highlighted the huge potential for AI to deliver significant benefits in productivity enhancements, but also with potentially large disruption costs and uncertain implications for equity.[20] SCs are neither 'smart' nor true contracts; however, they provide a mechanism for tying together the many semi-autonomous ICT systems already deployed throughout our economy and in so doing automate larger-system interactions whose emergent properties and system-wide implications we are not well positioned to anticipate or respond to.[21] The linking of semi-autonomous ICT systems is not new, but the potential for SCs to vastly expand those capabilities and/or to serve as the digital-world framework for managing those linkages makes SCs both necessary and important topics for focused attention.

## POLICY CHALLENGES AND RECOMMENDATIONS

What are some SC-relevant topics that policymakers ought to be preparing themselves for? The list is long, so in the following, the discussion will focus on a few areas that are expected to be especially important in governing the future of SCs.

*Regulatory oversight balance*: closing the floodgates is not an option. For one thing, there is too much needed value that virtual/real world convergence promises and too much (uncertain) innovation needed, so we do not want to foreclose important developments. For example, solving the global need to shift to more sustainable renewable power sources to address climate change will not be possible without more of the promised ICT advances. At the same time, a laissez-faire attitude is also inappropriate. Scholars as varied as Harari (2017), a historian; Bostrom (2014), a philosopher; Kahneman et al (2021), a psychologist; and Acemoglu (2021), an economist, have pointed out the important role that policy (laws, regulations, norms) may play in determining which future we realise. Existing regulatory institutions need to build capacity to understand and consider the role they should play in regulating SCs and the emerging world. Ultimately, this will be a global challenge and will depend heavily on the technical architectural choices, and hence the technical standards, that are adopted. Although there is a role for formal international governance bodies (such as the ITU), the inherent challenges associated with international governance coupled to recognition of realpolitik issues means that most of the effective governance will need to rely on markets and less formal coordination mechanisms such as those that currently govern the Internet.

*Disclosure/transparency and measurement policies*: effective governance of future developments, which, as argued above, must depend mostly on market-based coordination (rather than government command and control regulation), depends on stakeholders having the information they need to make good decisions. In a fast-moving, globally connected economy confronting significant uncertainty, collecting the right information and sharing it appropriately presents a critical and difficult challenge. Luckily, the convergence of AI and 5G provide powerful tools that can be used to collect and process that information, but the design of those systems will be complex. Sharing too much information threatens privacy, strategic interests, and security and so is neither incentive-compatible nor desirable. We need to build an ecosystem to collect

> What is at stake is who will control the future global economy – will it be humans or machines?

and share information on SCs and related developments that will include a mix of mandatory reporting requirements, but that will also rely on multiple parties and the markets themselves to reveal much of the relevant information. Fintech regulation of SCs was identified as an early flashpoint for attention. This is illustrative of the difficult challenges that need to be confronted.

*Open software and interfaces*: to minimise the likelihood of being locked into a path-dependent trajectory to an undesirable future as a consequence of early innovation decisions, it is important that the right interfaces and key open software components are available so that the benefits of the emerging future may be shared and the realisation of the Web3.0 future does not result in further concentration of economic control and power. Where these should be and how they may best be developed and implemented is first a technical architecture question, but one akin to the challenges addressed in the evolving governance of the Internet, which provides both useful and cautionary guidance for how to approach the Web3.0 global governance challenge.

*Intellectual property rights*: it is already clear to many that the digital economy future enabled by the AI/5G convergence has the potential to shift economic value from physical resources (labour, capital) to knowledge (information). A threat of ICTs is that the economic changes they enable can lead to winner-take-all economics (scale and scope economies, first-mover advantages, asymmetric information advantages, etc.). However, software may be easily replicated and shared at low incremental cost, raising the potential for realising redistributive goals. (Although the potential for rapid innovation and leap-frogging also has the potential to result in dynamic instability and magnified adjustment costs as stakeholders continuously compete with leap-frogging technologies.) Intellectual property rights (patents, copyright, trade secrets) are key policy frameworks that will have an impact on how incentives to invest in AI/5G innovations and how the benefits may be shared across time and across markets.[22]

## CONCLUSIONS

The above comments on policy are both high-level and abstract. Fleshing them out further will require substantial additional work across multiple regulatory/policy domains, but those are topics for a longer discussion. The COVID-19 pandemic has added a new urgency to addressing these issues because it demonstrated just how important our digital connectivity infrastructure is, but also that further improvements are necessary.[23] A key question confronting policymakers is how far (and with what urgency) to progress towards realising the 5G pervasive computing vision. The technologists can deliver the networked ICT capabilities to enable pervasive computing, but there have to be software applications satisfying real-world demands that require those 5G capabilities to justify the continued investment. AI provides those software applications and can lower adoption costs, helping to drive demand for ever-improving networked ICTs while also making it technically feasible to realise the 5G vision. Thus, there are important reciprocal positive feedback loops pushing for the convergence and continued evolution of 5G and AI. The pace of technical innovation in 5G, AI, and SC is accelerating, driven both by awakening market forces and by the capabilities that each contributes to the convergence. Although the need for coordination across these realms and the policy issues they engage is growing, achieving the necessary coordination and avoiding lock-in to an ill-chosen path may grow

> The capability to be continuously and ubiquitously connected will necessitate *choices*

**more difficult as the convergence proceeds. To avoid losing control of the accelerating 5G/AI convergence, we need to engage now.**

**NOTES**

**1**. The term was coined by Klaus Schwab, founder of the World Economic Forum, in 2016 (Schwab, 2016).

**2**. Although AI is the long-term focus, the comments here are not limited to ICT systems that employ AI. Indeed, most of the ICT is not (yet) AI-dependent or enabled.

**3**. Smart contracts are often defined as self-executing contracts on a blockchain; blockchains are a network mechanism for maintaining a distributed and immutable ledger database for recording transactions and tracking assets among anonymous agents. The blockchain protocol was created to support the cryptocurrency Bitcoin in Nakamoto (2008). Although Bitcoin remains the most widely used cryptocurrency, there are over 16,000 cryptocurrencies being traded today with a total market capitalisation of close to $2 trillion (see https://coinmarketcap.com/all/views/all/). Blockchain, cryptocurrencies, and SCs are all independent and separable concepts, as explained in Lehr (2021), although much of the energy propelling their development today ties them closely together. Herein, SCs will be used as shorthand for all three developments.

**4**. The 'Metaverse' as a rich virtual reality world represents an evolution and convergence of VR/AR systems (see, e.g., Chen, 2022). Facebook rebranded itself as 'Meta' in October 2021 (https://about.fb.com/news/2021/10/facebook-company-is-now-meta/), with the plan 'to bring the metaverse to life and help people connect, find communities and grow businesses' with a much more immersive Internet capable of interacting with the physical world in much richer and seamless ways.

**5**. For those hyping the Web3.0 vision, it will distribute and decentralise economic control (of value and decision-making) back towards end users, enabling competitive alternatives to the centralised concentration of economic control vested in today's Web2.0 digital platform providers. From the landing page for the Web3 foundation, their mission is to deliver a 'decentralised and fair internet where users control their own data, identity and destiny' (see https://web3.foundation/about/). One of the leaders of the Web3 effort is Gavin Wood, co-founder of the Ethereum Smart Contract platform.

**6**. Although I expect the growth of the Metaverse and Web3.0 to be mutually re-enforcing in the near term, that may not remain true in the future. My focus here will be on Web3.0, summarised as SC (see Lehr, 2021).

**7**. The dot.com boom, or as some refer to it, the dot.com bubble, is associated with the rise in the stock market values of Internet technology and Web company stocks from the initial public offering by Netscape in 1995 to when the NASDAQ peaked in March 2000 and then crashed (see Quinn & Turner, 2020).

**8**. Google, Amazon, Facebook, Apple, Microsoft (sometimes referred to as 'GAFAM') each operate ecosystems of platforms with global footprints (see Lehr et al., 2019). As will be discussed further below, SCs are seen by some as a potential solution to the market power threat posed by today's dominant platform providers and as a way to decentralize economic power and enable greater inclusive participation in the digital economy (see Schrepel & Buterin, 2020).

**9**. See ITU (2015), Lehr (2019), Lehr, Queder, and Haucap (2021), and Oughton et al. (2021) for a discussion of the progress of 5G.

**10**. To see what leading economists have to say about the economic implications of AI, see, for example, Goldfarb, Gans, and Agrawal (2019).

**11**. Software virtualisation allows ICT resources to be shared and thus heterogeneous resources to be combined (e.g., spectrum aggregation) or partitioned (e.g., 5G slicing) to provide customised quality of service on demand.

**12**. For example, the rise of software switching enabled delocalisation of telephone switching, which facilitated the realisation of scale and scope economies.

**13**. The First Industrial Revolution was associated with the emergence of machine power (steam engines) in the eighteenth century, while the Second Industrial Revolution involved the expansion of networks (railroads, telegraph, and electricity) in the nineteenth. The Third Industrial Revolution began in the twentieth century with the rise of digital computing. This is the continuation of the process of automation.

**14**. That is, super-intelligent AI is more able to have an impact on human economic activity when combined with rich digital connectivity, and the ability of rich digital connectivity to bypass direct human controls is much less likely in a world without AI.

**15**. Numerous authors point to the many ways in which AI is critical to the realisation of the 5G vision (see, e.g., Cayamcela & Lim, 2018; Dogra, Jha, & Jain, 2020; Qiao et al., 2021; You et al., 2019). In addition to AI, numerous scholars have been investigating the application of Smart Contract technologies for managing 5G, including spectrum sharing (see Nguyen et al., 2020; Weiss et al., 2019; Zhou et al., 2020). And finally, the launch of the Helium Blockchain to support decentralised wireless infrastructure provides a real-world example of how these technologies are already finding a home in the wireless ecosystem (see https://www.helium.com). The Helium project was founded in 2013, with Sean Fanning – of Napster fame – as one of the founders.

**16**. To understand how blockchain, cryptocurrencies, and SCs relate to each other, see Lehr (2021) and note 3 in this chapter.
**17**. Although SCs can assist in multiple aspects of criminal activity, a key attraction is the potential to use SCs for laundering money from criminal activity.
**18**. The European Commission's efforts to promulgate a regulatory framework for AI in advance of its realisation should be applauded; however, I am sceptical of the efficacy of the proposed framework (see https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai, accessed 6 February 2022). It seeks to implement a risk-based approach to categorising AI systems into various levels of riskiness. The problem with that approach is the risk of today's low-risk applications being turned into high-risk challenges, which in the absence of strong global cooperation will be difficult to stop. AI software, and especially SCs, are not easy to contain within sovereign boundaries.
**19**. In the US, regulatory authorities across the political spectrum (municipal, state, federal, and across the multitude of agencies with responsibility for financial regulations) are promoting diverse and mostly uncoordinated initiatives for regulating cryptocurrencies. The pace is rapid but the direction is chaotic. For a group of academics' review of one type of SC-enabled fintech innovation, initial coin offerings, and the current chaotic status of regulatory readiness, see Cohney et al. (2019).
**20**. As already identified in a previous note, see Goldfarb, Gans, and Agrawal (2019) for a collection of essays by leading economists focusing on many of the economic implications of AI. The potential for AI to enable ICT substitution for labour factor inputs may reduce employment and wages and result in skill-biased transformations across multiple sectors and countries, which could contribute to increased wealth concentration and widening disparities, with especially harsh implications for less skilled, lower-income workers in the absence of proactive policies to address such challenges (e.g., re-skilling education, enhanced safety nets, and other policies to smooth and reduce the impact of dynamic adjustment costs).
**21**. It should be clear that the vast majority of the semi-autonomous ICT systems enabling automation that are already deployed and will be deployed in the near future are *not* AI systems or AI dependent, just as the 'smart' in 'smart-X' (see note 2 in this chapter) is more a future goal than today's reality. However, the fact that SCs (whether on blockchains or otherwise) may tie together ICT systems (whether AI or otherwise) should not make us complacent regarding the risks we confront. ICT software techniques, once realised, may be implemented in many ways, and once AI is added to the picture, the ICTs may be capable of autonomous learning and enhancement.
**22**. Which may be threatened by excessive disclosure policies.
**23**. The ability to shift economic activity from physical to virtual engagement during the COVID-19 pandemic helped to sustain it during the lockdown, resulting in a step-change increase in social and business use of broadband-enabled, networked ICTs. However, availability, accessibility, and usability of these capabilities varied significantly across countries, markets, and jobs.

## REFERENCES


Acemoglu, D. (2021). 'Harms of AI'. National Bureau of Economic Research (NBER), Working Paper 29247, September. http://www.nber.org/papers/w29247.

Bostrom, N. (2014). *Superintelligence: Paths, Strategies, Dangers*. Oxford: Oxford University Press.

Cayamcela, M. & Lim, W. (2018). 'Artificial Intelligence in 5G Technology: A Survey'. In IEEE 2018 International Conference on Information and Communication Technology Convergence (ICTC), 17–19 October 2018, Jeju, Korea, pp. 860–865, doi: 10.1109/ICTC.2018.8539642.

Chen, B. (2022). 'What's All the Hype About the Metaverse?' *New York Times*, 18 January. https://www.nytimes.com/2022/01/18/technology/personaltech/metaverse-gaming-definition.html.

Cohney, S., Hoffman, D., Sklaroff, J., & Wishnick, D. (2019). 'Coin-Operated Capitalism'. *Columbia Law Review*, 119(3), 591–676.

Dogra, A., Jha, R., & Jain, S. (2020). 'A Survey on Beyond 5G Network with the Advent of 6G: Architecture and Emerging Technologies'. *IEEE Access*, *9*, 67512–67547.

Frey, C.B. & Osborne, M.A. (2017). 'The Future of Employment: How Susceptible Are Jobs to Computerisation?' *Technological Forecasting and Social Change*, 114, 254–280.

Goldfarb, A., Gans, J., & Agrawal, A. (eds.). (2019). *The Economics of Artificial Intelligence: An Agenda*. Chicago, IL: University of Chicago Press.

Harari, Y. (2017). 'Reboot for the AI Revolution'. *Nature*, 550, 324–327. https://doi.org/10.1038/550324a.

ITU (International Telecommunication Union). (2015). 'IMT Vision: Framework and Overall Objectives of the Future Development of IMT for 2020 and Beyond'. Recommendation ITU-R M.2083-0. https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf.

Kahneman, D., Sibony, O., Sunstein, C. (2021), *Noise: A Flaw in Human Judgment,* Little, Brown: New York, 2021.

Lehr, W. (2019). '5G and the Future of Broadband'. In G. Kneips & V. Stocker (eds.), *The Future of the Internet: Innovation, Integration, and Sustainability*. Baden-Baden: Nomos.

Lehr, W. (2021). 'Smart Contracts, Real–Virtual World Convergence and Economic Implications'. Paper presented at TPRC49: Policy Research Conference on

Communications, Information and the Internet, Washington, DC, September. https://ssrn.com/abstract=3898144.
Lehr, W., Clark, D., Bauer, S., & Claffy, K. (2019). 'Regulation When Platforms Are Layered'. Paper presented at TPRC47: Research Conference on Communications, Information and Internet Policy, Washington, DC, September. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3427499.
Lehr, W., Queder, F., & Haucap, J. (2021). '5G: A New Future for Mobile Network Operators, or Not?' *Telecommunications Policy*, 45(3), 102086. https://doi.org/10.1016/j.telpol.2020.102086.
Nakamoto, S. (2008). 'Bitcoin: A Peer-to-Peer Electronic Cash System'. White Paper. https://bitcoin.org/bitcoin.pdf.
Nguyen, D.C., Pathirana, P.N., Ding, M., & Seneviratne, A. (2020). 'Blockchain for 5G and Beyond Networks: A State of the Art Survey'. *Journal of Network and Computer Applications*, 166, 102693.
Oughton, E., Lehr, W., Katsaros, K., Selinis, I., Bubley, D., & Kusuma, J. (2021). 'Revisiting Wireless Internet Connectivity: 5G vs. Wi-Fi 6'. *Telecommunications Policy*, 45, 102127. https://authors.elsevier.com/sd/article/S0308-5961(21)00032-X.
Qiao, L., Li, Y., Chen, D., Serikawa, S., Guizani, M., L. Yujie (2021) 'A Survey on 5G/6G, AI, and Robotics'. *Computers & Electrical Engineering*, 95 (2021) 107372.
Quinn, W. & Turner, J. (2020). 'The Dot-Com Bubble'. In J. Turner & W. Quinn, *Boom and Bust: A Global History of Financial Bubbles*, pp. 152–169. Cambridge: Cambridge University Press. https://doi.org/10.1017/9781108367677.009.
Schrepel, T. & Buterin, V. (2020). 'Blockchain Code as Antitrust'. *Berkeley Technology Law Journal*, 18 May. https://ssrn.com/abstract=3597399.
Schwab, K. (2016). 'The Fourth Industrial Revolution: What It Means, How to Respond'. World Economic Forum, 14 January. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/.
Weiss, M., Werbach, K., Sicker, D., Bastidas, C., & Caicedo, C. (2019). 'On the Application of Blockchains to Spectrum Management'. *IEEE Transactions on Cognitive Communications and Networking*, 5(2), 193–205.
You, X., Zhang, C., Tan, X., Jin, S., & Wu, H. (2019). 'AI for 5G: Research Directions and Paradigms'. *Science China Information Sciences*, 62(2), 1–13.
Zhou, Z., Chen, X., Zhang, Y., & Mumtaz, S. (2020). 'Blockchain-Empowered Secure Spectrum Sharing for 5G Heterogeneous Networks'. *IEEE Network* 34(1), 24–31.

# 6G Means Redesigning Mobile Software Architecture for an Insecure World: Replacing the WWW and the Internet

Simon Forge

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**ABSTRACT**

**The mobile cellular technologies that lie behind LTE-A-Pro and 5G NR networks promise both significant risks as well as potential rewards. These trends drive the need to dispel cybersecurity risks, especially those of 5G. To respond adequately, we need novel trust models to implement much enhanced security paradigms for mobile networks. These measures should cover threats to our physical infrastructure and our personal lives – because mobile will be the most vulnerable of our future core critical infrastructures unless 6G can provide adequate security. This conclusion calls for radical measures, departing from much of today's online technologies.**

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## 1. WHERE ARE WE TODAY IN OUR ONLINE MOBILE WORLD?

As *The Economist* noted, there were two pandemics in 2021 that worsened in 2022: COVID-19 and cybercrime (Joshi, 2022). In reply to the cybercrime menace, we need to rethink our porous, unsafe online technology. Consequently, 6G must be designed as a quite different mobile technology from previous generations in its goals, responsibilities, and choice of technologies. It must fit the key problems of the decades to come and not just be a technology upgrade to 'churn the market'; it must solve the problems of society and so serve the market and its socio-economic environment up to 2050.

Its potential lies as much in social and political significance as in purely economic impacts. This is because mobile media have now become the preferred channel for news, 'nudging', and political orientation, as well as social attacks, to a degree unseen before, that affect the public sense of security and even the mental health of victims. Current mobile generations, especially since the move to native Internet use from 2007, have become host to numerous security hazards, ranging from identity theft to industrial and military espionage, from child pornography to money laundering and ransoming critical infrastructures, including energy distribution and national-scale medical care systems.

Consequently, the choices made in the design of a 6G architecture and its technology decisions can no longer be left to the supply side. Note that 5G rollouts in EU Members States (MS) have been under investigation by the European Court of Auditors (ECA, 2022) due to their cybersecurity risks for the EU economy and its citizens.

6G must be designed differently from previous generations in its goals, responsibilities, and choice of technologies

To support this, the choices made for 6G in terms of content and structure should follow (and form part of) the EU social and economic policy agenda for the long term and not be left to engineering and supply side interests. 6G cannot be a rapid fix: development time scales for 6G are perhaps five to ten years, for a potential 15–20-year operational life, at least. After all, GSM (2G), which first went live in Finland in 1991, is still used globally and in many EU MS, including Finland. Understanding the socio-economic design factors will assist in the creation of a secure mobile environment, as the scale of the security problem faced with LTE-A and 5G today continues to escalate.

### 1.1 The lack of security in the online world – and the rise of cyber criminality

The summit between Joe Biden and Vladimir Putin in June 2021 was dominated by accusations over cybersecurity attacks by state organisations on the United States' critical infrastructure and confidential data – commercial, consumer, and military. Cybercrime has now been repositioned by the military as a form of cyberwarfare, as occurred in Ukraine in January and February 2022 or against EU MS, as a way of disrupting critical infrastructure and the digital machinery of government.

The major cybercrime attacks in 2021 included one against one of the most frequently used software utility suites in the world – SolarWinds – and, more embarrassingly for the US, that software is the basis of much government network management and its programming. The software is difficult to exhaustively validate for safe operation. Unfortunately it is typical of much large-scale software today, be it commercial or government – the security of complex software is increasingly difficult to protect (Industrial Software, 2021).[1] Moreover, spyware attacks at strategic levels multiplied in 2021, especially via mobile handsets, with fatal results, as the NSO Pegasus affair has demonstrated across the Middle East and many other countries, such as France and other EU MS.

Ransomware attacks on critical infrastructures were a major feature of 2021 (such as those against the Colonial Pipeline, the largest hydrocarbon network on the US East Coast; in another first, a ransom attack shut down the United States' largest meat processor's plants). The Department of Homeland Security puts the US ransom damages in the hundreds of billions of dollars for 2021 (Joshi, 2022). In the EU, Ireland's healthcare system suffered similarly from ransom attacks. Moreover, the Internet is sufficiently opaque that its dark side can supply ransomware for hire. All of this is opening up a new insurance market for cyber-ransom, which looks forward to peak premiums in 2022. Future attack targets expected in 2022 may include contaminating or disrupting water supplies via their control systems, for which much of the industry is unprepared (Washington Post, 2022), the impact of which could be as great as that of the pandemic if not prevented.

### 1.2 What is the real problem?

In essence, the combination of the current Internet and Web technology is becoming an economic chasm into which global wealth is being poured. That is driving all major states in the West to respond to the financial disruption with greater Internet, Web, and application system security defences in software and hardware. At state level these must be augmented with offensive capability to have any effect in real terms, as part of the national military infrastructure. Thus while the developed world is moving its economies to the Internet and the Web, it is not recognising the significant risk exposure involved. A symptom of this is today's massive increase in spending on Web security software and hardware, while cybercrime continues to accelerate. As in the war on drugs, spending on policing has increased yearly – but the increase in drug profits is orders of magnitude larger, which is the same with online fraud. Escalating online banking and financial fraud is becoming the most common crime against the citizen in some OECD countries.[2]

Looking longer term at the global-level threats, two major types of macroeconomic threat can be discerned in the future that use the Web/Internet combination as the attack vector for mobile radio and fixed line networks. The first is a sudden destructive attack on high-value assets and critical infrastructures to sew chaos and test boundaries of response, as well as for ransom attacks and financial theft from institutions, enterprises, and individuals, sometimes using state-sponsored criminal groups. The second is the covert penetration of military and confidential business systems for industrial espionage to progress the high-technology economy and armaments of the attacking country over the long term.

Both may use mobile networks as part of sophisticated attacks involving phishing and eavesdropping. And today, both use the Web (the human interface for operations) combined with the Internet (for network communications). In some ways the Western developed economies may be their own worst enemies in not reinforcing their information networks because most governments underestimate the real threats, especially from mobile. However, the EU has been examining the security levels of 5G. The European Court of Auditors has noted major problems in a series of reports: the first to be published highlights the initial problems with 5G networks across the Member States (ECA, 2022).[3]

Today there is heavy pressure to roll out 5G (as 5G NR, or 'New Radio'), the latest version of mobile, with its move to higher frequencies to obtain wider bandwidth for its target of broadband services, largely for streaming video entertainment and social networking chat services. With widespread ignorance of the high levels of risk to ordinary online business and the everyday transactions of consumers, there is a need to compensate for the innate vulnerability of the Internet and the World Wide Web (WWW). They are fundamentally weak in their security engineering yet are our sole online infrastructure. Therefore, to a large extent, 6G is defined by the gaps in 5G due to its Internet/WWW dependence and the general progression of dependence on mobile, now essential to our existence. These high security needs define just what is 6G. In addition, 6G must integrate newer developments, such as re-engineering mobile for much higher sustainability with integration into the low earth orbit (LEO) space segment.

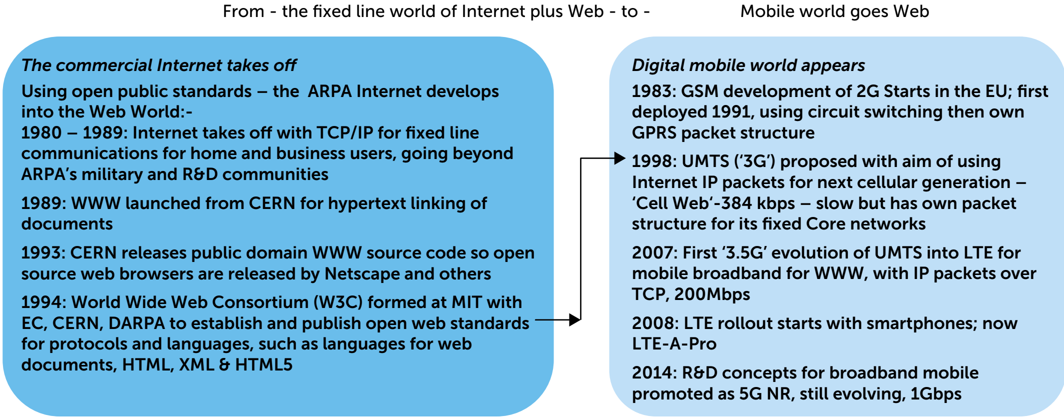
## 2. THE KEY PROBLEM OF THE WWW WITH THE INTERNET

However, there are complications. When we come to examine today's mobile technology and its relation to the pervasive insecurities of the Internet and the Web, just how we can improve the situation is unclear. Figure 1 outlines the unbreakable historical link between the latest mobile generations (LTE-A and 5G NR) and the Internet and WWW, which are the basis of today's mobile infrastructure.

### 2.1 Just why is Internet and Web technology a problem? We have used both together for over 30 years

The key problem of mobile security in the use of Internet and Web technology is that security was not considered as a factor. The fundamental

FIGURE 1: **The melding of the Internet, the Web, and mobile technology – the latest mobile technologies use Internet and Web technologies in the raw**




architectural principles were conceived and embedded from the 1960s to the late 1980s – 40 years ago for the Internet and 30 years ago for the Web. Neither architecture was designed with criminal attacks and exploitation as their most likely possible future.

Instead, both were conceived for a very different and fairly closed user group compared with today's open global population of users. Accordingly, great levels of trust were assumed for what was effectively then a privileged elite, so a system without any thought (or hope) of adequate safeguards was engineered.

The general public were essentially excluded from the core user group at that time because they had little or no technical knowledge of digital networks, which were not so user friendly then. In addition, the relatively high cost barriers for access acted as a further obstacle. Although open to anyone in theory by the late 1980s, in reality access was only available to those with the means and knowledge to connect – mostly the government/ university/ industrial research community. Consequently, the Internet and then the Web were designed for this trusted elite community of fairly high-security users who communicated via files and email in a fairly free manner. Dangers of monetary deception through consumer shopping fraud, e-banking with large-scale e-commerce scams, and business systems capture for ransom were yet to develop. Thus, a mandatory level of minimal security was effectually non-existent, perhaps comprising some simple passwords. Delegation of secure status via hierarchies, with federation, to share trusted status became common in the 1990s and 2000s.

The real ease of disrupting the Internet and its improved human interface, the Web, by modifying code or finding backdoors to steal information or breach confidential data and code was not recognised as a problem at the time because the computing experts in the closed community were unlikely to act in criminal ways. A RAND sociological study on the use of email in 1995 by the wider community only saw its advantages (Bikson et al., 1995). The study identified users then as an information elite, those with the knowledge and funds to access Internet services, and the research sought to widen that community. The idea of email acting as a scam vector through phishing was undreamt of, as was the notion of online banking fraud or identity theft. Thus, security was never built into an architecture originally designed for openess, nor to the applications that ran over it. As a result, today, anyone can join – anonymously – and access anything from anywhere, often far from where the routing coordinates may indicate.

Moreover, governments did not recognise the dangers to users – that connecting to the Internet and the Web, as well as into their own networked systems, makes them extremely vulnerable, and also that the data and exploits (such as extracting ransoms) would become of the highest value to criminal groups. Criminal groups now see the Internet/ Web as their major revenue source, because, for instance, they can extort ransom from a whole regional hospital administration. Governments have recently, but much too slowly, come to see it as the main espionage channel. And that access is increasingly centred on mobile devices – through the smartphone, with some extensions into the radio access network (the RAN) with false base stations (termed stingrays in the US).

The gap between the technical know-how of the average citizen and the need for self-protection has never been adequately admitted. Internet and Web security technology – such as anti-spoofing for addresses, or rejection of downloaded malicious code, such as key loggers, or underlying safeguards on naming and addressing – was not built into the foundations of Internet and Web architecture. The weak additions that were made afterwards therefore sit on top of the network architecture, while the foundations are left porous and unsafe.

The result is that anyone, anywhere, globally can enter the Web and even attack the Internet infrastructure. An individual can pretend to be someone else, behave in any way, and find ways, sometimes quite easily, to enter any website, any smartphone, any PC. Thus, intruders fake email sources; insert malicious code or data on smartphones, PCs or servers; eavesdrop (sometimes with fatal results) and steal financial details; and even steal personal identities or set up false e-commerce sites to take payments, a favourite in Europe, especially for banks and utilities scams. The latter exploits show the entry of professionals to take this attack far further as the rewards are becoming higher every day, as more business moves online and more interaction is via mobile, whether via local WiFi or over the air (OTA) mobile Web connections.

Social crimes are multiplying. With the merging of today's mobile world with the online world, total privacy invasion is enabled for crimes of racial abuse and criminal exploitation of underage users. All the above implies that the Internet itself, and the human interface via the Web, will need to be replaced for the next mobile generation, as soon as possible.

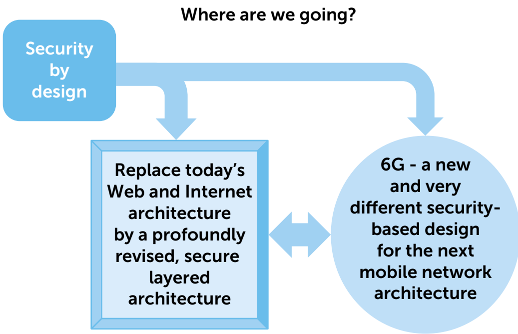
### 3. THERE IS A KEY QUESTION TO BE ANSWERED IF WE ARE TO ESCAPE FROM THE GROWING CYCLES OF CYBERCRIME AND MOUNTING THREATS IN CYBERWARFARE AND TO PERSONAL PRIVACY

But just what do we replace today's Internet and Web with? The new user environment (and its underlying packet network infrastructure) should be aimed at mobile as fixed line communications is to become less important than mobile for the 7 billion users. Effectively mobile becomes the predominant end point for broadband service globally. The future world communication system will be a mobile world, even more than it is today – but only if broadband penetration of dwellings and offices can be successfully engineered.

Building a secure mobile online networked system is an enormous task and will not be easy, nor will it be done rapidly. It may take a decade but probably longer, and migration to it may be slow at first. However, it is critical for an economy and society that will rely on a radio-based networked environment. Moreover, there are several key advances that require further architectural development for an acceptable mobile radio technology for 2050. These should be considered in parallel with the underlying security needs:

- *The environmental impact of telecommunications networks*: The carbon footprint of the telecommunications industry is not negligible – perhaps 2 per cent of all energy used and so at the level of the airline industry.[4] But the problems are diffuse and vary from the energy budget of smartphones – and their lifecycle cost – to the environmental budget for an online search over the network into a cloud data centre, as well as software energy cost of each process for advertising, with its

FIGURE 2: **The way forward in outline – a secure mobile multimedia environment**




consumer profiling and display programme. The basic engineering of the network in spectrum terms also has major environmental impacts. The density of a network for 5G in the upper mmWave bands may have a thousand times the density of base stations in the lower UHF range. That implies far higher power density and proportionally greater total network carbon footprint, both for construction and for use over its lifecycle.

- *The mobile space segment*: The arrival of communications links, both long distance and local via LEO satellites for a space segment that can host a global network, will be important for the vast spaces with no fixed infrastructure in Africa, the Middle East, and Latin America, but also for dense urban environments where terrestrial dense mobile networks are too expensive and/or lack planning permission, power supplies, and backhaul.
- *Advanced secure networking technologies*: Novel technologies for far more secure encryption may use quantum mechanics techniques. EU experimental initiatives to form a quantum key-based communications infrastructure across the EU (or across the world) are already under way.

We now turn to the form of the 6G mobile networking solution – the networked system architecture for the future radio cellular environment and its core network.

## 4. IN SEARCH OF THE NEXT MOBILE ENVIRONMENT MODEL, FOUNDED ON NEW NETWORK AND USER INTERFACE ARCHITECTURES, WHICH ARE SECURE BY DESIGN

The proposed solution may appear to be relatively radical: to replace the Internet and the Web, supplanting the software and systems infrastructures currently in use in all mobile networks worldwide. That requires discarding the legacy protocols, processes, layers, interfaces, and applications of the current Internet and Web in favour of a far more secure environment. This direction is shown in a simplified form in Figure 2.

The aim would be to replace the Internet and the Web by a secure mobile environment for user interfacing into high-security communications services with multimedia content storage, underpinned by a suitably protected network infrastructure. If remote, large server systems, which are likely to be 'cloud'-based, are employed, then their security model would also have to form part of a 6G architecture as they could act as a single point of failure.

### 4.1 Moving forward to a secure mobile architecture

A simplified comparison of the previous mobile Web and future architectures is shown in Figure 3.

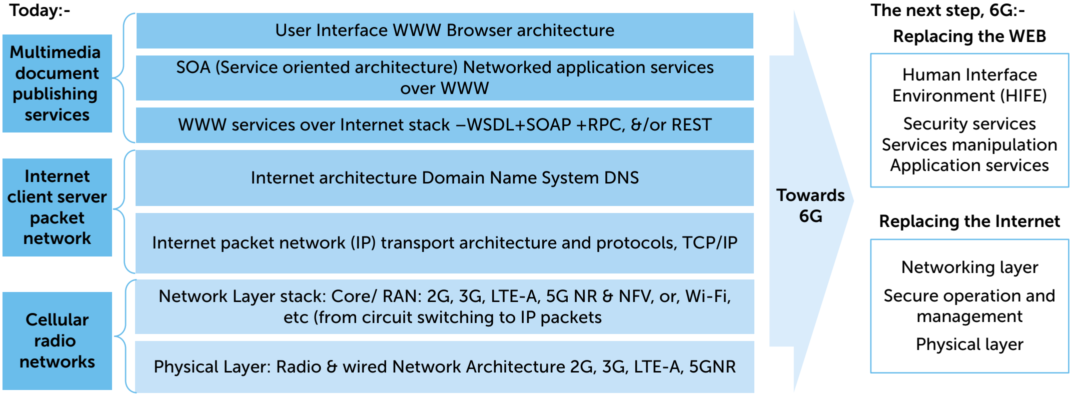
Moving to the new model demands architectural development along completely different principles, for a secure mobile networking architecture, at global scale, that includes the human interface environment (HIFE). Such an ambitious aim is much easier said than done. Major areas of effort of a 6G architecture include:

**Key areas of a 6G security architecture**

- Determining principles of the architecture with its underlying security concepts
- Global security model and its object patterns, interactions, and encapsulation
- Identification, naming, and addressing models, for example GUIDs/UUIDs for naming5
- Recognition and detection models and granularity of control

FIGURE 3: **Where are we now and where should we go with 6G?**

Towards a 6G architecture




- Logical and physical model of the network infrastructure and its transport layer
- User interface design for simplicity with safety and security
- Network operating system/grid system for cloud security
- Interfaces and gateways for secure backwards compatibility to Internet/WWW
- Models of cooperation with other networks and with stand-alone 6G dedicated networks – campus, home, office, enterprise private networks, and others.

The agenda for 6G outlined above concentrates on mobile communications between people and objects. It does not try to move into the industrial real-time control market, as the mobile network operators (MNOs) would like to do in order to expand their revenue streams. The models of real-time, very-high-speed controls for Internet of Things manufacturing and for vehicles, using ultra-low network signal latency, are at odds with mobile networking reality in several respects – firstly the field performance and reliability of mobile (5G) networks in terms of failure rates and times to repair (European Commission, 2015), and secondly the ability of the MNOs to act as system and network integrators. A third reality is the cost of 5G software and hardware compared with dedicated industrial radio networks (e.g. ZigBee) and the ubiquity of low-cost industrial Wi-Fi6 at 6Gbps.

Note that the area of backwards compatibility with the Internet/WWW environment, including the 5G and LTE-A networks, needs to be treated with respect and some caution. Gateways between the two worlds will require powerful inspection procedures for filtering out malicious code that may be harmful and intrusive. Additionally, throttling of data speed and volume capacity in both directions, to limit interaction and potential leakage rates, may be used, enabling deeper inspection.

### 4.2 High-level principles for a 6G architecture provide the security foundations

In creating the key principles of a secure architecture for 6G, several major areas need to be considered. Figure 3 above does not answer any of the architecture's issues in detail, giving some ideas of what is needed.

- Firstly, it is important that the architecture has the flexibility to add new capabilities as potential attacks evolve. The design principle that networked systems are certain to be attacked should be ever present and never forgotten.
- Secondly, there must be a strong separation of network and application architecture spaces and the user interface environment. All are complex areas to define and so more difficult to implement via clear rules. Some forms of authentication could be performed at the network or lower level predominantly. However, it may also be necessary to check at the upper, application level. For example, at the application level, authentication certificates, to identify the end points such as a smartphone or a server, might not be necessary (perhaps with specific exceptions) as they might be identified by the network layer whose certificates are invalid for the application layer. This implies the 'horses for courses' approach of assignments of exclusive responsibility for security checks to the layer at the most appropriate level to the function. Thus, for network-related security functions, for example, when authenticating information source locations and originating devices, the network layer would host the verifying agents.

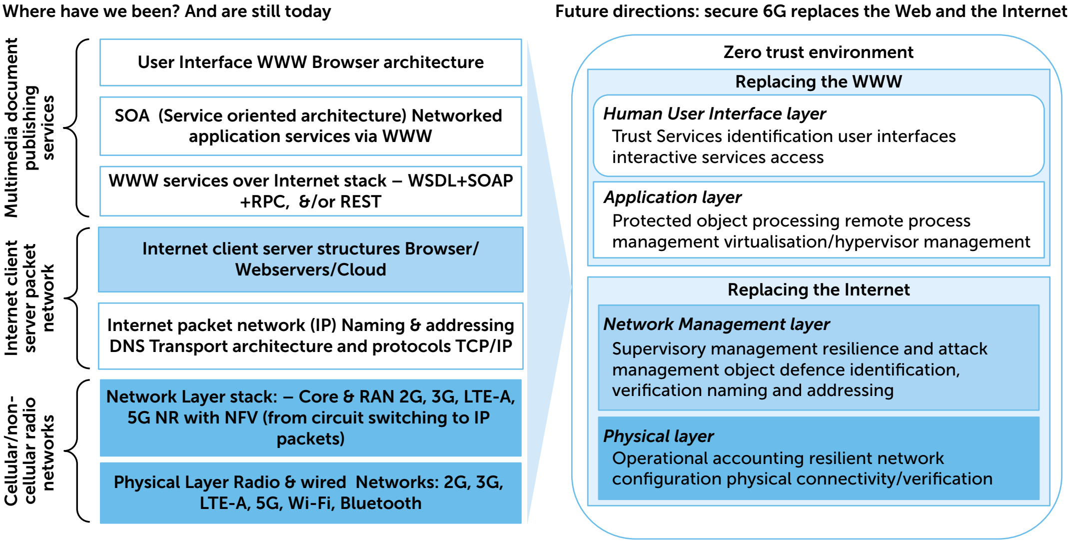
- All software objects in any layer should be registered and capable of being reliably corroborated. This follows the security principle of giving as few privileges as possible. It requires establishing identity for each object for each interaction. Verification may need to authenticate all constituent parts, so there will be recognition of patterns of behaviour and importantly of structure, with validation of what is expected, in detail – for example to establish whether code additions have been made to a module. That requires an authenticated software configuration map. Checks would be different for the two main classes of component – end points (e.g. smartphones) and network nodes (e.g. in the core network and RAN including edge processors). End points also provide the interface to the application space, so there needs to be a clear separation of applications, end points, and the network. Operational processes must enable the risks associated with the application space to be managed and monitored efficiently.

An important message here is that, for the security measures to be effective, the processing power available to the security procedures must be adequate, including network delay times – which means the computation must be suitably efficient. Two useful tools here are firstly the raw processing power available, down to gate level (5G already needs 5nm and 3nm technology) and secondly the security programming's constructs for code efficiency in terms of the operational structure.[6] All is made complicated by the delays in data transfers for complex security mechanisms across a network.

Perhaps unsurprisingly, for 6G to be secure, many features of the current Web and Internet combination must be abandoned – but which functions exactly? The following selection is perhaps fundamental in highlighting which attributes need to be discarded because they are hazardous from a security perspective:

- *Anonymity*: The Internet's 'anyone from anywhere' basis for joining is a major security problem – because who is really present is unknown. One example is the ubiquitous and persistent 'botnet' – linked robotic servers captured unknowingly by their owners for a wide variety of attacks – which form a constant Internet threat aspect, as spam mail spreads every minute while denial of service attacks occur every hour.
- *Connectivity*: Since the Internet was split in the early 1970s into military and civilian versions, the emergent public Internet has employed the principle of universal open access for all users to everything. The original principle was that any person or system from anywhere could connect from any location (known or unknown) to any destination, be it a person, an organisation, or a system. Thus, email with attachments that are malicious and spoofed addresses form the basis of phishing scams. Mobile Internet, with its always on and open listening mode, makes smartphones even more vulnerable than PCs and servers, which may have more prescribed durations of connection.
- *Access to media assets*: Via the Web (acting as the human–machine interface), an end user may connect to anything that is published on the Internet – and in any way they choose. That end user may be a machine, such as a search engine's web crawler – a computer programme for automated searching, accessing, and recording information on websites. Or, if it is a person, it may be a child or an adult, but there is no control on the Web or Internet on who views it; that could be checked at or perhaps below the application level.

FIGURE 4: **One possible outline of future architectural directions for 6G**




- *Falsified addressing*: The DNS address structure of the Internet is open to falsely originating addresses, be it for email on the Web or access to a web server. Consequently, any security measures must be at an individual end-point to end-point procedure, as the area between them is 'hostile territory'.
- *Unknown routing with unknown correspondents*: As its name indicates, the Internet is a network of networks. That means anyone joining via the WWW may have criss-crossed many networks to access their destination address, some less secure than others, but the Internet and the Web do not give any attributes to the path or method of that joining. With 6G, all should be verifiable.
- *Federated or shared trust*: As various major recent attacks have shown, trust in one application or utility does not mean requests or interactions with it can be trusted. The SolarWinds example shows that trust in interaction with a well-known mail server or virtualisation utility cannot be accepted as safe.

For these reasons, to assure security, the ownership of the request from an accepted utility or a new user for joining and for access should be explicit and clear, as well as the subsequent path and types of actions to access the target information. But neither the Web nor the Internet provide native embedded mechanisms for declaring the identity of the owner attached to a request for interaction. Identity verification is also essential to halt online hate crimes, for instance.

The issues highlighted above indicate some of the basic upgrades needed for a potentially secure network as the next generation of mobile technology. A high-level sketch of transition, comparing the earlier layered model with the future 6G, is given in Figure 4.

### 4.3 Recommendations for longer-term development – creating the future 6G

This outline does not refer to non-cellular radio networks, which today may use current IP packets and technologies and so will also need to be interfaced with – most importantly Wi-Fi, Bluetooth, and so forth, and industrial radio networks. 6G should also include non-cellular handset relay networks within the configuration shown in Figure 4, as LTE does.

The outline of the core aims, functions, and structure of a future mobile 6G environment should also point out where potential advances are to be expected. Recommendations for additional capabilities that will bear fruit over the coming decades need to be indicated; in this respect, three further areas for possible advance stand out.

### 4.4 Sustainability and 6G technology

Today, the sustainability impact of any new advance is a key question, especially if it may increase the global energy budget for decades. For 6G, the developments in the radiated energy equation are key and thus so are the frequencies targeted – plus software and hardware operation, perhaps with adiabatic software and novel logic.

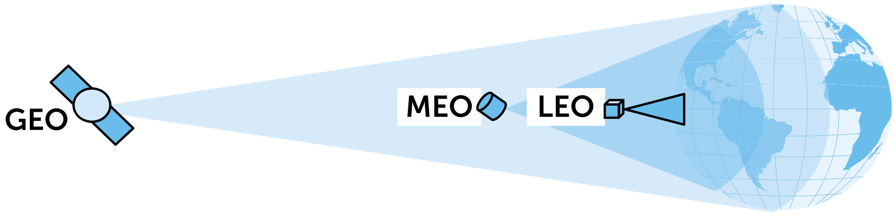
Energy budgets and generations of mobile technology are closely linked, in an increasing curve, despite the advances in power consumption at gate level in VLSI. Consequently, GSM (second-generation mobile) uses less power than the next, UMTS W-CDMA, in base stations and handsets. Power consumption increased yet again with the 'long-term evolution' into today's LTE-A-Pro. The succeeding 5G NR now takes this up to new levels of cell density and power consumption.

Note that it is the physics of radio signal propagation that drives energy consumption. Hence signal frequencies set mobile cell density – and overall infrastructure costs. As a result, current 5G technology has higher wattage power requirements per unit area than previous technologies. That is caused by the preference for higher-frequency bands for 5G, in order to increase its data speeds to broadband. The data speed is determined by the width of bandwidth per channel in 5G NR technology, and the higher bands may offer wider channels. The result of a higher frequency is shorter propagation distances, driving up mobile cell density. That in turn increases the power per unit area – and so increased power demand for the overall network, as the majority of power consumed is in the RAN rather than the core network, a long-distance network for switching and management, connecting into data centres over fibre optic, copper, and microwave links.

This introduces a core principle to spectrum management – of sustainability – which is that choice of mobile bands sets the network power consumption, as the RAN dominates power demands. Consequently, for sustainability reasons, the choice of spectrum bands should be for signal frequencies that do not require high power to propagate with meaningful range and can pass through ferroconcrete walls – because over 80 per cent of mobile communications are from indoors. For instance, one major MNO notes that to accommodate the wider bandwidth for 5G, needed for greater data speeds due to the 5G NR signal technology, a higher transmission power of 200W was adopted (Qi Bi, 2020). That maintains the transmissions' power density, per unit of spectrum, to be similar to that of LTE-A, which typically uses 60W. Thus, over three times the radio frequency (RF) transmission power is necessary. That draws a minimum of at least three times the generated electrical power consumed by each 5G base station over the previous LTE-A generation, a significant addition to the MNO's carbon footprint (and operational expenditure costs).

There is also a knock-on effect of using higher frequencies. To extend the range, beamforming may be necessary (as in 5G NR), which increases demand over conventional lower-frequency isotropic (three) sector antennae. The higher power for 5G beamforming uses MIMO (maximum input maximum output) antennae phased arrays. 5G MNOs with large installed bases have noted that 5G base stations with directional phased array (MIMO) aerials increase power consumption by 50–100 per cent (Qi Bi, 2020). The lifecycle carbon footprint in manufacture and operation (and cost) also increases. Smartphone handsets may also have higher consumption for maintaining the range at higher frequencies, demanding higher power for recharging handsets. Logically, consideration of frequencies in the UHF band (and possibly up to 4 GHz) should be the focus for 6G, to offer lower carbon footprint infrastructures, due to longer-range propagation and potentially higher data stream reliability. Lower frequencies should give reliable signals with lower cost, less dense networks, and lower energy consumption as more advanced processing technology could produce a median broadband speed while

FIGURE 5: **Satellite orbits – geostationary, medium earth orbits, and low earth orbits; the latter orbit range may vary by system ranging from 160kms up to 2000kms**




maintaining radiated power, well within ICNIRP RF guidelines for human exposure.

Scaling the engineering of network elements for use of renewables, such as solar panels for base stations, and possibly for wind power, should set the power demand budgets for all network elements, especially data centres, perhaps the greatest demand item after the RAN.

The various component systems for 6G will form one of the largest manufacturing initiatives and supply chains on the planet over several decades. Therefore the prevailing guidelines for manufacturing and lifecycle management of sustainable information and communications technologies (ICTs) that have been used for more than a decade would also apply from the first designs of 6G systems. Design for handsets, network equipment, and servers should be such that all is repairable – and recyclable at end of life, either by module, component, or materials reuse. ICTs also require that a 'green strategy' is applied to software and firmware generally, especially common utilities, drivers, and operating systems. New versions of code, or current upgrades, should use less memory, processing cycles, and storage accesses and provoke lower heating and cooling requirements than the previous version. The result would be aimed at running latest code versions on existing hardware/firmware/storage, avoiding forced obsolescence of the whole unit.

There are also specific computing techniques, researched over the last decade, that are now bearing ('greener') fruit. One potential avenue is adiabatic computing to reduce the energy load of software to operate a global network. The principle is to avoid energy dissipation in the computational operations by using recoverable energy in the state transitions of the VLSI gates (IBM, 2014). Other avenues include:

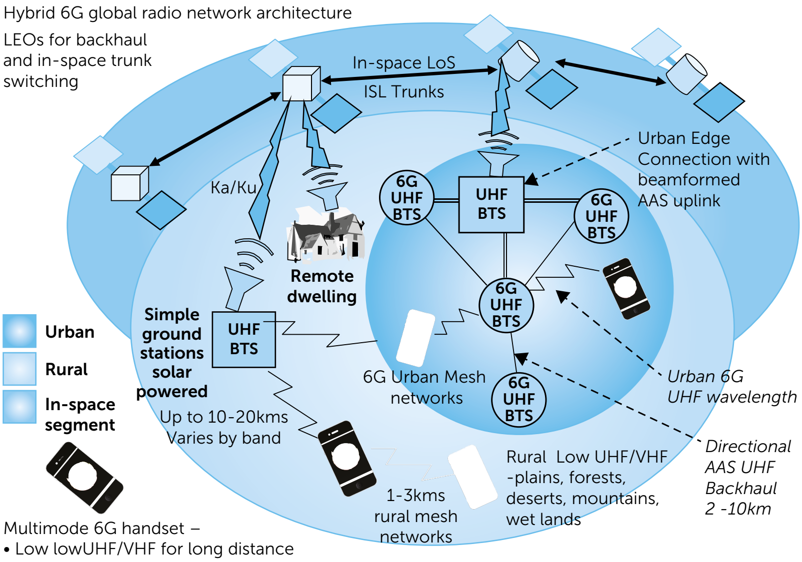
- Low power hardware – using lower power technology for switching broadband data at high rates – currently 5nm and 3nm technology. But the future may be smaller features, or perhaps quite different technology as MOSFET/CMOS advance stalls – so optical logic and photonic processing, with passive optical connectivity (PONs) wherever possible, become attractive to reduce power;
- Approaches to design of the product and the product lifecycle for minimal carbon footprint – that is, to design for reuse and repair before final complete recycling – making all 6G technology a core part of the 'circular economy'.

A 6G programme could be the trigger for a number of new directions in materials sciences as well as computational technology and network architectures with the aim of producing lower carbon footprint processes, materials, and end products. The size of the markets for networking equipment, specific 6G processors, and smartphones could justify an investment programme.

### 4.5 LEO satellites – the global transport layer (with some latency)

The possibility of 6G communications in remote areas without a fixed line infrastructure, and possibly in the densest of urban environments, using a space segment is an additional possibility. Any future dominant mobile architecture must be able to embrace that. To create its own space segment, several key areas for integrating 6G mobile networks into a constellation of microsatellites are required, keeping link latencies as low as possible. Delays of 20msecs are considered possible for the lowest orbits. Relative orbit sizes of traditional geostationary, medium earth orbit, of LEO satellites are shown in Figure 5.

FIGURE 6: **LEO space segment complements terrestrial 6G networked systems**




Multimode 6G handset –
• Low lowUHF/VHF for long distance
• Selected range 300Mhz -5GHz for urban
• Mesh device to device for urban and rural (medium range) multi-hop for blind-spots

Various connection modes are available. An LEO system would offer backhaul for 6G base stations. However, due to the LEO orbital distances plus the signal attenuation in buildings, direct connection from indoors of mobile smartphones to a microsatellite may not be workable for many systems. Direct LEO access from mobile handsets may only be feasible for outdoor use. So, for indoor use, a fixed wireless access unit for the building may be needed, with an external antenna array for LEO satellite connection with through-wall or roof connectivity, perhaps to an indoor 6G small (femtocell) repeater. This also depends on the LEO link frequency chosen. One view of the LEO environment and the 6G connectivity for the three settings of urban, rural, and in-space is shown in Figure 6.

Delivering such a network requires a system architecture – a blueprint for a 6G environment that includes its space segment, for local ground communications, and for wide area network coverage via the space segment. The long-distance coverage may be regional, international, or global. Key areas for development include:

**1**. *Design of the space segment for reliability and low power, with minimal latency* (including a real-time network operating system for unicast space routing of packets, with handover of the traffic flows to the next LEO unit in the revolving fleet plus management functions). The latter include security, failover, load balancing, multipath routing, Doppler effects, optimising minimal latency against path and propagation power, reducing packet loss, avoiding network congestion, and accounting and billing, while also being conceived for the low computational and storage capacity of an on-board orbiting processor and memory. This would use the native 6G mobile packet structure, which should take account of LEO system requirements in its specifications. The network operating system could be embedded in appropriate standards, detailed sufficiently to specify commercial implementations (Jang et al., 2014; Leyva-Mayorga et al., 2020).

**2**. *Architecture for integrating multiple LEO satellite service providers having different space segment systems and potentially different levels of security, data capacity, and interfacing* (e.g. currently there are SpaceX Starlink, Kuiper, OneWeb, SpaceMobile, Telesat, etc.). This may be dependent on reaching international agreements for global standards in these areas, most specifically on packet formats and space handovers between operators as well as handover across operators by a single user where gaps or holes appear in coverage from an LEO system to the terrestrial end user.

**3**. *Smartphone handset design for microsatellite communications* – which may use phased array MIMO beamforming for antenna arrays for RF or possibly for beamed optical links. Design of an appropriate power supply and battery system is critical, as is the overall retail cost of the unit. While the mode of mobile handsets to LEOs is important, for early proving of LEO systems and 6G cash flow, fixed 6G LEO transponder units on buildings, for homes and offices, would offer broadband connectivity in isolated locations. Antenna-tracking algorithms for the user handset for uplink and for the in-space antennae will be necessary for the downlink, taking account of microsatellites' Doppler effects.

**4**. *Operational standards for reliable and secure data processing in space* – especially for cloud operations, with embarked servers which may be spoofed or hijacked, destroyed, or have data evaporate with cosmic ray and other radiation.

The first two requirements above are for detailed large-scale design specifications, with agreements based on international standards. The technical challenges are significant, as LEO satellites may be in orbits between 160km and 2000km with velocities of up to 25,000 km/h, ~ 7km/sec, or 12 to 16 earth orbits every 24 hours.

For ground to satellite uplinks and downlinks, LEO systems may use existing satellite RF spectrum bands such as the Ka Band (18–28GHz) and Ku band (1–18GHz), or C-Band (3.8–4.2 GHz, for Fixed Satellite Services, FSS), with conditions which vary by country and ITU region. An alternative is to use more concentrated signal power by employing narrow beamed optical, as in free-space optical (FSO) for ground to satellite links (Giggenbach, 2014). Thus, an assessment of optimal RF bands is required, leading to international agreements which might maintain current industry preferences. Note that inter-satellite links (ISLs) in space can also be optical or on any RF frequency that is low cost in energy and equipment requirements for accurate beamforming. For ISLs, the spectrum range of RF bands may include centimetric, millimetric, and possibly terahertz frequencies.

### 4.6 Quantum network security – an integrated system of terrestrial and space segments for a quantum communications infrastructure with quantum key distribution

The 6G network will form part of the EU and global critical infrastructure. It will thus require adequate protection. Cyberattacks on critical infrastructures such as mobile communications are to be expected, particularly as a European-level threat, as well as globally. For example, the Network and Information Systems (NIS) Directive (EU NIS, 2016) specifies this risk and identifies some essential services which are critical for society and are potentially vulnerable to digital attack. Those would include 6G. Hence application of the next level of security with technology based on quantum computing may become necessary for the 6G core network and for the data repository connectivity.

Quantum mechanics for cybersecurity is still in its infancy but could be developed within the development time scales of 6G (perhaps five to ten years of research and development (R&D) with a 20-year operational life). The aim would be to build a secure 6G network for interactive sessions as well as file transfers and streaming. It would be based on a quantum communications infrastructure (QCI) consisting of an integrated terrestrial infrastructure, founded on a fibre optic network and a space infrastructure using LEO microsatellites, forming the twin terrestrial and the space segments of the 6G QCI. Whether entanglement via LEO satellite constellations may prove fruitful is unclear.

For the security keys that are essential to 6G network operation, the architecture should include a system of quantum key distribution (QKD) for the encryption keys, via a 6G-oriented QKD system. In the longer term, it might be followed by appropriate further services to support the 6G security architecture. Potential later candidates could be authentication services, digital signatures, and synchronisation of ultra-precise time signals for security checks. Over the much longer term, the QCI might evolve into the quantum 6G transport network, with its naming and addressing, to interconnect the servers via quantum networks to distribute information and link network resources securely all over Europe and eventually the globe. Protecting the 6G mirrored remote data centres would also be a high-priority task for the QCI.

A 6G QCI architecture should provide high resilience, with disaster recovery, failover, and wide sharing of communications and content across different MNOs while minimising latency time. Moreover, it should prevent the likelihood of massive eavesdropping on the high-capacity interconnections. If the security of one data centre for the 6G operation is compromised, transfer to another mirrored data centre using the quantum protected channel may enable faster restoration.

The zero-trust infrastructure envisaged in the 6G architectural foundations will demand far higher numbers of key distributions and verifications. Hence the rate of distribution required for effective 6G operations may be expected to exceed current capabilities but might be achievable by the QCI in the medium term. The QCI architecture's core concept for the 6G operation is that the QKD links are integrated on an ad hoc basis, on demand, and that the 6G architecture can optimise the full network to manage the classical as well as the quantum communications links, without resorting to central controllers – and a single point of failure.

### 4.7 Other directions for 6G developments

Major advances might be incorporated in many other areas. One possibility is further development of the concepts of mesh networking so that the dependence on cellular base stations can be reduced by using a flock of handsets. These act as message passing relays. The concept offers advantages in reducing congestion and acting as a 6G network where no infrastructure exists and to supplement the space segment as well as for 'not-spots' in urban, suburban, and rural areas. However, it presents serious security challenges. Furthermore, it would require some form of end user consent.

## 5. CONCLUSIONS

What has been outlined for the architectural design suggested for 6G is a rejection of current online technology. Instead, a fundamental revision of the networked system architecture for mobile is proposed, in a holistic fashion, to create its own version of the two online layers of the Web and the Internet, with security and resilience plus ease of use and ease of defence. The preceding section sketches just one possible outline. Much further research into the high-level architecture is required.

In terms of its business model and its business case, the aim for 6G is secure mobile connectivity for multimedia communications and content. It is not aimed at the industrial control sector, which is the secondary target market for 5G, ideally enabling MNOs to diversify beyond mobile services provision and bit carriage – and so in some ways reply to the web platform operators' dominance in web services. Instead, the core target is the communications market for multimedia interaction and communications – socialising, with privacy and data protection, entertainment, business, and e-commerce with safe financial transactions for citizens, enterprises, and

Western developed economies may be their own worst enemies in not reinforcing their information networks

banking, be it from the MNOs or from independent service providers. The 6G environment should open doors for new 6G service providers for every service – search, instant messaging, social networking, and so forth – for a host of new start-ups.

However, the creation of a global security architecture is a long-term initiative and standards will be necessary, while a suitably regulated set of standard essential patents (SEPs) on FRAND terms would also be required. Design will take several years, perhaps more than a decade, if the standards and design specifications development efforts behind LTE-A-Pro and 5G NR are any guide.

Doubtless the prior generations of online mobile, some using the Internet/WWW cocktail, will continue. Therefore, suitable backward compatibility will be necessary, via a carefully structured gateway architecture at a low number of specific, precisely known points, suitably monitored and controlled in content and volume.

Most importantly, 6G should not depend on a supply side initiative but should take a pragmatic view of the demand side's priorities and how they can be answered by the supply side. It should rely on using practical industrial policy, at EU level, to guide and support more rational directions in the architecture. The supply side, by its nature, tends to look first at profit, not security and resilience, and so must be appropriately balanced by a technical team supporting the demand side.

6G network success will depend on highly reliable software that has been suitably structured for resistance to attack and yet is still very efficient in the operation of its embedded security procedures. Importantly, it must have flexibility to add new capabilities as attacks evolve. The design principle that these networked systems will always be attacked should never be forgotten. Proving the HIFE and packet transport network for security with ease of use would take several years of design and testing.

High performance hardware will be necessary, one that has a much faster performance than today, as the complexities of future security procedures will require constant vigilance with verification across all the objects in the 6G environment. New approaches to that may come to light from QCI technologies. Firmware and software must be equally efficient as any inefficiencies at scale could be serious impediments. However, this is all within the time frame of mobile generations' evolutions – 2G GSM took approximately eight years, UMTS took some five years and, with its evolution into broadband, LTE, which gestated for a further six years, rolling out in force globally after 2011.

What are the next steps? Possibly an initial R&D schedule could consist of:

- Summary of the 6G architectural design via a feasibility study, in two stages – overview of main features and detailed description
- Organise a 6G steering committee along the lines of Groupe Speciale Mobile with a strong user presence having its own technical design support group
- Set up a detailed 6G architectural implementation study project with simulation tools and a user interfacing and secure experience group
- Invest in large prototypes with tests of advanced technology (for LEO, QCI, sustainability, as well as security)
- Plan a four-phase initial configuration roll-out with strong change control:
  - HIFE user tests of an initial prototype for early tests of main services
  - Security attacks on all the architecture's layers with breach evaluations

- Longer-term operational pilot tests of sparse installations across many MS
- Roll-outs of first full EU version of live systems for attacks and break tests.

### ACRONYMS

| | |
|---|---|
| 5G | NR Fifth Generation (of mobile cellular system) New Radio |
| AAS | Active Antenna System (beamforming phased array) |
| API | Application Programming Interface |
| BTS | Base Transceiver Station (mobile cellular base station) |
| CMOS | Complementary Metal Oxide Semiconductor (low power transistor) |
| FRAND | Fair, Reasonable and Non-Discriminatory (terms of use, usually for patents, SEPs) |
| FSS | Fixed Satellite Services |
| FWA | Fixed Wireless Access |
| GSM | Global Systems for Mobile (2nd Generation of Mobile, the first digital technology) |
| HIFE | Human Interface Environment |
| ICNIRP | International Committee for Non-Ionising Radiation Protection |
| ICT | Information and Communications Technology |
| IP | Internet Protocol |
| ISL | Inter Satellite Link |
| ITU | International Telecommunication Union |
| LEO | Low Earth Orbit (satellites) |
| LTE | Long Term Evolution (of UMTS); LTE-A: LTE Advanced |
| MIMO | Maximum Input Maximum Output (antenna) |
| MNO | Mobile Network Operator |
| MOSFET | Metal Oxide Semiconductor Field Effect Transistor |
| MS | Member State (of the EU) |
| NSA | National Security Agency, US |
| NFV | Network Function Virtualisation |
| nm | Nanometre |
| OPEX | Operational Expenditure |
| PON | Passive Optical Network |
| QCI | Quantum Communications Infrastructure |
| R&D | Research and Development |
| RAN | Radio Access Network |
| REST | Representational State Transfer (guidelines for Web APIs) |
| RF | Radio Frequency |
| RPC | Remote Procedure Call |
| SEP | Standard Essential Patent (basic set of patents necessary for building a technology) |
| SOA | Services Oriented Architecture |
| SPOF | Single Point of Failure |
| TCP/IP | Transmission Control Protocol/ Internet Protocol |
| UHF | Ultra High Frequency, 300 MHz–3GHz |
| UMTS | Universal Mobile Telecommunications System |
| VLSI | Very Large Scale Integration (of semiconductor circuits) |
| VSAT | Very Small Aperture Terminal (satellite communications ground antenna dish) |
| W-CDMA | Wideband Code Division Multiple Access |
| WSDL | Web Services Description Language |
| WWW | World Wide Web |

### NOTES

**1**. The SolarWinds intrusion may have been made via a vulnerability in a common email server but the exact method of intrusion seems unclear, and the US National Security Agency noted in a prior warning of 7 December 2020 (NSA Note U/OO/195076-20, PP-20-1385 – Dec.2020) that a common virtualisation utility could be compromised; however, the link to SolarWinds is unclear.

**2**. The UK consumer organisation '*Which?*' found that, online fraud is now the most common crime against individuals in England and Wales, measured between July 2019 and June 2020, being 40% of all crime against individuals at a cost of €1.04 Bn, to them – from fstech, bulletin 10 May 2022.

**3**. The European Court of Auditors has performed a series of investigations across the Member States by surveys of 5G roll-outs, looking closely at the role of MNOs and suppliers.

**4**. Ericsson gives a figure of 1.4 per cent (2018) but 5G has higher power consumption in its base stations (Qi Bi, 2020) as power to penetrate buildings at higher frequencies must be raised – from 60 watts for LTE-A to 200 watts is quoted, a 330 per cent increase – plus a higher density of base stations, so power demand per square kilometre increases significantly, with ducts, civil works, cable blowing, and so forth – all high carbon footprint factors.

**5**. Global Unique Identifiers, which can be linked, and also linked geospatially, are a likely contender for the identifier scheme and its naming convention. Variations exist such as the OSI Universally Unique Identifier, UUID (ITU, 2004, 2009).

**6**. For example, code efficiency may come from avoidance of repeated operations that expand delays, such as constant memory accesses for small amounts of data, or 'thrashing' for instance.

## REFERENCES


Bikson, T.K., Anderson, R.H., Mitchell, M.B., Law, S.A., & Kedzie, C. (1995). *Universal Access to E-mail: Feasibility and Societal Implications*. Santa Monica, CA: RAND Centre for Information Revolution Analyses.

ECA (European Court of Auditors). (2022). 'European Court of Auditors Special Report 03/2022: 5g Roll-Out in the Eu: Delays in Deployment of Networks with Security Issues Remaining Unresolved'. https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=60614.

EU NIS. (2016). Council/Parliament Directive (EU) 2016/1148, 6 July, Concerning Measures for a High Common Level of Security of Network and Information Systems.

European Commission. (2015). DG CNCT Unit B4, Published report – Use of commercial mobile networks and equipment for mission-critical broadband communications in the sectors of PPDR, Transport and Utilities (SMART 2013/0016), SCF Associates Ltd. http://ec.europa.eu/information_society/newsroom/image/smart_2013_0016_final_report_8211.pdf.

Giggenbach, D. (2014), 'Optical Free Space Links for Satellite-Ground communications', DLR (German Aerospace Centre), 7th Advanced Satellite Multimedia Systems Conference, Livorno. https://elib.dlr.de/105805/1/Giggenbach_FSO_for_Sat-GND-Links_Tutorial_ASMS2014_20140908_HANDOUT20160818.pdf.

IBM Research. (2014). 'Reversible Adiabatic Classical Computation: An Overview'. Presentation, DJ Frank, IEEE Rebooting Computing Summit, Santa Cruz, CA, 15 May. https://rebootingcomputing.ieee.org/images/files/pdf/7-rcs2-adiabatic-reversible-5-14-14.pdf.

Industrial Software Solutions. (2021). 'Why the SolarWinds Attack Easily Slipped by All EDR/EPP Solutions'. 5 April. https://industrial-software.com/community/news/why-the-solarwinds-attack-easily-slipped-by-all-edr-epp-solutions-virsec-blog/.

ITU (International Telecommunication Union). (2004). X667, Series-X, Naming, Addressing and Registration, OSI data networks and open system communications, procedures for operation of OSI Registration authorities: generation and registration of universally unique identifiers as object identifiers. http://www.itu.int/ITU-T/studygroups/com17/oid/X.667-E.pdf.

ITU (International Telecommunication Union). (2009). Recommendation ITU-T E.101, (11/2009), SERIES E: Overall network operation, telephone service, service operation and human factors, International operation – Definitions of terms used for identifiers (names, numbers, addresses and other identifiers) for public telecommunication services and networks in the E-series Recommendations. https://www.itu.int/rec/dologin_pub.asp?lang=f&id=T-REC-E.101-200911-I!!PDF-E&type=items.

Jang, I.S., Kim, D.U, Lee, W.M., & Chung, D.W. (2014). 'Development of the Operation Management System for LEO Satellite Operation and Improvement Plan for Next Phase'. Korea AeroSpace Research Institute (KARI), SpaceOps Conference, Pasadena, CA, May, pp. 1–6.

Joshi, S. (2022). 'Hitting Back at Cybercriminals'. In *The Economist*, *The World Ahead*.

Leyva-Mayorga, I. Soret, B., Roper, M., Wubben,D, Matthiesen, B., Dekorsy, A, & Popovski, P. (2020). 'LEO Small-Satellite Constellations for 5G and Beyond-5G Communications'. *IEEE Access*, 8, pp 184955–184964. https://www.researchgate.net/publication/347268791_LEO_SmallSatellite_Constellations_for_5G_and_Beyond-5G_Communications/fulltext/6050911aa6fdccbfeae221fe/LEO-Small-Satellite-Constellations-for-5G-and-Beyond-5G-Communications.pdf.

Marks, J. & Schaffer, A. (2022), 'New water standards are coming', Washington Post, Cybersecurity 202 supplement 27 January. https://s2.washingtonpost.com/35df2c5/61f2a5b29d2fda14d70c3186/5af3699eae7e8a5dbe0505a0/5/54/61f2a5b29d2fda14d70c3186.

Qi Bi. (2020). 'Progress and Challenges in the Cellular Industry and 5G'. *IEEE Future Networks Tech Focus*, 4(1). https://futurenetworks.ieee.org/tech-focus/november-2020/progress-and-challenges-in-the-cellular-industry-and-5g.

# Sustainability and Innovative Spectrum Management Defining Future Mobile Connectivity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**ABSTRACT**

**Digitalisation and the green transition are driving change in societies at large. Information and communication technologies are important enablers in this dual transition, which is not only about technology development and deployment but involves a number of challenging business and regulatory decisions that have a fundamental impact on our future society. This chapter focuses on future mobile connectivity in the context of sustainability, highlighting discussion points that need to be addressed in Europe. This chapter also explores one concrete example of the complex interactions of technology, business, and regulation, in the form of spectrum management, which has a fundamental role in defining the future mobile connectivity market.**



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### THE ROLE OF COMMUNICATIONS SOLUTIONS IN THE DIGITALISATION OF SOCIETY

The digitalisation of different sectors of society is now a high priority in national and European agendas. Academia, industry, and policymakers jointly share the pressure to develop innovative solutions that tackle major sustainability challenges presented in the United Nations Sustainable Development Goals (UN SDG) framework. Digitalisation and related information and communication technology (ICT)-based services have emerged as important enablers needed to achieve these goals, and the resulting sustainable ICT solutions are opening new business opportunities to stakeholders.

The ICT-related discussions in Europe often focus on 5G technology-based solutions through the deployment of outdoor cellular networks by a handful of dominant mobile network operators (MNOs). The digitalisation of society as a whole is not only about faster mobile data rates provided by 5G networks, but it involves an ever-increasing complexity of different services, applications, and technology combinations, provided by a large and complex set of old and new stakeholders. Various monthly service subscriptions have surpassed the pure connectivity service, leading to customers paying for a variety of content delivered in addition to their broadband subscription.

The business ecosystem around 5G is changing and differs from prior generations of cellular technologies, including companies taking new roles and completely new entrants emerging. One concrete example of a recent paradigm shift is the emergence of local 5G networks that can be established by different stakeholders, not only the MNOs. These local 5G networks can serve a closed group of users in the private 5G network model, MNOs' customers in the neutral host model, or a mix of closed and open user groups through the same local network (Matinmikko et al., 2017). These local 5G networks are starting to serve the needs of different vertical sectors in several countries globally. Their emergence opens new business opportunities for several stakeholders but is constrained by regulatory decisions, especially on the local availability of the radio spectrum. Even though Europe has played a leading role in the development of the concept of local 5G networks (Matinmikko et al., 2017), identification of related regulatory challenges (Matinmikko et al., 2018), and business opportunities (Ahokangas et al., 2019), the internal market in Europe is inconsistent due to varied implementation of rules at the national level. Some administrations view these new deployments as an opportunity for growth, while others see them as a threat to timely roll-out of 5G by traditional operators.

Today, 5G still plays a relatively small role in delivering Internet capacity. In fact, a variety of different connectivity technology solutions exist that will continue to aim at solving the same end customer needs, which today is primarily broadband connectivity. There are a range of wired and wireless technologies that aim to connect humans and things that include both mobility-supporting solutions and fixed solutions, as well as combinations of the two. It comes as no surprise that one solution does not fit all situations, but different resource combinations are needed to flexibly address different local needs. There is also varying legacy development in different countries including both deployed technologies and regulatory choices made, which also impacts the potential future choices available in terms of, for example, existing fixed infrastructure to build on. The availability of the technology choices needs to reach a balance that involves business opportunities that in turn are influenced by regulations, in addition to pure technical characteristics. 5G has dominated the European policy discussions, limiting the focus unnecessarily, even though the actual amounts of data transmitted through the different technology solutions indicate that other technology options carry significantly higher amounts of data. For example, high data volumes in stationary use in indoor locations are primarily served through non-cellular networks via a fixed network and its wireless local area network component, which is often ignored in policy discussions. For application providers and end users, different technology solutions now provide similar performances measured via technical parameters, such as capacity and latency, but these criteria will no longer be the only meaningful parameters influencing decision-making over technology choices in the future sustainable society.

It is important to find a balance between the needs of various end users and user groups, and the capabilities provided by different technology solutions, through proper sets of indicators that match the various end users' needs in order to maximise the benefits while responding to future sustainability needs. 5G and 6G in the future will be needed together with other technology solutions. Various end users' needs will have to be incorporated in the development of technology solutions to avoid pure technology push and to implement the necessary technologies in the right context. These assessments need to reach the political decision-making level as well, where a holistic and balanced view is needed, based on facts of technologies and their deployment, which allows fair and transparent comparisons instead of opinions based on marketing materials.

Different countries promote different technology combinations globally due to their own agendas.

> Academia, industry, and policymakers jointly share the pressure to develop innovative solutions that tackle major sustainability challenges

At the same time, companies that develop technology solutions promote their own solutions in order to market their products. These agendas are often mixed – what is a company's view and what becomes a nation's view, and, more importantly, what is the marketing view and what is based on technical facts or end user needs. The operational environment continues to become more complex, with a large number of possible technology combinations to serve the needs of users. An increasing number of companies are involved in the development of solutions and their use, and the increasingly complex partnerships of the companies make it that much more challenging to distinguish a marketing-based view stemming directly from the partner network from a technology-based fact. This makes it difficult for governments and end users to evaluate the potential solutions in terms of how they meet specific needs.

### THE ROLE OF SPECTRUM DECISION-MAKING

As a concrete example of the increasing complexity of the business ecosystem and policymaking around mobile communications, decisions on the radio spectrum will have a significant impact on the future connectivity market. These decisions fundamentally determine who can deploy mobile communication networks. Spectrum awards decisions, such as recent 5G spectrum auctions whose outcomes are published as major news, are undertaken by national regulators, after extensive global and European harmonisation processes. The European Electronic Communications Code sets the general principles of radio spectrum management in the European Union. The European Commission adopts implementing decisions to harmonise technical conditions about the availability and efficient use of spectrum for the proper functioning of the single market, including decisions for the harmonisation of spectrum for wireless broadband electronic communications services including 5G. Countries then have the power to make spectrum award decisions, including who can deploy 5G networks within a particular spectrum band, where, when, and how. These spectrum regulatory decisions have a long-term impact on the market as they define all wireless communications markets for decade(s) to come.

Spectrum sharing, where two or more radio systems operate in the same frequency band, presents a paradigm shift that calls for the development of new governance models for the precious natural resources that aim at different users to collectively improve the efficiency of overall spectrum use by making it available to others when it is not being used otherwise. Despite two decades of extensive research, spectrum sharing is still not taken seriously in regulatory bodies that decides on spectrum matters (Matinmikko-Blue et al., 2019). Current spectrum sharing models are based on static use of spectrum with long geographical separation distances without taking technical advancements into full consideration. Spectrum sharing is encouraged by regulators, but concrete European-level actions remain limited compared with those in other regions such as the United States. The same decades-old principles of protecting the incumbent spectrum users are still in place in the European spectrum regulatory discussions despite progress in innovative sharing-based methods and models. Existing incumbent spectrum users, such as MNOs, dominate discussions and do not promote spectrum sharing, which might open their spectrum bands to other stakeholders. In fact, there is no room for new technologies or entry of non-dominant stakeholders to the market due to incumbents' resistance that spans their partner network to the extent that only like-minded voices that prevent spectrum sharing are usually heard.

Europe needs to urgently update its spectrum regulatory framework to promote innovative spectrum access models that are based on spectrum sharing. The role of academia together with non-dominant stakeholders is critical as most incumbents do not drive a change that they feel is threatening to their existing strong position. The innovation landscape needs to be opened up to smaller stakeholders, including small and medium-sized enterprises (SMEs), to influence decision-making, including those without a currently dominant position and power to influence, to make new business opportunities a reality in Europe. Stakeholders who currently lack spectrum access rights will be interested in spectrum sharing if that gives them access to the precious natural resource.

## SUSTAINABILITY AS THE FUNDAMENTAL DRIVER FOR FUTURE MOBILE CONNECTIVITY

The goal of sustainability, that is, that our choices today should not limit the range of options available for future generations, must become a fundamental driver of both the development and the use of ICTs. Today's sustainability discussions around mobile connectivity focus on energy efficiency, which is used to compare technologies in terms of required energy per transmitted bit. However, efficiency does not solve the sustainability challenge when the amounts of data keep increasing. In fact, overall energy consumption keeps increasing, and it cannot be offset by the potential enabling effect of ICTs for the achievement of sustainability targets in other sectors of society.

The design phase of technology is critical to realising sustainability targets. 6G aims at deployment in the 2030s and there is a common consensus that sustainability and particularly the UN SDGs will be the key driver of 6G research and development (R&D) (Latva-aho & Leppänen, 2019; Matinmikko-Blue et al., 2021). For 6G to play a fundamental role in a future society that has adopted sustainable development in all aspects, the whole future 6G system and its ecosystem need to be built based on new design criteria that emphasise sustainability at all levels (Matinmikko-Blue et al., 2020). National and European-level actions that bring together academia, industry, and policymakers are needed to determine the new sustainability-based system requirements and to develop the needed elements.

Sustainability should be the driver for R&D on future connectivity solutions, including 6G. As making society smarter and building more networks must be done in a sustainable way for various reasons, there is a need to pay particular attention to the sustainability of future connectivity solutions. As an example, the ICT sector itself talks about how to limit the growth of energy consumption without decreasing consumption. Sustainability needs to cover the triple bottom line of social, economic, and environmental sustainability perspectives. At the same time, it is important to maintain the principles of technology neutrality. If new business opportunities consider the conflicting needs of stakeholder holistically, significant business opportunities for 6G will result (Yrjölä, Ahokangas, & Matinmikko-Blue, 2020).

From the social perspective, future connectivity solutions need to be developed from a human-centric point of view in addition to considering the growing need for connecting machines. For social sustainability, it is important that no one is left behind. Including households in a Gigabit network alone does not solve the issue of the digital divide, because a single metric does not describe what end

Local 5G networks are starting to serve the needs of different vertical sectors in several countries globally

users will actually get, not to mention the price they have to pay, which leads us to economic sustainability.

From an economic perspective, sustainable solutions to solve major global sustainability problems are a business opportunity for Europe. Innovations from non-dominant players that are under the influence of existing leaders need to be given opportunities for development to ensure synergy between newcomers and existing players and thus the implementation of common European goals. SMEs are important stakeholders, and the opportunities for innovation in Europe should not be worse than those outside Europe because of the differences in the availability of technology combinations in different regions.

The environmental perspective of sustainability must be understood broadly. Improving energy efficiency is not enough. Even energy efficiency itself is a difficult metric to define, measure, and compare. The principles of environmental sustainability developed and applied in other sectors should be taken into use in ICT, too. This will require political will and political decisions – the sector itself cannot do it.

To realise a sustainable future, we cannot wait until 2030, the target year for the achievement of the UN SDGs, and for the roll-out of 6G. A great deal must be done now. Currently, the ICT and mobile communications sector is focused almost exclusively on how it will help other sectors of society reach their sustainability targets (Matinmikko-Blue et al., 2021). Helping others, however, is not enough. For the ICT sector itself to act now, new indicators to assess the sustainability of connectivity solutions and services are urgently needed to make their sustainability burden visible and to allow consumers to compare data and connectivity solutions. For example, the resources consumed when downloading web pages on a mobile device vary greatly based on the decisions made by the content providers and access providers. A website that displays the same video ad on every page that is visited creates a significantly higher environmental footprint if the ad is sent to the consumer from a third party with every page visited, compared with if it is cached by the service provider or on the phone, but the inefficient choice might be necessary based on the business needs of the advertiser. To make matters worse, because today's comparisons of countries' forerunner positions in mobile communications are based on the total consumed mobile data, inefficiencies such as those in the above example are rewarded, encouraging non-sustainable practices. There is an urgent need for new sustainability indicators in the end-to-end delivery of wireless content. In order to develop such indicators, the actual consumption-based data necessary to assess the sustainability impact of the ICT solutions and services must be made available. Policymakers should request sustainable solutions and the R&D community, including academia and industry, needs to be responsible for developing these sustainable solutions, but the necessary measurement tools also need to be developed.

## DRIVING INNOVATION IN THE FUTURE SUSTAINABLE CONNECTIVITY LANDSCAPE

5G developments and deployments have already shown how complex our operational environment has become, including new stakeholders and roles such as local 5G networks for private or public use. Such developments are expected to continue in the future.

The real social, economic, and environmental success of future connectivity solutions including 6G will depend on innovative ideas that tackle the major sustainability challenges. In this development, it is critical that not only the players with the strongest influencing position are heard and get to sell their solutions, but also that academia plays a role in presenting unbiased research to promote innovation, and that users' insights on their actual needs are heard. Additionally, SMEs must be included despite their limited resources to participate in the discussions.

The early inclusion of end user needs in the 6G R&D process is a real challenge – that is, how to make the voices of future consumers and vertical sectors heard and followed. This includes defining new requirements that stem from end users' needs as opposed to traditional key performance indicator (KPI)-driven cellular mobile communication system development. Today's public consultation formats represent mechanisms for collecting feedback from existing strong players and leave out important categories with diverse expertise that lack the same resources to influence decision-making. The arguments of non-dominant players who participate are not heard. Meaningful participation in regulatory initiatives by new stakeholders is needed to ensure proper innovation management both at national and European levels towards a bottom-up regulatory approach.

The research sector is a critical player in sustainability discussions, particularly when it comes to identifying and promoting goals that benefit the whole of society. Research and related funding is needed both for independent academic research that does not require close collaboration with today's strong stakeholders and for R&D done together with industry to develop commercially viable solutions. The perspective in research funding needs to be long enough to allow for entirely novel innovations to solve major sustainability challenges that make economic sense.

Finally, research findings need to be incorporated into decision-making processes. This requires coherence between European research activities as well as regulatory initiatives to ensure both that funding is channelled to it and that there are mechanisms for cooperation between regulators and academia. These need to go beyond traditional public consultations and constitute a more formal interplay between academia, industry, and the public sector, where perspectives are clearly defined to avoid marketing getting mixed up with technical and deployment-based facts. This is particularly urgent for all sustainability-related actions – the ICT sector itself is not in a position to define requirements for itself.

## CONCLUSIONS

Our future sustainable society will depend on sustainable connectivity solutions whose development is not only about technological advancements but also about the identification of business opportunities and the development of related regulations. The development of future sustainable connectivity solutions calls for close collaboration between academia, industry, and policymakers in order to set the right goals from the very beginning. These goals need to address sustainability broadly, considering social, economic, and environmental perspectives and focusing on the various needs of real end-users including consumers and developers. Spectrum management, as one concrete example of how regulations impact the adoption of new technology solutions that can change the connectivity market and available business opportunities, deserves a fundamental rethink for the future sustainable world so that today's decisions do not limit the range of options available for the future.

**REFERENCES**


Ahokangas, P., Matinmikko-Blue, M., Yrjölä, S., Seppänen, V., Hämmäinen, H., Jurva, R., & Latva-aho, M. (2019). 'Business Models for Local 5G Micro Operators'. *IEEE Transactions on Cognitive Communications and Networking*, 5(3), 730–740.

Latva-aho, M. & K. Leppänen, K. (eds.). (2019). 'Key Drivers and Research Challenges for 6G Ubiquitous Wireless Intelligence'. White paper, 6G Research Visions, No. 1, University of Oulu, Finland. http://urn.fi/urn:isbn:9789526223544.

Matinmikko, M., Latva-aho, M., Ahokangas, P., & Seppänen, V. (2018). 'On Regulations for 5G: Micro Licensing for Locally Operated Networks'. *Telecommunications Policy*, 42(8), 622–635.

Matinmikko, M., Latva-aho, M., Ahokangas, P., Yrjölä, S., & Koivumäki, T. (2017). 'Micro Operators to Boost Local Service Delivery in 5G'. *Wireless Personal Communications*, 95(1), 69–82.

Matinmikko-Blue, M., Yrjölä, S., Ahokangas, P. Ojutkangas, K., & Rossi, E. (2021). '6G and the UN SDGs: Where Is the Connection?' *Wireless Personal Communications*, 121(2), 1339–1360. https://doi.org/10.1007/s11277-021-09058-y.

Matinmikko-Blue, M., Yrjölä, S., Seppänen, V., Ahokangas, P., Hämmäinen, H., & Latva-Aho, M. (2019). 'Analysis of Spectrum Valuation Elements for Local 5G Networks: Case Study of 3.5-GHz Band'. *IEEE Transactions on Cognitive Communications and Networking*, 5(3), 741–753.

Matinmikko-Blue, M., Aalto, S., Asghar, M. I., Berndt, H., Chen, Y., Dixit, S., Jurva, R., Karppinen, P., Kekkonen, M., Kinnula, M., Kostakos, P., Lindberg, J., Mutafungwa, E., Ojutkangas, K., Rossi, E., Yrjölä, S., & Öörni, A. (Eds.). (eds.). (2020). 'White Paper on 6G Drivers and the UN SDGs'. White paper, 6G Research Visions, No. 2, University of Oulu. http://urn.fi/urn:isbn:9789526226699.

Yrjölä, S., Ahokangas, P., & Matinmikko-Blue, M. (eds.). (2020). 'White Paper on Business of 6G'. White paper, 6G Research Visions, No. 3, University of Oulu. http://urn.fi/urn:isbn:9789526226767.

Part 3

# Comparative Studies of Leading Asian Countries

# China's 5G Development Strategies and Challenges in the Context of Global Competition

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**ABSTRACT**

**China has built the world's largest 5G mobile network, leading 5G development worldwide. This has provided Chinese companies with technological and business leadership for the first time in the Internet era. This chapter applies Michael Porter's Diamond model to discuss China's 5G development, to focus on the role of government, factor conditions, related and supporting industries, demand conditions, strategy, structure, rivalry, and chance. It also analyses the domestic and international challenges of 5G development in China.**

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## INTRODUCTION

The fifth-generation mobile communication technology (5G), which features high speed, low latency, and large connectivity, was first commercialised in South Korea in 2019 (Park, 2019). 5G, used in conjunction with artificial intelligence, extended reality, edge computing, and the Internet of Things (IoT), will provide tremendous benefits for businesses and society (PricewaterhouseCoopers, 2021). As a result, the development of 5G is becoming a central element of the social, economic, and political competitiveness of each country (Agiwal, Roy, & Saxena, 2016).

Numerous countries in the world, including China, the United States, Japan, South Korea, and some European countries, are participating in the 'race of 5G' (Herman, 2019). According to GSA (2022), 487 operators from 145 countries/regions were investing in 5G as of the end of 2021. The market is expected to reach $188 billion in 2025, reflecting a compound annual growth rate of 23 per cent (Research and Markets, 2021).

The development of 5G has enabled Chinese companies to enjoy technological and commercial leadership for the first time in the Internet age (Erie & Streinz, 2021). In 2019, the Chinese Ministry of Industry and Information Technology (MIIT) issued 5G licences to four major telecom operators, representing China's entry into the first year of 5G commercialisation (Wang, 2019). As the number of 5G users has increased, the proportion of 5G network access traffic to national mobile access traffic reached 17.3 per cent in 2020. By April 2021, with 260 million 5G mobile connections, China had established the world's largest 5G mobile network (Global Times, 2021). By the end of 2021, with strong support from the government, China had built and opened more than 1.3 million 5G base stations, and

TABLE 1: **The advantages of China's 5G industry**

| The role of government | Factor conditions | Related and supporting industries | Demand conditions | Strategy, structure, and rivalry | Chance |
|---|---|---|---|---|---|
| – Policy Support | – Number of Patents | – Basic Industrial Segments | – Huge Scale of Domestic Consumers | – Different service targets (2B & 2C) | – COVID-19 pandemic |
| – Financial Subsidies | – Infrastructure Capabilities | – Rapid Growth of Various Industrial Branches | – 2B Business Expansion | – Differentiated value-added services | – the Development of 6G |
| – Military-Civil Fusion | – Discourse Power in Standard Setting | | – Potential Market Overseas | | |
| | – Talent Development Strategy | | | | |

5G terminal users amounted to 497 million households (People.cn, 2021). Looking forward, China has started to launch 6G research and development (R&D) and is expected to play a leading role in 6G development (Global Times, 2021).

The Diamond model is a model proposed by Michael Porter (1990) that is widely used to analyse the competitive advantage of a national industry in international markets. Previous literature has adopted the Diamond model in analysing, among others things, the international competitiveness of China's service trade (Dong & Zhang, 2016), the Turkish tourism industry (Esen & Uyar, 2012), and the G20's renewable energy industry (Fang et al., 2018). In this chapter, we apply Porter's (1990) Diamond model to analyse 5G development and strategies in China and discuss why China's 5G is internationally competitive.

## DISCUSSION BASED ON THE DIAMOND MODEL

In the specific context of China, the government has played a crucial role in the development of 5G. Therefore, we first examine the role of the Chinese government in the development of 5G in China. We then apply each of the four attributes in the Diamond model to discuss 5G development and strategies in China. Moreover, we explore the chances for 5G development in China as an extended component. Finally, we analyse the domestic and international challenges for 5G development in China.

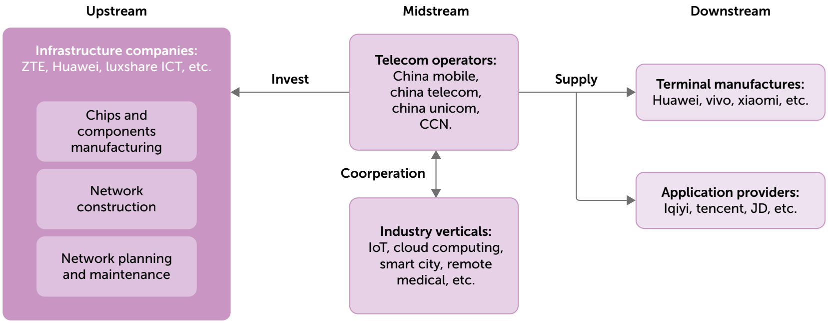
### The role of government

The Chinese government provides support for the development of the 5G industry through strategic planning, policy development, financial subsidies, and so on. It has been working closely with the technology industry to promote national technological innovation and economic development. In particular, the telecom operators holding 5G licences are all state-owned enterprises (Cardinale, 2021), implying that the government has played a crucial role since China began its 5G development in 2013.

In 2013, the MIIT, the National Development and Reform Commission, and the Ministry of Science and Technology convened the first meeting of the MT-2020 (5G) Promotion Group (CAICT, 2013). The 'Made in China 2025' policy released by the State Council in 2015 and the National Information Technology Plan launched in 2016 both emphasise the importance of R&D in 5G technology. In addition, the MIIT has issued documents such as the Information and Communication Industry Development Plan (2016–2020), which focused mainly on encouraging companies to engage in R&D in 5G technologies and standards. Since entering the phase of 5G commercialisation, government policies have begun to focus more on encouraging 5G network construction and the development of 5G applications. In 2021, the National People's Congress adopted the 14th Five-Year Plan and further proposed accelerating the extensive deployment of 5G and the prospective layout of 6G.

In addition, the Chinese government also provides substantial subsidies, either directly or indirectly, to 5G players (Jeon et al., 2020). Government subsidies have led to a significant increase in the number of Chinese 5G patents and the speed of construction, as well as a price advantage for 5G-related products. However, the Chinese government's heavy subsidy policy has been criticised by the English-speaking media as it could lead to a weakening of other competing companies and result in the world's critical infrastructure becoming too dependent on Chinese equipment (Bourke, 2020). Moreover, 5G technology is in line with the national

FIGURE 1: **The ecosystem of the 5G industry in China**




strategy of Military-Civil Fusion of the Communist Party of China,[1] which serves as a basic guarantee for the development of artificial intelligence, virtual reality (VR), and other high-end technologies.

### Factor conditions

Factor conditions refer to the elements that a country creates and updates for its industry production, such as technical innovation, infrastructure, skilled labour, and capital (Porter, 1990). In the case of China's 5G industry, the factor conditions are mainly reflected in the number of patents and in the development of infrastructure.

In 2021, China ranked first in the world in terms of the number of 5G standard essential patent declarations. Among its enterprises, China Mobile, one of the major telecom operators in China, has filed more than 3,300 5G patents and ranks high among global operators (Guo, 2021). Apart from the telecom operators, Chinese infrastructure companies and application providers have made significant contributions in terms of patents. For example, Huawei, which holds the largest number of core patents in 5G, has taken a major step towards patent realisation by starting to charge royalties to handset manufacturers (White, 2021).

As regards 5G infrastructure construction in China, by the end of 2021 the number of 5G base stations in China had exceeded 1.4 million, including more than 800,000 shared 5G base stations (Chinanews, 2022). China's 5G network has covered all prefecture-level cities, over 98 per cent of county cities, and 80 per cent of towns. The breadth and depth of network coverage is still increasing in China (Chinanews, 2022). Compared with European countries and the U.S., China's achievements in infrastructure development have benefited in part from the fact that the Chinese government has a higher level of jurisdiction over national assets (Lee, 2020).

Furthermore, China's 5G development cannot be achieved without skilled talent. According to the China Academy of Information and Communications Technology (CAICT), 5G will provide approximately 8 million jobs by 2030 (CAICT, 2017). Chinese 5G companies have been training 5G talent for themselves. For example, Huawei provides comprehensive 5G training courses and has trained more than 440,000 5G talents for the industry so far (Chen, 2020).

### Related and supporting industries

Although not fully developed, China's 5G industry chain has international advantages in terms of the speed of development and the degree of readiness of the chain segments. The key elements of 5G industry development are almost in place, and companies in China's 5G industry chain are in a rapid growth phase (CAICT, 2021). In general, the 5G industry chain can be divided into three parts: upstream, midstream, and downstream. However, there is overlap in the business scope of these three parts, and the same player may be engaged in different types of business at the same time. For example, Huawei is not only engaged in base station construction but is also a world-renowned cell phone manufacturer.

As shown in Figure 1, enterprises such as ZTE and Huawei, which are engaged in the manufacturing of chips and components, base station and network construction, and network planning and maintenance, belong to the upstream of the industry. They have laid the foundation for the construction and investment of large-scale 5G networks (Ge, 2020).

As for the midstream, the four major telecom operators invest in the upstream enterprises to improve the coverage of their 5G signals. Furthermore, unlike the 4G era, the midstream of the 5G industry also includes a variety of industry verticals. In other words, with the increasing demand for digitalisation and intelligence in various industries, China Telecom, China Unicom, and China Mobile have extended their business to the fields of intelligent manufacturing, intelligent network connection, intelligent medical care, intelligent education, and so forth (GSMA, 2021).

The downstream of the industry is mainly focused on the level of applications, including end manufacturers and application providers. During the commercial phase of 5G, numerous downstream application scenarios have already attracted huge technology and capital investment. Many Internet giants, such as Tencent, are also working on 5G+video and other businesses (163.com, 2021). However, currently there are not many 5G applications in the downstream industry that already have a high level of technical maturity and a clear business model.

### Demand conditions

The rapid development of 5G in China is inseparable from the huge market demand. China's 5G industry has not only the largest user base in the world but also business demand from the government and enterprises. In addition, the implementation of policies such as the Belt and Road Initiative has driven the development of China's overseas markets.

China's population of 1.4 billion is the largest of any country in the world and is at the forefront of digitisation and Internet penetration in society. According to operational statistics released by China Telecom, China Unicom, and China Mobile, China already had 730 million 5G subscribers as of January 2022 (Sharwood, 2022). Users' increasing demand for network performance while enjoying VR, cloud gaming, and ultra-high-definition (HD) video services has also boosted the rapid development of the 5G industry.

Unlike previous generations of cellular network technology, the development of 5G is shifting from the consumer Internet to the industrial Internet, bringing new incremental growth for players. Numerous new application scenarios, including telematics, smart cities, energy/utility monitoring, and smart homes, have high reliability and low latency requirements for communications, which creates new market segments for the 5G industry. These application scenarios show greater potential and development space, with broad market prospects.

China is not only developing 5G domestically but is also participating in 5G-related infrastructure development in other countries globally through investments and acquisitions. China's Belt and Road Initiative has helped the 5G players open up the market for other Eurasian and African countries to build digital infrastructure.

### Strategy, structure, and rivalry

In order not to be subject to Western 5G technology and standards, China's major 5G players have concentrated on investing in 5G technology R&D. With regard to promoting 5G business and services, Chinese telecom operators believe that 2B (to business) is the main force in the 5G era. 2B business has become the main driver of revenue growth, because it promotes the development of 5G applications and traffic growth. As for 2C (to consumers) services, telecom operators have increased their investment in content, using HD video, VR/augmented reality, and cloud games as breakthroughs to create rich 5G application scenarios and to rapidly increase the scale of new users and enhance customer stickiness. In terms of competing for 5G business, the three telecom operators have shifted their focus from price competition to providing differentiated value-added services. China's three largest telecom operators have adopted different approaches to generating revenue and attracting traffic. China Mobile has created its own content platforms and products, while China Unicom and China Telecom have mainly relied on purchasing existing video and entertainment content products (Aixdlun, 2020).

### Chance

The COVID-19 pandemic has expanded the demand for telecommunications, which has driven Chinese investments in capital expenditure and R&D in 5G technology. China is expected to account for $1.5 trillion in the 5G value chain in 2035, about $400 billion more than the $1.1 trillion forecast for 2019 (IHS Markit, 2020). In addition, the demand for telecommuting, distance learning, telehealth/medicine, online retail, and e-commerce generated by the epidemic will continue. These services cannot be provided without low-latency 5G technology, thus providing opportunities for 5G development in China.

China's leadership in 5G drives its development of 6G, and the development of 6G will, in turn, drive the continuous development of 5G. According to the *Global Times*, China's telecom operators started the basic development of 6G network infrastructure around 2019 (Li & Xiong, 2021). Chinese telecom operators are working to build their own 6G network systems and reduce their reliance on patents developed by foreign companies. At the end of 2021, China was ranked first in the world with 40.3 per cent of patent applications in nine major areas related to 6G (Yang, 2021). From a long-term perspective, the innovative R&D of 6G technology will also boost the expansion of 5G industry capacity and the speed of related facility construction deployment.

## THE CHALLENGE

The development of 5G in China has not always been plain sailing. The three major telecom operators' spending on 5G and the pace of 5G base station construction by companies such as Huawei and ZTE all declined in the first half of 2021 (Li & Kawase, 2020). This indicates that after a period of rapid development, the further deployment and development of 5G may face constraints and bottlenecks. These challenges are not only domestic but also international.

The first domestic challenges facing China's 5G development is the huge investment required (Midatala, 2020). Although the central and local governments have been supporting the construction of 5G networks by establishing financial subsidies and by other means (Liu et al., 2017), the development of 5G in China has still been confronted by the problem of high costs. Furthermore, having been affected by the US–China trade war, China considers 5G construction more as a kind of international competitiveness. Policies that promote greater intervention, such as accelerating network construction, especially by local Chinese governments, may have a negative impact on firm value (Jeon et al., 2020). In addition, compared with the 4G era, 5G development not only requires more investment for more intensive base station construction, but also faces higher operational costs of 5G networks, including maintenance costs and power consumption expenses (Qian et al., 2015).

Another domestic challenge is that the complete industrial ecology of 5G has not yet been estab-

## The development of 5G in China has not always been plain sailing

lished. At present, the development of 5G is mainly driven by operators, but there is not enough cooperation among other players in the industry, such as hardware manufacturers and application service providers (Qian, 2021). For example, there are currently no 'killing' applications on the market dedicated to 5G (Hu, 2021). As a result, it might be difficult for users to perceive the benefits of 5G development. Moreover, telecom operators in the 4G era and earlier mainly provided 2C services, but the development of 5G involves more 2B services (Hu, 2021). The new types of services may have completely different hardware and software requirements for different industries and enterprises, bringing new challenges to 5G players.

In addition, the security and environmental issues involved in the development of 5G are also worth considering. 5G development with better convergence of cloud, data, and the IoT may lead to new and potentially greater security risks (Kechiche, 2021). In particular, cybersecurity is often highly correlated with national security in China (Cheung, 2018). As for environmental issues, China's 5G development still faces huge pressure from power consumption. With the rapid construction of base stations in China, no sufficiently effective solution has been found for the excessive carbon emissions caused by the massive power consumption. This type of development, which is not environmentally friendly, may not be sustainable.

In addition to facing domestic cost, industrial ecology, security, and environmental issues, China's 5G development is also currently threatened by the international situation. The main challenges are reflected in international cooperation and import restrictions. Countries with security concerns about China's 5G network equipment may not cooperate with China on 5G. China has been accused of installing backdoors in cellular network devices for its international intelligence activities (Bryan-Low et al., 2019). Chinese laws, such as the Cybersecurity Law, have been criticised for forcing companies (including foreign companies) to assist national intelligence agencies in gathering information (Bryan-Low et al., 2019). As a result, Australia, Japan, the United Kingdom, the United States, and European Union countries including Bulgaria, Czech Republic, Estonia, Latvia, Poland, Romania, Slovakia, Slovenia, and Sweden, have banned Chinese 5G terminal manufacturers (i.e., Huawei Technologies Co., ZTE Corp., and Hytera Communications Corp.) from their 5G networks for security reasons (Noyan, 2021; Chikermane, 2020). While some countries have not explicitly blocked Huawei from the 5G network, they have prohibited local telecom operators from working with Huawei on 5G. For example, by banning the country's telecom companies from renewing licences for 5G equipment purchased from Huawei, France is set to gradually eliminate 5G equipment from Huawei by 2028 (Gehrke, 2020). There are also countries where telecom operators have chosen to prioritise cooperation with companies other than Huawei. For instance, Singapore's largest telecom operators Singtel and StarHub have chosen Ericsson and Nokia, two European 5G network equipment suppliers, to develop the country's telecom network (AsiaNews.it, 2020). Huawei only has a presence in the Singapore market through TPG Telecom's small local network system (AsiaNews.it, 2020).

Major 5G terminal manufacturers in China also face import blockage of semiconductors and related accessories for their 5G products. China is highly dependent on the import of integrated circuits. According to China's General Administration of Customs, China's total chip imports (635.48 billion

China's rapid development of 5G has laid a good foundation for the development of 6G in the future

units) and import value (nearly $432.6 billion) both hit record highs in 2021. However, the tightening of chip export policies in many countries will bring uncertainty to the development of 5G in China. For example, the US Department of Commerce banned US companies from supplying chips to ZTE for seven years beginning in 2018 (Wu, 2018). It has subsequently increased chip export controls for Huawei in 2021, prohibiting US companies from dealing with foreign manufacturers that supply semiconductors to Huawei (Boehm, 2021) and requiring additional US government export licences for manufacturers that use US equipment or software to design or manufacture semiconductor chips for Huawei (Shi, 2020).

## CONCLUSION

By focusing on China's 5G industry, this chapter has applied the Diamond model to discuss the development strategies and challenges that 5G players are facing. As China is at the forefront of the global race in 5G and even 6G industries, discussing its advantages and challenges may provide a reference for other countries.

The development of China's 5G industry is not only supported by the government, but it also has advantages in terms of development factors, industry chain, user demand, and competitive strategies. Firstly, the rapid development of 5G in China has benefited from the Chinese government's policy support and financial subsidies. The Chinese government has formulated policies to encourage the development of 5G networks and 5G applications and has provided 5G players with subsidies for 5G patent research and development, accelerated construction, and reduced prices of 5G products.

Secondly, China's 5G industry has a world-leading number of patents, a well-developed industry structure, influence in shaping technical standards, and a talent development strategy, all of which are important factors in promoting the development of 5G in China. Thirdly, China's 5G industry chain is robust, with upstream, midstream, and downstream segments all developing rapidly. Fourthly, China has the necessary demand conditions for 5G development, with a large subscriber base and expanding 2B business and overseas markets.

Finally, Chinese 5G operators have adopted different service strategies to address 2B and 2C business, developing differentiated value-added services to improve their competitiveness in the market. Currently, the COVID-19 pandemic also presents opportunities for the development of 5G in China. Looking forward, China's rapid development of 5G has laid a good foundation for the development of 6G in the future. The experiences China has gained in 5G development can be used as a reference for European countries. European countries can explore their own development models, tailored to their national conditions and characteristics. An analysis of the opportunities and challenges of 5G development in China may help to facilitate the development of 5G and 6G in Europe.

### NOTE

1. Military-Civil Fusion (MCF) is a Chinese national military modernisation strategy that aims to transform the People's Liberation Army (PLA) into a 'world-class army'. See Joshi (2022).

### REFERENCES

Agiwal, M., Roy, A., & Saxena, N. (2016). 'Next Generation 5G Wireless Networks: A Comprehensive Survey'. *IEEE Communications Surveys & Tutorials*, 18(3), 1617–1655. https://doi.org/10.1109/comst.2016.2532458.

Aixdlun. (2020). 'Content + 5g, Telecom Operators Who Ignore Their Proper Occupations Have Found a New Way Out?' JMedia, 14 December (in Chinese).

AsiaNews.it. (2020). '5G Internet Networks: Singapore Says No to Huawei'. PIME Asianews, 25 June.
Boehm, E., Welch, M., Linnekin, B., Regan, S., Watkins, T., Walker, J., & Binion, B (2021). 'A Silicon Curtain Descends'. Reason.com, 11 January.
Bourke, L. (2020). Why Are Huawei and 5G Such a Big Deal Around the World? *The Sydney Morning Herald*, 14 February.
Bryan-Low, C., Packham, C., Lague, D., Stecklow, S., & Stubbs, J. (2019). Hobbling Huawei: Inside the U.S. War on China's Tech Giant'. Reuters, 21 May.
CAICT (China Academy of Information and Communications Technology). (2013). 'Minister of MIIT Miao Wei attended the first meeting of the IMT-2020 (5G) Promotion Group and awarded an appointment letter to the group leader, President Cao Shumin' (in Chinese)
CAICT (China Academy of Information and Communications Technology). (2017). 'White Paper on the Economic and Social Impact of 5G'. June.
CAICT (China Academy of Information and Communications Technology). (2021). 'White Paper on 5G Development and Economic and Social Impact in China'. December.
Cardinale, R. (2021). 'State-Owned Enterprises' Reforms and Their Implications for the Resilience and Vulnerability of the Chinese Economy: Evidence from the Banking, Energy and Telecom Sectors'. *Networks and Spatial Economics*, 1–26. https://doi.org/10.1007/s11067-021-09540-x.
Chen, X. (2020). '"White Paper on New Ideas for 5G Talent Development" released, people-oriented will help the industry to accelerate'. *The Paper*, 11 November (in Chinese).
Cheung, T. M. (2018). The Rise of China as a Cybersecurity Industrial Power: Balancing National Security, Geopolitical, and Development Priorities'. *Journal of Cyber Policy*, 3(3), 306–326. https://doi.org/10.1080/23738871.2018.1556720.
Chikermane, G. (2020). Predictable, Shabby, Amusing: China's Reactions to Countries Banning Huawei'. ORF, 22 October (in Chinese).
Chinanews. (2022). 'China Has Opened More Than 1.4 Million 5g Base Stations, and 5g Mobile Terminal Connections Have Reached 518 Million'. 20 January (in Chinese).
Dong, D. X. & Zhang, Q. (2016). 'Empirical Analysis on International Competitiveness of China's Service Trade on the Basis of Diamond Model. In *2nd International Conference on Economy, Management, Law and Education (EMLE)*, December, 39–43. https://doi.org/10.2991/emle-16.2017.8.
Erie, M. S., & Streinz, T. (2021). 'The Beijing Effect: China's "Digital Silk Road" as Transnational Data Governance'. *New York University Journal of International Law and Politics (JILP)*, 54(1). https://ssrn.com/abstract=3810256.
Esen, S. & Uyar, H. (2012). 'Examining the Competitive Structure of Turkish Tourism Industry in Comparison with Diamond Model. *Procedia-Social and Behavioral Sciences*, 62, 620–627. https://doi.org/10.1016/j.sbspro.2012.09.104.
Fang, K., Zhou, Y., Wang, S., Ye, R., & Guo, S. (2018). 'Assessing National Renewable Energy Competitiveness of the G20: A Revised Porter's Diamond Model'. *Renewable and Sustainable Energy Reviews*, 93, 719–731. https://doi.org/10.1016/j.rser.2018.05.011.
Ge, Q. (2020). 'In-Depth Analysis and Summary of China's New Infrastructure 5G Industry Chain Panorama in 2020 (in Chinese).
Gehrke, L. (2020). France introduces de facto ban on Huawei 5G equipment by 2028 Politico, 23 July.
Global Times. (2021). China Rolls Out the World's Largest 5G Network: MIIT. 19 April.
GSA. (2022). '5G Market Snapshot 2021 – End of Year'. 6 January.
GSMA. (2021). 'China 5G Vertical Industry Use Cases 2021'.
Guo, J. (2021). 'China Mobile Has Over 560,000 5G Base Stations, the Largest in the World'. *China Daily*, 2 November (in Chinese).
Herman, A. (2019). 'The War for the World's 5G Future'. *Forbes*, 10 April.
Hu, S. L. (2021). 'China's 5G Development Faces Four Major Challenges'. *Communication Management and Technology*, 1, 12–14 (in Chinese).
IHS Markit. (2020). The 5G Economy in a Post-COVID-19 Era: The Role of 5G in a Post-Pandemic World Economy'. Qualcomm, November.
Jeon, C., Han, S. H., Kim, H. J., & Kim, S. (2020). The Effect of Government 5G Policies on Telecommunication Operators' Firm Value: Evidence from China'. *Telecommunications Policy*, 46(2), 102040. https://doi.org/10.1016/j.telpol.2020.102040.
Joshi, M. (2022). 'China's Military-Civil Fusion Strategy, the US Response, and Implications for India'. ORF, 27 January.
Kechiche, S. (2021). Securing Private Networks in the 5G Era'. June.
Lee, N. T. (2020). 'Navigating the US–China 5G Competition'. Brookings, 27 April.
Li, L. & Kawase, K. (2020). 'Huawei and ZTE Slow Down China 5G Rollout as US Curbs Start to Bite'. Nikkei Asia, 19 August.
Li, X. & Xiong, X. (2021). China Aims to Commercialize 6G by 2030: White Paper'. *Global Times*, 6 June.
Liu, Q., Shi, X., Wang, X., & Li, J. (2017). '5G Development in China: From Policy Strategy to User-Oriented Architecture'. *Mobile Information Systems*, 2017, 1–11. https://doi.org/10.1155/2017/2358618.
Midatala, S. (2020). 'Top 7 Challenges Faced During 5g Network Deployment'. TelecomLead, 23 October.

Noyan, O. (2021). 'EU Countries Keep Different Approaches to Huawei on 5G Rollout'. Euractiv.com, 20 May.

Park, J. (2019). 'S.Korea First to Roll Out 5g Services, Beating U.S. and China'. Reuters, 3 April.

People.cn. (2021). 'Ministry of Industry and Information Technology: Over 1.3 Million 5G Base Stations Have Been Built and Opened, with 497 Million 5G End Users'. 12 December (in Chinese).

Porter, M.E. (1990). 'The Competitive Advantage of Nations'. *Harvard Business Review*.

PricewaterhouseCoopers. (2021). 'The global economic impact of 5G'.

Qian, L. F. (2021). 'Today, China 5G is Two Years Old' (in Chinese).

Qian, M., Wang, Y., Zhou, Y., Tian, L., & Shi, J. (2015). 'A Super Base Station Based Centralized Network Architecture for 5G Mobile Communication Systems'. *Digital Communications and Networks*, 1(2), 152–159. https://doi.org/10.1016/j.dcan.2015.02.003.

Research and Markets. (2021). '5G Services Global Market Report 2021: COVID-19 Growth and Change to 2030'. September.

Sharwood, S. (2022). 'China Signs Up 400 Million New 5G Subscribers in a Year, More Than Doubling User Population'. *The*, 21 January.

Shi, S. (2020). TSMC Says It Will Stop Shipping to Huawei within Two Months'. FTChinese, 17 July (in Chinese).

Wang, R. (2019). 'China's 6G R&D Officially Launched'. People.cn, 7 November (in Chinese).

White, E. (2021). 'Demystifying the 5G Standard Essential Patent Landscape: Phase 2'. Clarivate, 29 October.

Wu, M. (2018). 'U.S. Investigates Huawei, Worried about Falling Behind China in 5G Competition'. People.cn, 2 May (in Chinese).

Yang, Q. (2021). 6G Battle for Supremacy, China Takes a Big Lead'. *Commercial Times*, 18 November (in Chinese).

163.com. (2021). 'Baidu, Tencent, and Other Companies Joined the 5G + Video Ringtone Industry Alliance "Circle of Friends"' (in Chinese).

# Leadership in 5G: The Korean Example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**ABSTRACT**

**Since the early 1990s, Korea has been on the front lines of the exponential development and deployment of mobile networks. The Korean government's interventionist approach as well as its role as a catalyst in technological and business innovation have enabled the country to become the epicentre of an advanced 5G mobile environment. Korea became the first country in the world to launch a nationwide 5G network and to commercialise 5G services. As of January 2022, Korea had registered 21.56 million 5G subscribers, roughly 42 per cent of the total population in the country. Though 5G network availability is still limited and there is a lack of killer applications, the Korean government plans to be a leader in the sixth generation (6G), beyond 5G.**



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### INTRODUCTION

The Korean government has played a crucial role in the development of advanced mobile networks, including 5G. The government has not only created a tailored institutional arrangement but also facilitated collaborative work between companies, research institutes, and universities in Korea. Accordingly, Korea became the first country in the world to launch a nationwide 5G network and to commercialise 5G services. In addition, Korea is known as one of the most connected nations globally. In fact, almost everyone in Korea enjoys mobile broadband connection with their own smartphone. 5G subscribers in Korea totalled 21.56 million by the end of January 2022, corresponding to roughly 42 per cent of the total population in the country (The Chosunilbo, 2022). Korea has also covered all households with about 22.95 million broadband internet subscriptions (MSIT, 2022). Furthermore, with the advanced 5G network and a unique online gaming culture, Korea is regarded as the ideal location for exploring cloud gaming services (Park & Kim, 2021). Korea's globally acknowledged leadership in 5G is unprecedented. Therefore, this chapter aims to explain how Korea could become a first mover globally in the field of 5G.

### THE UPS AND DOWNS IN THE DEPLOYMENT OF PREVIOUS-GENERATION MOBILE NETWORKS

The Korean leadership in mobile communications networks might be said to start from the development of code division multiple access (CDMA) technology and the commercialisation of its service. In June 1993, the Korean government announced that 2G mobile network operators (MNO) should provide the digital service of the CDMA system from 1995. The Korean government not only chose CDMA as the technological standard but also executed new policies to support its development, and Korean MNOs were the first to try to commercialise the service.

In addition, following the 1997 Asian financial crisis, the Korean government promoted information and communications technology (ICT) to assist in its economic recovery and facilitated the development of broadband infrastructure. The government's interventionist approach contributed to transforming Korea from one of the poorest to one of the most developed countries in ICT (Park & Kim, 2014).

Based on the success of the development of CDMA and the corresponding growth of the Korean mobile communications market, the Korean government tried to develop WiBro, short for 'Wireless Broadband', Korea's homegrown portable Internet services technology. Firstly, the government expected to benefit from the intellectual property rights of WiBro in the emerging global mobile broadband market (Nam, Kim, & Lee, 2008). At the time, Korean MNOs were paying substantial amounts of money in CDMA royalties to Qualcomm for using its source technologies for mobile communications. Secondly, 3G International Mobile Telecommunication 2000 (IMT-2000) systems seemed inadequate for accommodating the steadily increasing amount of data traffic, and thus the market needed additional capacity. Thirdly, Korea was seeking another opportunity to be a leader in the mobile communications market after its success as the first country to implement the commercial launch of CDMA. WiBro represented one of Korea's first attempts to create its own mobile communications technology during the era of the third generation (3G) of mobile communications technology (Massaro & Kim, 2022).

In 2004, the Korean government announced the 'IT839' growth strategy, and WiBro was one of the core services to be nurtured under this project. The International Telecommunication Union (ITU) selected WiBro as the sixth global standard for 3G telecommunications. In the meantime, the Korean government granted WiBro business licences to existing MNOs who had other technologies in competition with WiBro. However, the Voice Over Internet Protocol (VoIP) licence for WiBro service was delayed. Since Korean MNOs already had alternative network technologies such as HSDPA-based services and 4G LTE technology, they had fewer incentives to put their best efforts into WiBro. Accordingly, despite the promising potential of WiBro, it did not succeed in the Korean mobile communications market (Park, Kim, & Nam, 2015).

## THE EARLY TRANSITION TO THE 5G NETWORK

Mobile communications technology has experienced numerous technological advances from the initial launch of 1G in the late 1970s to that of the powerful 4G in 2009. The generational transition of mobile networks is very important because the spread of a next-generation mobile broadband network has a positive spillover effect of improving corporate productivity and creating new business opportunities by delivering information faster and more efficiently. Beyond its effect of promoting economic growth, the transition to the 5G network is important because 5G technology will be at the heart of the Fourth Industrial Revolution, which will radically change every aspect of our lives. Unlike previous generations, 5G can offer unprecedent levels of connectivity. 5G technology is a powerful tool in building Internet of Things (IoT)-based communication between devices and can be used as an infrastructure to create inter-industry convergence. 5G service has up to 20 Gbps speed. In other words, it is 20 times faster than 4G. In the 5G environment,

> 5G subscribers in Korea totalled 21.56 million by the end of January 2022 . . . roughly 42 per cent of the total population

users can download a movie in a few seconds and watch virtual reality or ultra-high-definition videos in real time (Kwon & Kim, 2021). Recognising the value and potential of 5G technology, Korea has tried to realise its 5G vision.

Based on its experience with the WiBro case, the Korean government has moved away from a pure interventionist approach to 5G. Instead, it has tried to play the role of a catalyst in technological and business innovation. The Korean government established the 5G Forum as an arena in which ideas can be exchanged and collaborations formed. It has also made dedicated efforts to expand its global network for multilateral cooperation in the context of 5G. Several international events centred on 5G have been hosted by Korea over the years and various memorandums of understanding have been signed for 5G alliances across the globe (MSIT, 2017).

The global attention directed towards the Korean Olympic Games accelerated the international standardisation process of 5G, which, in turn, helped Korea begin the process of commercialising 5G services almost one year ahead of schedule (ITU, 2018). The Pyeongchang Olympics, held in February 2018, marked one of the most important milestones in 5G development in terms of both accelerating technology development and attracting public attention for the successful commercialisation of 5G services. Korea used the event to ensure its 5G leadership by becoming the first in the world to set up a full 5G network and demonstrating a variety of services (Maeil Business News Korea, 2019).

In June 2018, the Korean government held one of the world's first 5G spectrum auctions, one year earlier than initially planned (Ryu, Kim, & Oh, 2020). 280 MHz in the 3.5 GHz band and 2400 MHz in the 28 GHz band were awarded to the three major Korean MNOs, SKT, KT, and LGU+. The 3.5 GHz band was divided into 28 blocks of 10 MHz width, and the 28 GHz band was divided into 24 blocks of 100 MHz width. Each MNO had a ten-block cap per spectrum band (Massaro & Kim, 2022).

The starting price for the 3.5 GHz band was KRW 2.65 trillion (US$ 2.49 billion), and the initial price for the 28 GHz band was KRW 621.6 billion (US$ 0.56 billion). Licence durations were set at ten and five years, respectively, for the 3.5 GHz and 28 GHz bands. MNOs could start using the 5G frequencies in December 2018. SKT and KT were awarded ten blocks each in the 3.5 GHz band, while LGU+ won access to eight blocks. All three MNOs secured 800 MHz of the 28 GHz band, despite a higher spectrum cap set at 1000 MHz. The MNOs paid a total of KRW 3.6183 trillion (about US$3.3 billion) for their licences (Kim et al., 2020). In the 3.5 GHz range, SKT paid nearly KRW 1.22 trillion (US$1.09 billion), KT paid KRW 968 billion (US$870 million), and LGU+ acquired spectrum for about KRW 809.5 billion (US$730 million). In the 28 GHz segment, each MNO paid about KRW 207 billion (US$186 million), corresponding to the reserve price (Yonhap News Agency, 2018).

The Korean government attached an obligation to the spectrum licences for the 3.5 GHz band to instal 45,000 base stations within five years, that is, by the end of 2023, numbering up to 150,000 base stations within ten years. MNOs invested in 5G network deployment on a large scale across the country, covering 85 cities, corresponding to 90 per cent of the population (KISDI, 2020). Initial efforts of network deployment were directed at serving highly populated areas such as universities, high-speed trains, and metropolitan subways, aiming at 100 per cent population coverage by 2022 (Yonhap News Agency, 2020).

> The Korean government promoted ICT to assist in its economic recovery and facilitated the development of broadband infrastructure

Leveraging the technical expertise it had developed over the years, Korea was able to play a leading role in developing 5G standards to catch up with the foreign tech giants. Learning from past experiences, Korean tech companies developed clear visions about 5G ahead of their international counterparts and played an active role in the global research and standardisation community. Public investments in ICT research and development supported public research institutes and companies in developing technical standards. With 5G, Korea eventually succeeded in reaching mobile technology independence and becoming a frontrunner in mobile communications technology (Massaro & Kim, 2022). In particular, the contributions of the Electronics and Telecommunications Research Institute, Samsung Electronics, LG Electronics, and KT in the standardisation process for 5G made Korea the country with the highest number of 5G patents.

In December 2018, MNOs launched limited 5G commercial services in Seoul and six other metropolitan areas (Busan, Incheon, Daegu, Daejeon, Ulsan, and Gwangju). 5G mobile services were first launched for corporate customers (B2B) and were based on mobile routers. The commercialisation of 5G services for consumers using a smartphone-type terminal began in April 2019, eight months before the planned deadline of December 2019 (Kim et al., 2020). At 11 pm on 3 April 2019, a limited number of Korean celebrities became the first 5G users. Mass commercialisation began on 5 April (The Guardian, 2019).

Korean MNOs made considerable efforts in aggressive marketing campaigns and offered large-scale subsidies for mobile devices to make 5G-enabled devices attractive to customers. MNOs established partnerships with various content providers to offer service experiences and other enhanced media applications. In June 2019, Korea registered 1.6 million 5G subscribers, which amounted to 77.5 per cent of 5G subscribers worldwide at the time. As of January 2022, Korea had registered 21.56 million 5G subscribers, roughly 42 per cent of the total population in the country (The Chosunilbo, 2022).

One major issue in Korea is that 5G network availability is still limited, which has led to many consumer complaints. Korean MNOs achieved the government-set target of installing 45,000 base stations in the 3.5 GHz band during the second year of commercialisation. As of January 2022, 202,903 5G base stations had been installed. However, this is less than a quarter of the number of 4G base stations in the country (The Chosunilbo, 2022). In March 2021, thousands of 5G subscribers banded together in a class action lawsuit against the MNOs, demanding compensation for the poor quality of their services, which did not meet the promised ultra-fast download speed and ubiquitous availability. There are several geographical areas of the country, especially rural areas, that are still not covered by 5G networks based on the 3.5 GHz band. The COVID-19 pandemic has also caused delays to network deployment. In April 2021, the three main Korean MNOs signed an agreement whereby they would share their infrastructure to extend 5G coverage to remote coastal and rural areas. According to a recent survey of 1,000 5G users conducted by local civic organisation Voice for Consumers, the average amount of 5G data consumers received from mobile carriers was 60.9 gigabytes while their actual data usage averaged 31.1 gigabytes. The survey indicates consumers are not using 100 per cent of their data due to the narrow coverage of 5G or a lack of desirable content (The Korea Times, 2022a).

In addition, the main obstacle to the full success of the 5G system in Korea seems to be the lack of killer applications. Korean MNOs need to look for consumer killer applications that can fuel business growth. Moreover, regulatory challenges that slow down the emergence of new business models in vertical industries need to be tackled. Accordingly, companies in the vertical industries are adopting a wait-and-see approach because of the great uncertainty associated with finding fruitful industrial-use cases for 5G, with high risks related to returns on investments (Massaro & Kim, 2022).

The Korean government is exploring the possibility of assigning local licences to different kinds of actors for the deployment of private networks tailored to the needs of, for instance, factories, ports, and airports. In this respect, the formation of a 5G+ Industrial Ecosystem Policy Council was announced to discuss mid- to long-term policies to strengthen the competitiveness of the Korean 5G+ ecosystem.

## WRAP-UP: BEYOND 5G AND TOWARDS 6G

Since the early 1990s, mobile networks have experienced tremendous deployment and Korea has been on the front lines of this development. The Korean government's interventionist approach as well as its role as a catalyst in technological and business innovation enabled the country to become the epicentre of an advanced 5G mobile environment.

The Korean government plans to be a leader in the sixth generation (6G) beyond 5G. It is expected to again play the role of catalyst to facilitate the development of 6G technologies, defined as Internet speeds 50 times faster than 5G and expanded maximum altitude for service coverage to 10 kilometres. Its full commercialisation is expected between 2028 and 2030 (The Korea Times, 2022b). Looking into the future, towards 6G, the Korean government would favour the balanced co-evolution of all the components coexisting within the ecosystem.

## REFERENCES


The Chosunilbo. (2022). '3 Years After the World-First Commercialization of 5G'. 28 March. https://www.chosun.com/economy/tech_it/2022/03/28/TEB5BPTN2JGIBICGEFMFCSQYGU/?utm_source=naver&utm_medium=referral&utm_campaign=naver-news.

The Guardian. (2019). 'US Dismisses South Korea's Launch of World-First 5G Network as "Stunt"'. 4 April. https://www.theguardian.com/technology/2019/apr/04/us-dismisses-south-koreas-launch-of-world-first-5g-network-as-stunt.

ITU (International Telecommunication Union). (2018). 'KT Showcases 5G Innovation at the Olympics in Pyeongchang'. https://news.itu.int/kt-showcase-5g-olympics/.

Kim, D.K., Lee, H.-W., Lee, S.-C., & Lee, S. (2020). '5G Commercialization and Trials in Korea'. *Communications of the ACM*, 63(4), 82–85.

KISDI (Korean Information Society Development Institute). (2020). '2020 ICT Industry Outlook of Korea'. https://www.kisdi.re.kr/report/view.do?key=m2101113024770&arrMasterId=3934580&masterId=3934580&artId=557537

The Korea Times. (2022a). 'Consumers Dissatisfied with Low 5G Quality'. 17 January. http://www.koreatimes.co.kr/www/tech/2022/01/129_322418.html.

The Korea Times (2022b). 'ICT Minister Promotes Korea's Advanced 5G Technology at MWC'. 2 March. http://www.koreatimes.co.kr/www/tech/2022/03/129_324821.html.

Kwon, H. & Kim, S. (2021). 'Effects of the Development of Competition Framework and Legal Environment for Media Contents on the Generational Transition of Mobile Networks'. *Telematics and Informatics*, 63, 101667.

Maeil Business News Korea. (2019). 'Korea Ranks No.1 in 5G Leadership: ADL Study'. 6 March. https://pulsenews.co.kr/view.php?year=2019&no=135017.

Massaro, M. & Kim, S. (2022). 'Why Is South Korea at the Forefront of 5G? Insights from Technology Systems Theory'. *Telecommunications Policy*, 46(5), 102290. https://doi.org/10.1016/j.telpol.2021.102290.

MSIT (Ministry of Science and ICT). (2017). '2017 Annual report on the promotion of the Korean ICT industry' (summary). https://www.msit.go.kr/publicinfo/view.do?sCode=user&mPid=62&mId=63&publictSeqNo=331&publictListSeqNo=5&formMode=R&referKey=331,5

MSIT (Ministry of Science and ICT). (2022). 'Broadband subscribers'. http://www.index.go.kr/potal/main/EachDtlPageDetail.do?idx_cd=1348.

Nam, C., Kim, S., & Lee, H. (2008). 'The Role of WiBro: Filling the Gaps In Existing Mobile Broadband Technologies'. *Technological Forecasting and Social Change*, 75(3), 438–448.

Park, J., Kim, S. & Nam, C. (2015). 'Why Has a Korean

Telecommunications Technology Failed: A Case Study on WiBro'. *Telematics and Informatics*, 32(4), 603–612.
Park, J. & Kim, S. (2021). 'A Case Study on Business Models of Cloud Gaming Services in Korea'. *The Journal of Korean Institute of Communications and Information Sciences*, 46(11), 2000–2012.
Park, S. & Kim, G.J. (2014). 'Lessons from South Korea's Digital Divide Index (DDI)'. *Info*, 16(3), 72–84.
Ryu, J.M., Kim, K., & Oh, A.S. (2020). '5G in Korea: Lessons for the Developing World'. World Bank Blogs. https://blogs.worldbank.org/eastasiapacific/5g-korea-lessons-developing-world.
Yonhap News Agency. (2018). 'SKT and KT Obtained Enough Spectrum for 5G 3.5GHz'. 18 June. https://news.einfomax.co.kr/news/articleView.html?idxno=3453933.
Yonhap News Agency. (2020). '5G Availability in S. Korea at Just 15 Pct: Report'. 30 June. https://en.yna.co.kr/view/AEN20200630002451320.

# 5G Development and Use Cases in Thailand: Collaboration vs Competition


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**ABSTRACT**

**Although initially a laggard in mobile technology adoption, Thailand is now among the first group of 5G commercial users. Thailand's national regulatory agency plays a vital role in spectrum planning, spectrum auction, and related regulation in 5G development. Supportive roles from government ministries have also had a significant impact on this development. Further, the Thai government has set up a dedicated 26-member committee to facilitate and promote 5G. The chapter urges collaboration between institutions in order to facilitate 5G development and implementation.**



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**INTRODUCTION**

Thailand was ranked 51st in the Network Readiness Index in 2020 and was simultaneously ranked the third-most network-ready economy in South East Asia, after Singapore and Malaysia. Thailand's mobile and fixed telecommunications infrastructure has seen remarkable development in recent years, with mobile network coverage of 3G and 4G reaching 98.72 per cent and 93.56 per cent respectively of Thailand's population nationwide. Moreover, fixed broadband is now reported to reach more than 74,000 villages in Thailand, with mobile and fixed broadband penetration above the global average at 91.52 per cent (65.23 million subscribers) of the population and 57.19 per cent of household penetration, respectively (NBTC, 2021b). The average monthly mobile data consumption per user in 2021 was 24.9 gigabytes (AIS, 2021), which saw an annual compound annual growth rate of 27.55 per cent over the past three years.

However, Thailand's adoption of 3G and 4G technologies was considered late, with Thailand's communications regulator (the National Broadcasting and Telecommunications Commission, or NBTC), having had its first spectrum auctions in 2012. From 2012 onwards, the NBTC gradually implemented spectrum auctions, with a 3G auction in 2012 and another in 2015 for 4G.

While early adopter countries such as Germany, the United Kingdom, and Sweden have implemented these technologies since 2000 (3G) and 2010 (4G), Thailand's position as a late adopter surprisingly led to some unexpected benefits. These included Thai mobile operators being able to build 3G and 4G networks at a much lower capital expenditure while also saving a significant amount of time to roll out network coverage. Additionally, these unseen benefits allowed Thai mobile users to obtain 3G and 4G

## Thailand was ranked 51st in the Network Readiness Index in 2020

access using a wide variety of mobile handsets at a reasonable price.

5G technology is now allowing access to even higher-speed mobile broadband, which is advertised as able to provide nearly unlimited connections per square kilometre and low-latency services. It is therefore a key mechanism driving economic reform and changes within multiple vertical industries in the Kingdom.

However, implementing a spectrum auction for new technology is challenging, with Thailand's 5G ecosystem preparation steps once again lagging behind those of others pursuing 5G implementations. Multiple studies have found limitations in 5G roll-out including spectrum and network equipment availability, consumer premises equipment, and commercial use cases.

Importantly, other Asian nations have achieved greater success with their 5G roll-outs due to their early start on 5G preparation and better management of the COVID-19 pandemic since 2020. This has allowed them to free up spectrum in the higher bands and forge ahead in their respective 5G roll-outs (EIU, 2021).

Although it is a latecomer to 5G, Thailand hopes to leapfrog over its neighbours by implementing newer 5G technology. In late 2019, the NBTC drafted a spectrum auction regulation in which three potential bands, 700 MHz, 2600 MHz, and 26 GHz, were made available for auction. One of the reasons these spectrum bands were chosen was that the Global Mobile Supplier Association (GMSA) announced that network and consumer premise equipment for 5G will support those bands and be available from 2020 onwards. In addition, the NBTC has published an International Mobile Telecommunications (IMT) spectrum release plan 2020–2023, which includes 1800 MHz and 28 GHz bands and a specific timeline for band allocation.

The commercial use case is another crucial factor in 5G development. Developed countries have clear targeted industries for 5G use cases. For instance, Germany wanted to support their automobile industry, and their network industries regulator, BNetzA, established a 5G network roll-out obligation to cover the German autobahn (motorway). One reason for this regulatory requirement for the German automotive industry is Germany's vision for self-driving vehicles on their highways. Similarly, South Korea's KT Telecom is developing 5G strategies by implementing 5G mobile broadband packages with gaming and other entertainment services. These services will strengthen their competitive advantage over other industries with their 5G development and implementation.

Thailand has learned from the practices of other countries and is therefore focusing on 5G implementation on a regional level and across targeted industries. Thailand's NBTC and the newer Ministry of Digital Economy and Society (MDES) have collaborated on related policies and pilot projects to facilitate 5G development and promote commercial use cases. Specifically, the NBTC has set 2600 MHz roll-out obligations for two areas. The first includes Thailand's Eastern Economic Corridor (EEC) industrial estate area. The roll-out obligation required the winners of the 2600 MHz band to build 5G infrastructure covering 50 per cent of the geographical area in the industrial parks defined by the EEC committee before February 2021. In addition, the network roll-out requirement also required the winners of the 2600 MHz band to provide 5G service to 50 per cent of the populated area in eight smart cities as defined by MDES before February 2023. Finally, the MDES and the NBTC jointly established a 5G Steering Committee in order to promote and facilitate 5G use cases and pilot projects (Tortermvasana, 2020).

The national 5G Steering Committee has two main roles. The first is to stimulate the use of 5G and promote spectrum sharing. In addition, the committee will consider investment policy through fibre and investment tax incentives. These auction regulations and policy initiatives have become essential factors in 5G development in Thailand.

Therefore, this chapter will describe the progress of 5G development in Thailand, including the IMT spectrum release plan 2020–2023 and the 3500 MHz re-farming and auction. In addition, the 5G ecosystem and pilot projects are also discussed as case studies. The last section summarises the discussion and concludes with recommendations for policymakers and stakeholders.

## ACHIEVEMENT OF 5G DEVELOPMENT IN THAILAND

According to Thailand's NBTC January 2021 network roll-out assessment survey, 5G networks are expected to cover all 77 Thai provinces, 76 per cent of all populated areas nationwide, and 100 per cent of Bangkok's metropolitan area (Manager Online, 2021). In addition, the winners are expected to build 5G infrastructure to cover more than 50 per cent of the geographical area in Thailand's eastern seaboard EEC zone. Within one year after the spectrum auction, the auction winners are required to build 5G infrastructures to cover more than 50 per cent of the requirements in the auction regulation.

Therefore, rising from an industry laggard to an industry leader in 5G performance, Thailand has moved to the forefront: according to the Opensignal report, in March 2021 Thailand's 5G vs 4G download speed improvement ratio had moved to first place and its 5G download speed was 13 times higher than that for 4G. Moreover, Thailand has an average 5G download speed of 162.3 Mbps, which places it in the world's top ten (Fogg, 2021). Crucial factors in accelerating the 5G network roll-out are the IMT spectrum release plan 2020–2023 and the 3500 MHz re-farming and auction plans.

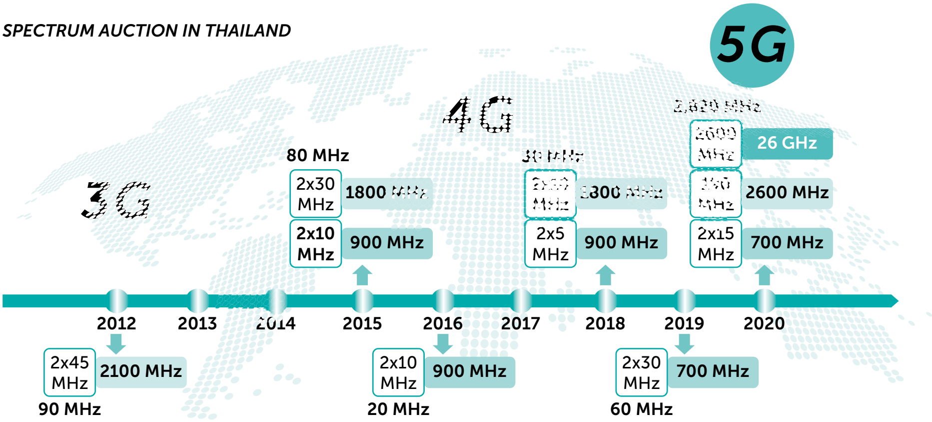
However, it was only in 2019 that Thailand developed a spectrum release plan, which entailed spectrum bands that had expired from legacy concessions as well as leftover concessions from past assignments.

Examples of this include a 2100 MHz auction in 2012 in which TOT (Telecommunications Organization of Thailand) was given, but never used, the spectrum. In another case, an auction in 2015 took place for 900 MHz and 1800 MHz spectrums but the concessions to TOT and CAT (Communications Authority of Thailand) expired before their use and implementation (Figure 1).

The IMT spectrum release plan is the first IMT spectrum road map in Thailand. It will provide an opportunity for mobile operators to know the bands and expected timelines of their release. Of the six spectrum bands planned for release from 2020 to 2023, three were already released in an auction in February 2020. The remaining three bands, 1800 MHz, 3500 MHz, and 28 GHz, are to be released sometime in 2023.

Another dominant 5G spectrum is the 3500 MHz band. However, Thailand has not been able to release this band quickly due its use of two different technologies, fixed satellite service (FSS) and IMT (APT, 2008). Added to this issue is the fact that more than 60 per cent of Thai households rely heavily on satellite television (NSO, 2019), which concerns NBTC of because it wants to ensure co-use between FSS and IMT technologies within 3500 MHz band. Therefore, a field trial has been proposed in which related technical parameters include the amount of bandwidth in guard band specification for the

FIGURE 1: **Thailand's spectrum auction and assignment from 2012 to 2020**




Source: NBTC (2021a)

low-noise block downconverter (LNB) satellite receiver. Furthermore, test scenarios for indoor and outdoor use need to be conducted to ensure there is no interference between FSS and IMT.

### 5G ECOSYSTEM AND PILOT PROJECTS

As might be expected with any new technology, implementation involves a learning curve. In countries that are auctioning their 5G supporting spectrum, this is no less so, especially in the industries and industrial estate areas for which 5G use is targeted. Therefore, government and regulator assistance is needed.

Cave (2018) has also reported on the major changes that 5G creates in the vertical and horizontal structure of the mobile marketplace, with 5G now focused on a nation's digitisation, whereas previous technologies focused on the consumer marketplace. Therefore, collaboration among key stakeholders in the telecommunications market and industries is needed.

The importance of 5G is not in the consumer marketplace but instead in industry affected by digital transformation. Therefore, 5G is not just another 'G' developed from 4G but is instead a technology in which each existing operator's market conditions, roles, and strategies must change.

The 5G Steering Committee was established in May 2020 to promote 5G implementation in Thailand. The committee consists of a total of 26 ministers, their representatives, and others from commerce and industry councils. It is chaired by Thailand's Prime Minister. Figure 2 provides an illustration of the current 5G ecosystem in Thailand.

Another joint study by the NBTC and the Bank of Thailand (BoT) on 5G adoption in Thailand (NBTC & BoT, 2020) identified sectors where 5G adoption gives a significant benefit to Thai society. They used three criteria: economic impact from 5G adoption, readiness for 5G adoption, and potential demand for 5G from various sectors of the economy. Their results suggest that healthcare, manufacturing, education, and agriculture are the most impacted sectors, with support from telecommunication vendors and industries essential for success.

The 5G Steering Committee approved a number of pilot projects related to sectors that could benefit from the technology. The NBTC proposed a 5G *smart hospital healthcare* prototype in which Thailand's Siriraj Hospital was nominated for the pilot project. The project proposal consisted of eight services, including 5G artificial intelligence (AI) emergency systems, 5G uninhabited vehicles, 5G AI pharmacy inventory optimisation, and 5G AI diagnostic pathology. The ultimate goals for this project were to improve operational efficiency using 5G and related technologies and to improve efficiency in optimising pharmacy inventory and medical equipment. The project also conceptualised how efficiency could be improved in pathology diagnostic systems by implementing 5G, AI, and cloud computing, which could potentially shorten patient analysis times from days to minutes. Additionally, cancer patients were identified as the users who would benefit the most. The NBTC funded this project, and it was opened at the end of December 2021. Other hospitals could also benefit from this project by learning how Siriraj Hospital is using 5G and related technologies to transform itself into a smart hospital.

Thailand's Office of the National Digital Economy and Society Commission is another sponsoring agency for 5G pilot projects, including two *smart agricultural pilot projects* across different regions

FIGURE 2: **5G ecosystem in Thailand**

NBTC
National Brodcasting and Telecommunications commission

NBTC assigns spectrum for boosting 5G adoption, promotes a telecom infrastructure-sharing system and improving related regulations to ensure the level of competition and consumer benefits.

**Mobile operators & vendors**

AIS true dtac

ERICSSON HUAWEI

Ministry of digital economy and society oversees and implements relevant policies that support the growth of the technology sector and the digital economy.

**Example of public organizations & industries**

depa

Depa supports the development of the digital industry through innovation and digital technology.

Mae Fah Luang Foundation under Royal Patronage

SIRIRAJ PIYAMAHARAJKARUN Hospital

eeci

ptt GLOBAL CHEMICAL

of Thailand. The first project used the Mae Fah Luang Foundation as manager of a 5G smart farming project in Thailand's far northern province of Chiangmai. This project proposed using 5G, Internet of Things (IoT), AI, drones, and data analytics to improve efficiency in managing high-value crops, such as vanilla, with multiple water and soil sensors installed to collect data. Water and fertiliser management systems will also be developed using IoT along with drones for land survey and fertilisation. It is expected that a large repository of sensor and output data will be available for future seasonal use and project expansion, which will improve the quality of the products and plantation techniques.

Another proposed pilot project in the agricultural sector is *smart irrigation*. This project aims to set up a rule-based water management system proposed by the Royal Initiative Discovery Foundation using 5G and IoT to manage water resources in reservoirs in Udon-Tani province.

The NBTC has also published a pamphlet called 'Regulatory Sandbox' that allows a private company to access a spectrum band at a particular location for research and development (R&D) without any restrictions. PTT Global Chemical (PTTGC) expressed interest in participating in the 5G pilot project using 5G, IoT, and AI technology to reduce production costs while using real-time data to help with decision-making and warehouse management. PTTGC also collaborated with a mobile network operator to apply the 26 GHz band in managing the *autonomous forklift* in their finished products warehouse.

## DISCUSSION AND CONCLUSION

For the past five years Thailand's NBTC has been pushing for the development of the Kingdom's telecom infrastructure in an effort to fully adopt and implement 5G technologies using collaboration rather than competition as its primary strategy. Implementing the NBTC's spectrum allocation road map for various spectrum ranges is a priority task for the regulator. Therefore, to support the roll-out and implementation of IoT, each mobile operator will be required to hold a combined minimum of 200 MHz of bandwidth spectrum (upload and download) to ensure 5G service capacity sufficiency. Thus, 5G will enable the development of an IoT ecosystem and the transformation of critical industries such as manufacturing, energy, and utilities. As first movers in the 5G ecosystem, telecom operators will gain several competitive advantages. These include offloading the existing 4G network, moving data-heavy users to 5G, capturing lucrative new use cases, and strengthening their brand.

Spectrum assignment is a crucial issue in addition to a clear frequency road map, particularly regarding frequency availability. Auction pricing is vital as 5G network investment carries a very high cost. IHS Markit (2020) expects that 5G-related investment from 5G value chain companies for capital expenditure and R&D from 2020 to 2035 in seven major countries (China, France, Germany, Japan, South Korea, the United Kingdom, and the United States) will average over $260 billion annually.

Thus, the telecom regulator will consider the most beneficial assignment method for the whole industry. The actual value of a national resource such as spectrum is not being unlocked in the collection of auction proceeds or regulatory fees but in improving network performance and downstream economic benefits to society at large. Otherwise, a barrier may arise that prevents it being used widely in the industrial sector. Finally, the promotion of

## Although a latecomer to 5G, Thailand hopes to leapfrog over its neighbours by implementing newer 5G technology

Industry 4.0 may be affected. In addition, the telecom regulator may need to consider allocating financial assistance to mobile operators or introducing an infrastructure sharing scheme to ease operators' financial burdens.

Spectrum re-farming is also a challenging issue. The regulator should pursue spectrum re-farming because Thailand lacks sufficient spectrum. Re-farming can support 5G service by utilising spectrum more efficiently. Sufficient spectrum allocation will also move the country forward in its quest for a Thailand 4.0 vision. Spectrum sharing and trading, which are standard practices in many countries, must be considered. Moreover, the use of an unlicensed band should be promoted as a complement to 5G service for improving speed in data transmission in some use cases, such as with Wi-Fi and IoT.

Thailand's NBTC also needs to work with local telecom operators and global vendors to create 5G awareness among enterprises, corporations, and the public through multiple public forums and pilot projects. This can help the regulator and relevant government agencies to find and exploit new opportunities by ensuring the right resources are in place. In the end, the high-potential use cases could help lead the way as the country moves towards Industry 4.0.

From all the above, it is clear that Thailand is a good example of building 5G ecosystems by using sandboxes. 5G players in Thailand have forged partnerships that include mobile network operators, solution providers, enterprise users, regulatory authorities, and policymakers to create a robust ecosystem. This ecosystem can secure production efficiencies, lower operating costs, gain network savings, and incentivise investment. This is a key learning for operators as well as the regulator in Europe and other countries. At the same time, the assignment method, flexible terms of payment in spectrum auctions, re-farming, and creating awareness in Thailand are needed to strengthen the 5G ecosystem.

Another lesson learnt is that it is necessary to forge partnerships between mobile operators and application developers and vendors, who can find use cases that fit specific industry opportunities. The 'one-size-fits-all' approach would be difficult to implement for 5G. Each industry has unique connectivity, latency, and reliability requirements.

Moving from being a gate-keeper to a facilitator is challenging for the regulator. Lessons learnt from other Asian developed countries such as Singapore and Japan clearly show that working and proactively creating sandboxes to assess innovative ideas with industry is essential. This enables companies to innovate more quickly and deliver more relevant services. This approach can also be seen in telecom licensing regimes, where many countries are now adopting less restrictive licences to accelerate the deployment of innovative technologies. The NBTC needs to push for efforts on industry collaboration to boost 5G adoption and the digitalisation transformation.

### REFERENCES


AIS (Advanced Info Service). (2021). 'Average Volume of Internet Use Per Subscriber Per Month in Quarter 4 of 2021'. https://tinyurl.com/yepwhaxe.

APT (ASIA-PACIFIC TELECOMMUNITY). (2008). 'The Co-Existence of Broadband Wireless Access Network in the 3400–3800 Mhz Band and Fixed Satellite Service Networks in the 3400–4200 Mhz Band'. https://www.apt.int/sites/default/files/APT-AWF-REP-05Draft_APT_Report_on_BWA-FSS_sharing_report_final_versionDFA.doc.

Cave, M. (2018). 'How Disruptive is 5G?' *Telecommunications Policy*, 42(8), 653–658. https://doi.org/10.1016/j.telpol.2018.05.005.

EIU (Economist Intelligent Unit). (2021). 'The 5G Readiness Guide 2021'. https://www.eiu.com/n/campaigns/5g-readiness-guide-report?utm_source=blog&utm_medium=website&utm_campaign=5G-guide-july-21&utm_term=campaign_page&utm_content=anchor_link

Fogg, I. (2021). 'Benchmarking the Global 5G Experience'. Opensignal, 3 February. https://tinyurl.com/mpmnc5ct.

IHS Markit. (2020). 'The 5G economy in a post-COVID-19 era: The role of 5G in a post-pandemic world economy'. shorturl.at/hkoN5

Manager Online. (2021). 'AIS Is the First in Thailand, Elevating 2 Gbps Fiber Network Coverage Nationwide and Ready for "Cognitive Telco" Transformation'. 16 December. https://tinyurl.com/48tf93sr.

NSO (National Statistical Office). (2019). 'The 2019 Household Survey on the Access of Television Service'. shorturl.at/djCEU

NBTC (National Broadcasting and Telecommunications Commission) & BoT (Bank of Thailand). (2020). '5G Sectoral Adoption for Thailand'. Join Research Paper (in Thai). shorturl.at/tvAIQ.

NBTC (National Broadcasting and Telecommunications Commission). (2021a). 'Five-Year Spectrum Roadmap for International Mobile Telecommunication Service (2019–2023) (Revised)'. (in Thai). https://tinyurl.com/mrkh4th5

NBTC (National Broadcasting and Telecommunications Commission). (2021b). 'Report on Telecommunications Regulation in Quarter 3 of 2021'. (in Thai) https://tinyurl.com/yckjafs9.

Tortermvasana, K. (2020). 'National 5G Committee Welcomes 26 Members'. *Bangkok Post*, 20 May. https://tinyurl.com/2p9csas2.

5G and 6G are excellent platforms from which to reconsider how Europe should organise its relationship with technology and such related notions as strategy, resilience, and autonomy. The ubiquity of application and innovation that accompanies these new communication technologies offers a potential to strengthen the domestic market while at the same time revolutionise the way we communicate. Moreover, these complex technological processes presage growth in terms of research, development, new technologies and applications in various fields, from smart cities to medical instruments, from financial markets to autonomous driving. Europe cannot but be ready for the future.

This study, edited by Professor Erik Bohlin and Francesco Cappelletti, focuses on these and other essential aspects, such as the most appropriate policies and regulations in Europe, while at the same time offering a perspective on the world's significant pioneers in the deployment of this technology. This volume, a bridge between academia and policymakers, represents an important step for the European Liberal Forum towards this new way of thinking that considers policymaking as a tool to support our future. Embedding techno-politics in our societies is the way to make Europe ready for its digital future.

**Daniel Kaddik, ELF Executive Director**

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