EUROPEAN
COMMISSION

Brussels, 21.2.2024
COM(2024) 81 final

WHITE PAPER

How to master Europe's digital infrastructure needs?

- White paper –

"How to master Europe's digital infrastructure needs?"

1. INTRODUCTION

A cutting-edge digital network infrastructure is the foundation for a flourishing digital economy and society. Secure and sustainable digital infrastructures are one of the four cardinal points of the EU's Digital Decade Policy Programme 2030, one of the main priorities of the current Commission. It is also at the heart of citizens' interest, who made several digital-related proposals in the context of the Conference on the Future of Europe. Without advanced digital network infrastructures, applications will not make our lives easier, and consumers will be deprived of the benefits of advanced technologies. Only with the highest performance of such infrastructures, for example, will doctors be able to care for patients at a distance rapidly and safely, drones be able to improve harvests and reduce water and pesticide use, while connected temperature and humidity sensors enable real-time monitoring of the conditions in which fresh food is stored and transported to the consumer.

There are also many examples across the economy of how enterprises need advanced connectivity and computing infrastructures for the processing of data closer to their operations and to their customers, to use or provide innovative applications and services. This is especially important for applications that require real-time data processing, such as Internet of Things (IoT) devices, autonomous vehicles, and smart grids, as well as to reduce latency for applications related to predictive maintenance, real-time monitoring, and automation, leading to more efficient and cost-effective operations. Advanced digital network infrastructures and services will become a key enabler for transformative digital technologies and services such as Artificial Intelligence (AI), Virtual Worlds and the Web 4.0, and for addressing societal challenges such as those in the fields of energy, transport or healthcare and for supporting innovation in creative industries.

The future competitiveness of all sectors of Europe's economy depends on these advanced digital network infrastructures and services, as they form the basis for global GDP growth between EUR 1 and 2 trillion[1] and the digital and green transition of our society and economy. There is, according to many sources, a strong link between the increased deployment of fixed and mobile broadband and economic development[2]. Demand for connectivity is essential to stimulate the economy. Higher speeds and new generations of mobile networks have a positive impact on GDP[3]. Similarly, studies show that a resilient backbone infrastructure based on secure submarine cables can boost GDP[4]. With the current demographic trends, European

---

1 Connected World: An evolution in connectivity beyond the 5G evolution, McKinsey 2020 available at https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/connected-world-an-evolution-in-connectivity-beyond-the-5g-revolution

2 Cf."Analyzing the Economic Impacts of Telecommunications" Exploring the Relationship Between Broadband and Economic Growth", Background Paper prepared for the World Development Report 2016: Digital Dividends, Michael Minges, 2015; "Europe's internet ecosystem: socio-economic benefits of a fairer balance between tech giants and telecom operators", Axon Partners Group, May 2022; Kongaut, Chatchai; Bohlin, Erik (2014): Impact of broadband speed on economic outputs: An empirical study of OECD countries, 25th European Regional Conference of the International Telecommunications Society (ITS): "Disruptive Innovation in the ICT Industries: Challenges for European Policy and Business", Brussels, Belgium, 22nd-25th June, 2014, International Telecommunications Society (ITS), Calgary.

3 Specifically, mobile's baseline connectivity impact increases by about 15% when connections are upgraded to 3G. For connections upgrading from 2G to 4G, the impact increases by approximately 25%, according to Mobile technology: two decades driving economic growth (gsmaintelligence.com)

4 https://copenhageneconomics.com/publication/the-economic-impact-of-the-forthcoming-equiano-subsea-cable-in-portugal/

competitiveness needs to rely on productivity-boosting technologies, and digital infrastructure and services are key.

In parallel, digital networks are undergoing a transformation where connectivity infrastructure is converging with cloud and edge computing capabilities. To harness the benefits of this transformation, the electronic communications sector needs to expand from the traditional consumer internet market towards digital services in key economic sectors, such as the Industrial Internet of Things (IIoT). Moreover, the equipment sector also faces major technological transformations linked to the trend towards software and cloud-based networks and open architectures. Convergence of the electronic communications and IT ecosystems brings opportunities for lower cost and innovative services, but also new risks of bottlenecks and dependencies in the field of cloud infrastructure and services as well as leading chip platforms[5]. To ensure economic security, it is therefore of utmost importance that innovation in this field continues to be driven in the Union and led by its industry. To achieve this, in the current geopolitical context, the Union needs to leverage its current strength in the network equipment supply market, with two of the three global suppliers being European.

From a societal perspective, the availability of high-quality, reliable and secure connectivity for everybody and everywhere in the Union, including in rural and remote areas, is indispensable[6]. The necessary investments are massive[7]. A modern regulatory framework that incentivises the transition from legacy copper networks to fibre networks, the development of 5G and other wireless networks and cloud-based infrastructures as well as the scale up of operators within the single market, and which takes account of emerging technologies such as quantum communication, is key to ensuring that Europe has the advanced, secured communications and computing infrastructure it needs. Short of that, the EU risks missing its 2030 digital targets and falling behind other leading regions as regards competitiveness and economic growth and related user benefits.

Finally, recent geopolitical developments highlighted the importance of security and resilience of infrastructures against both human-made and natural hazards, as well as the complementary role of terrestrial, satellite and submarine connectivity solutions, for uninterrupted availability of service under all circumstances. In a rapidly changing security landscape, a strategic Union-wide approach to security and resilience of critical digital infrastructures is essential for the EU's economic security, building on the solid existing legislative framework, notably the NIS2

---

5 Cybersecurity of Open Radio Access Networks, Report by NIS Cooperation Group, May 2022.

6 This was also acknowledged in the Digital Decade Policy Programme 2030 (Decision (EU) 2022/2481 of the European Parliament and of the Council of 14 December 2022 establishing the Digital Decade Policy Programme 2030, OJ L 323, 19.12.2022, p. 4.). According to its Art. 4(2)(a), by 2030 all end users at a fixed location should be covered by a gigabit network up to the network termination point, and all populated areas should be covered by next-generation wireless high-speed networks with performance at least equivalent to that of 5G, in accordance with the principle of technological neutrality.

7 https://digital-strategy.ec.europa.eu/en/library/investment-and-funding-needs-digital-decade-connectivity-targets.

Directive[8], the Directive on the resilience of critical entities[9] and the Council Recommendation on a Union-wide coordinated approach to strengthen the resilience of critical infrastructure[10] [11].

Against this background, this White Paper identifies challenges and discusses possible scenarios for public policy actions, such as a possible future Digital Networks Act, that aim to incentivise building the digital networks of the future, master the transition to new technologies and business models, meet future connectivity needs of all end-users, underpin competitiveness of our economy and ensure secure and resilient infrastructures and the Union's economic security as reflected by the common commitments of the EU Member States in the Digital Decade Policy Programme[12].

2. TRENDS AND CHALLENGES IN THE DIGITAL INFRASTRUCTURE SECTOR

2.1. Europe's connectivity infrastructure challenges

The connectivity infrastructure of the Union is not yet ready to address the current and future challenges of the data-driven society and economy and the future needs of all end-users.

On the supply side, the 2023 Report on the state of the Digital Decade[13] underlines in particular limited fibre coverage (56% of all households, 41% of households in rural areas)[14] and delays in the deployment of 5G standalone networks in the EU. Current trends concerning the trajectories for the digital infrastructure targets laid out in the Digital Decade Policy Programme 2030[15] are a cause for concern. As regards fibre coverage, progress beyond 80% by 2028 does not seem likely, putting the achievement of the 2030 target of 100% in doubt. In comparison to the 56% fibre coverage in the EU in 2022, the US, which has traditionally relied on cable, had 48.8%, while Japan and South Korea each reached 99.7%[16], due to clear strategies in favour of fibre.

As regards 5G roll-out, while basic 5G population coverage in the EU currently stands at 81% (with only 51% coverage of the population in rural areas), this metric does not reflect the delivery of actual advanced 5G performance. Most often, where 5G is deployed, it is not "stand-alone", i.e. with a core network separate from previous generations. Prospects for deployment of 5G stand-alone networks ensuring high reliability and low latency, which are key enablers

---

8 Directive (EU) 2022/2555 of the European Parliament and of the Council of 14 December 2022 on measures for a high common level of cybersecurity across the Union, amending Regulation (EU) No 910/2014 and Directive (EU) 2018/1972, and repealing Directive (EU) 2016/1148 (NIS 2 Directive), OJ L 333, 27.12.2022, p. 80–152.

9 Directive (EU) 2022/2557 of the European Parliament and of the Council of 14 December 2022 on the resilience of critical entities and repealing Council Directive 2008/114/EC, OJ L 333, 27.12.2022, p. 164–198.

10 Council Recommendation of 8 December 2022 on a Union-wide coordinated approach to strengthen the resilience of critical infrastructure, 2023/C 20/01, OJ C 20, 20.1.2023, p. 1–11.

11 This approach should also integrate challenges and opportunities for EU enlargement policies.

12 Decision (EU) 2022/2481 of the European Parliament and of the Council of 14 December 2022 establishing the Digital Decade Policy Programme2030, OJ L 323, 19.12.2022, p.4.

13 https://digital-strategy.ec.europa.eu/en/library/2023-report-state-digital-decade.

14 https://digital-strategy.ec.europa.eu/en/library/broadband-coverage-europe-2022.

15 The Digital Decade Policy Programme sets a series of objectives and targets to promote the development of resilient, secure, performant and sustainable digital infrastructures in the Union, including a digital target for the Commission and Member States to achieve gigabit connectivity for all by 2030. The Programme should enable connectivity across the Union and around the globe, for citizens and business, including, but not limited to, providing access to affordable high-speed broadband that can help remove communication dead zones and increase cohesion across the Union, including its outermost regions, rural, peripheral, remote and isolated areas and islands.

16 See Global Fibre Development Index 2023, Omdia.

for industrial use cases, are not good. The deployment of such networks can be estimated at significantly less than 20% of populated areas in the EU. Although there is progress on early-stage trials, operators have launched this architecture only in a small number of Member States and limited to some urban areas[17]. Such limited deployment could, among others, be related to the early stage of 3.6 GHz band deployment. Coverage by 5G in this mid-wave band, that is needed for higher speeds and capacity, currently stands at only 41% of the population. 5G will need, however, to extend its footprint beyond populated areas, to cater for advanced services, such as precision farming. Also, while basic 5G coverage in the largest Member States is relatively similar to the US, other regions such as South Korea and China are better prepared for 5G stand-alone deployment. According to the 5G Observatory's International Scoreboard, South Korea has deployed more than five times the number of 5G base stations per 100,000 inhabitants than the EU, and China almost triple[18].

Finally, satellite broadband can bring broadband services with up to 100 Mbps download speeds to very rural and remote areas, where no very high-capacity networks are available, even if affordability remains crucial to facilitate take-up in these areas. They can also provide resilient emergency services in disaster or crisis situations. However, while satellite services can bridge the digital divide, they cannot currently replace the performance of ground-based networks.

Overall, and without taking into account population density and quality of connectivity, the EU has similar fixed and mobile coverage than the US but lags significantly behind other parts of the world in particular on fibre coverage and 5G stand-alone. However, what counts more is what remains to be covered and more importantly whether the EU is in a good position to achieve its Digital Decade objectives for ubiquitous fibre and 5G coverage. In this respect, take-up of high-speed services is of paramount importance, as it affects the capacity of the sector to invest. On the demand side, the take-up of at least 1 Gbps broadband is very low (at 14% in 2022 at EU level) and just above half of all EU households (55%) have adopted at least 100 Mbps broadband. The take-up of high-speed fixed broadband subscriptions is lower in the EU than the US, South Korea or Japan[19]. Standard mobile broadband take-up is better and lies at 87%, despite almost ubiquitous coverage with at least 4G networks.

These delays represent a critical vulnerability for Europe's economy as a whole, as the delivery of advanced data services and AI-based applications depends on them. The same applies to the deployment of edge computing infrastructure, another key enabler for time critical applications and computing capabilities in relation to real-time data-intensive use cases and IoT. There is a strong correlation between the deployment of capable digital networks and the take-up of modern technologies, which are currently not developing at large scale. The Digital Decade Policy Programme sets out a target of 10,000 climate-neutral highly secure edge nodes to be deployed by 2030 as well as targets for adoption of digital technologies, such as cloud, big data and AI, by European companies. The 2023 Report on the state of the Digital Decade underlined the risks for the achievement of these targets. Edge computing is still at its infancy in Europe[20]. The first data collected by the Edge Observatory[21] show that Europe is on track in the initial

[17] 5G Observatory Biannual Report October 2023, page 8, https://5gobservatory.eu/wp-content/uploads/2023/12/BR-19_October-2023_Final-clean.pdf

[18] 5G base stations per 100,000 inhabitants: 419 (South Korea), 206 (China), 77 (EU), 118 (Japan), 30 (US).

[19] Cf. International DESI (to be published on the basis of OECD data). 24.07 subscriptions per 100 inhabitants are higher than 100 Mbps in the EU, comparing to 29.60 in the US, 33,36 in Japan and 43,60 in South Korea.

[20] Report on the state of the Digital Decade 2023, SWD Digital Decade Cardinal Points, section 2.4.

[21] https://digital-strategy.ec.europa.eu/en/policies/edge-observatory.

phase of edge nodes deployment. However, under current trends, and without further investment and incentives, the targets are unlikely to be met by 2030.

Modern digital networks capable of expanding and maturing would stimulate the development of new use cases, creating business opportunities contributing to the digital transformation of Europe. The impact of missing the Digital Decade digital infrastructure targets would be far-reaching, going beyond the scope of the digital sector, and would lead to missed opportunities in innovation areas such as automated driving, smart manufacturing, and personalised health care.

2.2. Technological challenges

New business models and entirely new markets are emerging from technological developments around the App Economy, IoT, Data Analytics, AI or new forms of content delivery such as high-quality video streaming. These applications require a continuous exponential increase in data processing, storage, and transmission. The ability to process and transport large amounts of data across the entire global Internet has led to the remote storage and processing of data in the cloud, between the cloud and the end-user through Content Delivery Networks (CDNs), and close to the end-user (edge computing). This has led to the virtualisation of electronic communications networks functions in software and a shifting of these functions to the cloud or the edge[22].

This new model of network and service provision relies not only on traditional electronic communications equipment, network and service providers but also on a complex ecosystem of cloud, edge, content, software and component suppliers, amongst others. The traditional boundaries between these various actors are increasingly blurred as they form part of what can be described as a computing continuum: from chips and other components for high-speed processors embedded in devices, to edge computing working cohesively with centralised cloud services and AI-powered applications managing the network. This will allow computing to be integrated everywhere in the network.

There is a need to orchestrate these different elements. This coordinated management of computing and network resources ensures that end-users have a seamless experience, no matter if they are on their mobile phone, at home, or in the car or train. This is because the orchestrator ensures that a broad range of computing environments interact in the background.

One example is the connected and autonomous vehicles, which will increasingly rely on advanced high-speed and low-latency communication and computing to ensure that they communicate with network and road infrastructure in real time. This will allow these vehicles to contribute to optimising traffic flow and reducing congestion and accidents.

---

[22] This technological shift and new paradigm have been confirmed by the large majority of respondents to the Commission's exploratory consultation launched last year to gather views and identify Europe's needs in terms of connectivity infrastructure to lead the digital transformation. In particular, respondents identified network virtualisation, network slicing, and Network as a Service, as the technological breakthroughs that will have the largest impact in the coming years. These technologies are expected to drive the shift from traditional electronic communications networks to cloud-based, virtualised, software-defined networks, reducing costs, improving the resilience and security of networks, and introducing new, innovative services, while transforming ecosystem and business models.
The results of the exploratory consultation were published in October 2023 and are available at https://digital-strategy.ec.europa.eu/en/news/consultation-electronic-communications-highlights-need-reliable-and-resilient-connectivity.

Another example is the use of secure high-speed connectivity in order to provide advanced e-health services, including advanced e-health monitoring and e-health care in remote areas, using low-cost devices. For this, it will be necessary to migrate functionality and use artificial intelligence to the network, which should be located as close to the user as possible. Other technologies that could be part of the health care system of 2030 are sensor-based monitoring, extended reality (XR) and drones.

This technological change triggers the emergence of new business models in the electronic communications services sector. The increasingly complex network operations push companies in different segments of the value chain to work together at the infrastructure layer while competition at the service layer becomes more complex. Main trends include network sharing, the separation of infrastructure and service layer and the creation of service platforms based on concepts like Network as a Service (NaaS) and IoT. NaaS creates a common and open framework between operators that makes it easier for developers to build apps and services in partnership with large cloud providers and content application providers (CAPs) that seamlessly communicate with each other and work for all devices and customers. At the same time, it also makes it possible for unconventional players in the network services domain, such as cloud hyperscalers, to begin enterprise-grade services in that space[23].

These changes are being gradually introduced to exploit the full potential of 5G networks, especially for industrial sectors, the so-called 'verticals' such as manufacturing or mobility. With its successful industry and public-private partnerships, the EU is currently leading (together with China) the development of these future industrial applications of 5G in vertical industry sectors. Examples include operational campus networks, e.g. in factories, ports and mines[24] as well as the planned deployment of 5G corridors along EU transport networks[25]. Such changes will be key building blocks of the future 6G computing continuum, which is currently still at the development stage, but which will create further realignment of networks and business cases, and further investment requirements for operators.

Convergence of European electronic communications networks and cloud services to an EU "Telco Edge Cloud", as envisaged in the Industrial Technology Roadmap of the European Alliance for Industrial Data, Edge and Cloud[26] could become a major enabler for hosting and managing network virtualised functions, as well as for bringing complementary services addressing the rapidly growing markets for IoT-related products and services. This is expected to enable the transition to an industrial Internet enabling critical services in a broad range of sectors and activities of great benefit to citizens and industry alike. Concrete examples range from robot and drone services for industry, connected and autonomous vehicles interacting with edge networks deployed along the road for smart mobility and smart transportation systems, to use cases with stringent data privacy requirements such as remote patient healthcare. This calls for the broad availability of computing resources, fully integrated with network resources, to provide the data transmission and data processing capacities required by these novel

---

[23] See for instance: Integrated Private Wireless on AWS, https://pages.awscloud.com/rs/112-TZM-766/images/AWS%20Integrated%20Private%20Wireless%20eBook.pdf, Announcing private network solutions on Google Distributed Cloud Edge, https://cloud.google.com/blog/products/networking/announcing-private-network-solutions-on-google-distributed-cloud-edge.

[24] 5G Observatory biannual report October 2023, Omdia's Mobile Infrastructure Intelligence Service.

[25] https://digital-strategy.ec.europa.eu/en/policies/cross-border-corridors.

[26] European industrial technology roadmap for the next generation cloud-edge offering, May 2021 https://ec.europa.eu/newsroom/repository/document/2021-18/European_CloudEdge_Technology_Investment_Roadmap_for_publication_pMdz85DSw6nqPppq8hE9S9RbB8_76223.pdf

applications. The Alliance is currently developing a further thematic roadmap on Telco Edge Cloud, which should be ready by mid-2024.

Nowhere is that more obvious than in the city and large urban environments where these sectors and activities come together. The data that they generate can be processed and combined locally, to reduce the use of network resources, orchestrate mobility and services in real-time, and optimise health and medical care for the citizen. If the different actors in this ecosystem work together, the Telco Cloud would potentially develop a new generation of compute and data orchestration systems capable of managing networked resources in environments such as smart cities, as well as providing interoperable services to develop and optimise the execution of data- and compute-intensive AI applications.

However, this inevitable opening of the traditionally "closed" electronic communications network in a NaaS approach exposes network capabilities to third parties and bears the possible risk of large non-EU providers becoming leading players in such ecosystems. In the current geopolitical context and from an economic security point of view, this would constitute a significant risk of additional dependence on non-EU players in the entire digital service sector. It is therefore key that European players develop the necessary capacities and scale[27] to become service platform providers.

This creates vast opportunities for the sector, in particular for equipment suppliers. The ability of European suppliers to seize them and become leading global providers of 6G equipment will largely depend on how they navigate the broad technological changes in the industry and embrace the paradigm shift that comes with them (see section 2.4.1). The 2023 Beyond 5G/6G Roadmap of EU and US industries is a welcome development in this regard.

In the next 5-10 years, both our infrastructure and encryption systems risk being compromised by ever more powerful computing brute force, and by the advent of quantum computing itself. These could render all existing key encryption systems at risk, leaving Europe's communication networks and services and sensitive data (health, financial, security or defence-related and more) extremely vulnerable. There is a clear and immediate need for the EU to start preparing its digital assets to face this risk. A number of recent developments based on quantum technologies, such as quantum key distribution, have significant potential to protect the EU's sensitive data and digital infrastructure.

For instance, the EU is working to deploy over the next ten years a fully certified end-to-end quantum communication infrastructure (EuroQCI) for the distribution of keys used in encryption technologies that will be gradually integrated in the EU Infrastructure for Resilience, Interconnectivity and Security by Satellite (IRIS^2). Low Earth Orbit (LEO), and Medium Earth Orbit (MEO) satellite constellations and other non-terrestrial connectivity such as High-Altitude Platforms (HAPs) further extend the boundaries of the technological changes to come.

To conclude on technological challenges, the sectors of European electronic communications networks and services and network equipment stand currently at cross-roads; either they will embrace and endorse technological transformation, or they will leave space to new players, largely from outside the EU, with consequences in terms of EU economic security.

[27] The concept of scale may be very different in a NaaS environment in nature and magnitude compared to the economies of scale of typical current electronic communication networks.

2.3. Challenges of achieving scale in EU connectivity services

2.3.1. Investment needs

According to a recent study conducted for the European Commission[28], reaching current Digital Decade targets for Gigabit connectivity and 5G may require a total investment of up to EUR 148 billion, if fixed and mobile networks are deployed independently, and stand-alone 5G-offering European citizens and businesses the full capabilities that can be offered by 5G mobile networks is deployed. A further EUR 26-79 billion of investments may be required under different scenarios to ensure full coverage of transport corridors including roads, railways, and waterways, bringing the required total investment needs for connectivity alone to over EUR 200 billion. Despite the need to densify mobile networks to achieve higher performance, EU operators are focussing on reusing existing sites for low and mid-band deployments. However, for future upgrades, e.g. 6G or WiFi 6 the required network densification is likely to increase by a factor of 2-3 by the end of the decade at least in high-density demand areas.

Beyond terrestrial connectivity, further investments are required for the integration of advanced satellite services providing complementary solutions for backhaul, device connectivity in remote areas not covered by terrestrial technologies or to ensure service continuity in case of crisis or disaster relief.

The successful completion of software and cloud-based solutions to provide NaaS would require additional significant investment capacities. There is an estimated cloud investment gap in the EU of EUR 80 billion until 2027[29][30]. A slow transition of EU players towards cloud-based solutions for electronic communications services and beyond would present risks of further dependencies in the area of digital services.

2.3.2. Financial situation of the EU electronic communications sector

The EU capacity to carry out the investments needed to successfully transform the connectivity sector to tackle technological challenges will depend on the financial situation of its electronic communications sector.

In this context, the current financial situation of the EU electronic communications sector raises concerns for its capacity to find funding for the substantial investments that are needed to catch up with the technological shift.

The average revenue per user (ARPU) of electronic communications operators in the EU is relatively low compared to other economies such as the US, Japan or South Korea[31]. This has

---

[28] https://digital-strategy.ec.europa.eu/en/library/investment-and-funding-needs-digital-decade-connectivity-targets.

[29] European Alliance for Industrial Data, Edge and Cloud: "European industrial technology roadmap for the next-generation cloud-edge", extrapolating until 2030 the investment gap identified in the Commission Staff Working Document (27.5.2020): *Identifying Europe's recovery needs*, SWD(2020) 98 final/2, Brussels, pp. 17-18.

[30] Synergy Research Group, e.g. based on Q1/2023 data, Investments related to general cloud capacities tailored to the business model of each cloud provider and not significantly overlapping with the general EU connectivity investment needs.

[31] In 2022, mobile ARPU was EUR15.0 in Europe, as opposed to EUR42.5 in the US, EUR26.5 in South Korea, and EUR25.9 in Japan. Fixed broadband ARPU was EUR22.8 in Europe versus EUR58.6 in the US, EUR24.4 in Japan, and EUR13.1 in South Korea. ETNO, State of Digital Communications 2024, January 2024.

led to declining Return on Capital Employed (ROCE)[32]. The capital expenditure (Capex) per capita in the EU is also lower. In 2022, it stood at EUR 109.1 compared to EUR 270.8 in Japan, EUR 240.3 in the US and EUR 113.5 in South Korea[33]. During the last decade stocks of European electronic communications networks and services providers have underperformed in both global electronic communications indices and European stock markets[34]. European providers of electronic communications networks and services also face low enterprise value/EBITDA multiples, suggesting lack of market confidence in the potential for sustainable long-term growth in revenues.

Against this background, the proportion of at least some of the electronic communications operators' net debt over their EBITDA has continued to grow. In addition, access to finance seems to have degraded as interest rates jumped from historical lows and widespread risk aversion linked to the new global crises result in macroeconomic uncertainty. As other infrastructure providers, providers of electronic communications networks will also need to recover investment costs over several decades, and even a slight change in the interest rate impacts the financial viability of investment projects.

In this context, perception of attractiveness of advanced digital networks by private investors is of crucial importance for the future of connectivity. Certain investors have underlined that mobilising private investments requires a clear business case for profitability and higher margins. Profitability depends on the take-up of enhanced fixed and mobile networks, which is itself linked to the development and increased take-up of data intensive applications and use cases, e.g. based on edge computing, AI, and IoT.

Also, in this context, some stakeholders underlined the importance of demand-side measures. In this regard, the Union supports the adoption of digital technologies by SMEs through the objectives and targets set in the Digital Decade and notably through the European Digital Innovation Hubs, the deployment of data spaces for stakeholders to share and reuse industrial data in a trustworthy environment and the access to future "AI factories"[35]. Increased use of advanced electronic communication services by businesses will reinforce the digitalisation of local ecosystems participating in EU wide supply chains and promote access to infrastructure-intensive applications such as generative AI, edge computing and supercomputing, while avoiding possible undue competition distortion.

Some investors pointed to the prudential rules for banks and insurance companies as inhibiting the deployment of capital and the stimulation of equity markets. They argue for reducing the levels of required capital set by the legislative framework on prudential regulation. For example, they claim that, in relation to insurance companies, the Solvency II directive[36] would encourage insurance companies to reduce their exposure to equities for prudential reasons[37] as equity prices are volatile. As a consequence, more equity investment would arguably lead to lower solvency

---

[32] As regards fixed markets, according to the 2023 State of the Digital Communications ETNO report, the ARPU of ETNO members was at EUR 21.8 compared to EUR 50.6 in the US and EUR 26.2 in Japan, and only ahead of South Korea (EUR 13) and China (EUR 4.9).

[33] Ibid.

[34] State of Digital Communications 2023, ETNO.

[35] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on boosting startups and innovation in trustworthy artificial intelligence, COM(2024)28 final.

[36] Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II), OJ L 335, 17.12.2009, p. 1–155.

[37] Financer la quatrième révolution industrielle, Philippe Tibi, 2019.

ratios[38]. The recently agreed current review of the Solvency II framework has addressed these claims, and will result in substantial capital relief thanks to a reduction of the risk margin, to changes to the symmetric adjustment and the definition of clear criteria for long-term equity[39]. Investments, particularly those in infrastructure, would potentially be stimulated thanks to the increased insurance industry's capacity to invest in EU businesses[40].

Nonetheless, since equity invested in unlisted stock such as innovative businesses and new electronic communications operators are still likely to be deemed riskier, public support is a necessary incentive. Investors also consider that public support, in particular from the Recovery and Resilience Facility and other EU funds (Next Generation EU, Structural Funds, Connecting Europe Facility (CEF), etc.) will help reach market failure areas, where demand is insufficient to adequately remunerate private deployment. At the same time, in investors' view, public-private partnerships, where the public capital takes the form of guarantees or junior co-investment, could possibly be a good and efficient way to help the electronic communications sector fund its transformation.

Investors finally explained that another element hindering the attractiveness of the European electronic communications market for large investors is its fragmentation and hence the lack of assets with sufficient scale. It is common that large investors have minimum thresholds for their investments because of their limited capacity to manage and/or monitor their portfolio. This means there are fewer financiers competing for smaller investments than for larger ones, resulting in less favourable conditions. Further, the relative cost of administering large investments is lower than for smaller ones thus investors can offer better conditions. The integration of national markets could be an opportunity to tap into a larger potential pool of investors and financing conditions for electronic communications investments. In addition, increasing the size of projects can improve their cost efficiency and boost the projects financial viability. A better return profile will improve their attractiveness and eventually the financial conditions.

2.3.3. Lack of single market

At present, the EU does not have a single market for electronic communications networks and services, but 27 national markets with different supply and demand conditions, network architectures, different levels of coverage of very high-capacity networks, different national spectrum authorisation procedures, conditions and timing, as well as different (albeit partly harmonised) regulatory approaches. The fragmentation does not only concern the supply side of the market. Also from the demand side, i.e. end-users, market conditions differ from one Member State to another. This fragmentation was underlined by the majority of respondents to the exploratory consultation on the future of the electronic communications sector and its infrastructure[41]. They highlighted that the removal of obstacles, notably burdensome and/or

---

[38] Deloitte Belgium and CEPS for the European Commission, DG for Financial Stability, Financial Services and Capital Markets Union, Study on the drivers of investments in equity by insurers and pension funds, December 2019.

[39] Confirmation of the final compromise text with a view to agreement, Proposal for a Directive of the European Parliament and of the Council amending Directive 2009/138/EC, 2021/0295 (COD).

[40] Communication from the Commission to the European Parliament and the Council on the review of the EU prudential framework for insurers and reinsurers in the context of the EU's post pandemic recovery, COM(2021) 580, 2021.

[41] The results of the exploratory consultation were published in October 2023 and are available at: https://digital-strategy.ec.europa.eu/en/news/consultation-electronic-communications-highlights-need-reliable-and-resilient-connectivity. In this regard, the large majority of the respondents to this question (including telecom

fragmented sectoral regulation, can create incentives for cross-border consolidation and emergence of a fully integrated Digital Single Market. Concerning the barriers to market integration, the majority of the respondents to the exploratory consultation[42] called, in particular, for a more integrated spectrum market and a more harmonised approach to spectrum management across the EU. They suggested that it would be appropriate to align the approaches related to, for example, duration of licences, reserve prices, annual cost of spectrum, or spectrum sharing practices.

Radio spectrum policy is an area of shared competence between the EU and Member States. The EU adopts rules, in particular for the EU-wide designation of frequency bands under harmonised technical conditions. Member States' action focuses on the implementation of spectrum authorisation, management and use. However, the way spectrum is managed and used in one Member State has an impact on the internal market as a whole, for example through disparate starting times in the development of new wireless technologies or new services or through harmful cross-border interference, with further possible repercussions for EU competitiveness, resilience and technological leadership. Therefore, it is imperative that spectrum is managed in a more coordinated way among all Member States to maximise its social and economic value and enhance terrestrial and satellite connectivity across the entire EU.

The past attempts for more EU coordination, convergence and certainty in spectrum management, for example, in the context of the proposal for a Telecommunications Single Market regulation[43] and the European Electronic Communications Code (hereinafter referred to as the "Code")[44], were not successful in many respects. Ultimately, this had detrimental consequences for the EU as a whole. For example, the authorisation process for bands anticipated to enable future 5G deployment started in 2015 in the first Member States[45] and is not yet fully completed now in 2024, despite the deadlines set at EU level. The authorisation process for the use of the 800 MHz and 2.6 GHz bands for 4G took 6 years for 26 Member States and even 10 years for 27, despite the absence of an exceptional pandemic event as for 5G[46]. This has resulted in fragmented 4G and 5G roll-out landscapes across the EU, where some Member States were almost one wireless technology generation behind others.

---

and satellite business associations, vendors, operators as well as NGOs) noted that the digital single market is hampered by the fragmentation of the sector into national markets. This is due both to cultural and diverging market circumstances and the lack of full harmonisation of sector rules (e.g. building lawful interception capabilities, data retention, data protection, reshoring requirements, cybersecurity and reporting obligations and network/service incident reporting requirements, spectrum auction conditions, etc.), which is also caused by a slow and piecemeal implementation of EU rules at national level and fragmented approaches to enforcement.

42 When replying to the consultation, the majority of the respondents, mostly companies (ECN providers and digital platforms), business associations and consumer organizations, welcomed the idea of a more integrated spectrum market and a harmonised approach to spectrum management across the EU.

43 COM(2013) 627 final.

44 Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code, OJ L 321, 17.12.2018, p. 36.

45 Commission study on assessing the efficiency of radio spectrum award processes in the Member States, including the effects of applying the European Electronic Communications Code, available at https://digital-strategy.ec.europa.eu/en/library/study-assessing-efficiency-radio-spectrum-award-processes-member-states-including-effects-applying.

46 Commission study on spectrum assignment in the European Union, available at https://op.europa.eu/en/publication-detail/-/publication/2388b227-a978-11e7-837e-01aa75ed71a1/language-en.

Moreover, in certain cases where spectrum bidders ended up paying higher prices due to artificial scarcity created by auction design, this has been associated with a reduction in investment capacities and delays in services deployment by providers of electronic communications networks and services. Ultimately, it is the consumers and business users who have paid the price in terms of suboptimal quality of services, which ultimately negatively impacts EU's economic growth, competitiveness and cohesion.

There are also national rules beyond sector specific electronic communications legislation imposing obligations, as regards, for instance, lawful interception, data retention or localisation of Security Operations Centres, that were also raised in the exploratory consultation as barriers to the full integration of the Single Market[47]. In these areas, lack of uniform legislation at EU level contributed to significant fragmentation (e.g. different duration of data retention obligations, localisation requirements for Security Operations Centres, lack of mutual recognition for security vetting for relevant staff) preventing a provider operating a network in more than one Member State from exploiting economies of scale.

Regulatory fragmentation is mirrored in the market structure. While there are around 50 mobile operators, and more than 100 fixed operators in the EU, only few European operators (e.g. Deutsche Telekom, Vodafone, Orange, Iliad and Telefonica) are present in several national markets. When it comes to mobile markets, at service level, 16 Member States have three mobile network operators, nine Member States have four and two Member States have five. In certain Member States, in terms of distinct mobile electronic communications network infrastructures, the number is lower than the number of service providers due to existing network sharing arrangements (e.g. in Denmark or Italy). Even the mobile operators that are part of corporate groups with a large footprint across the EU, operate within national markets and do not seem to harmonise their offerings and operational systems at EU level, due to the inherently different market and regulatory landscapes, beyond the need to ensure affordability in Member States with lower purchasing power.

Against this backdrop of fragmentation in the EU (which is specific to the EU compared to other regions of the world) and low profitability levels, the question arises as to whether industrial policy measures further facilitating the cross-border provision of electronic communications networks or different forms of cooperation upstream could allow operators to acquire sufficient scale, without compromising downstream competition. Some operators are of the view that there are no obstacles to cross-border provision of networks and services other than the net negative efficiencies and synergies (despite expected cost reductions which could be allowed by more centralised operations, especially in virtualised networks) that are due to fragmented regulatory conditions. Cross-border consolidation in itself has never been a problem from a competition standpoint because of the national dimension of the EU electronic communications markets. However, as long as the benefits of cross-border consolidation are limited by the persistence of national regulatory frameworks and the lack of a genuine single market, it cannot as such overcome the fallbacks mentioned earlier.

[47] The results of the exploratory consultation were published in October 2023 and are available at https://digital-strategy.ec.europa.eu/en/news/consultation-electronic-communications-highlights-need-reliable-and-resilient-connectivity. For this point see page 12 under point ii. Obstacles to the Digital Single Market.

While prices and coverage differ considerably between Member States[48] due to the inherently different market and regulatory landscapes, beyond the need to ensure affordability in Member States with lower purchasing power, mobile and fixed broadband prices are typically lower in the EU compared to the US for the vast majority of tariffs, bringing significant short-term consumer benefits. At the same time, coverage for fibre is higher in the EU and basic 5G coverage is comparable to the US levels. However, while the single market, on average, delivered on price, it did not deliver on the mass deployment of advanced infrastructures and services like 5G standalone or the proliferation of advanced industrial and IoT services[49].

Overall, the fragmentation of the EU market for electronic communications networks and services along national borders impacts the ability of operators to reach the scale needed to invest in the networks of the future, in particular in view of cross-border services, important for an effective deployment of IoT, and a more centralized operation.

2.3.4. Convergence and level playing field

The convergence of electronic communications networks and services and cloud infrastructures does not only concern the infrastructure layer, but also the service operations. As explained in section 2.2 above, connectivity markets are facing transformative technological developments the result of which will be both a converged supply (i.e. network and service provision) as well as a converged demand by end-users. Yesterday's separation between "traditional" electronic communications networks/service providers and cloud or other digital service providers will tomorrow be superseded by a complex converged ecosystem. These developments raise the question whether the players in such converged ecosystem should not fall under equivalent rules applicable to all and whether the demand side (i.e. end-users and in particular consumers) should not benefit from equivalent rights.

Currently, the existing EU regulatory framework for electronic communications networks and services does not establish obligations related to the activities of cloud providers and does not regulate the relationship between the various players in the new complex digital infrastructure ecosystem. More specifically, the cloud infrastructure and services provision are not in the scope of the Code (contrary to the recent NIS2 Directive[50] for instance). Even if cloud providers run large (backbone) electronic communications networks, these networks are exempt from parts of the electronic communications regulatory framework, notably in the area of access regulation and dispute resolution.

More than 60%[51] of the international traffic transits through submarine cables, which do not belong to "public electronic communication network operators" within the meaning of the Code. Moreover, large cloud providers operate their own backbone networks and data centres and hand over the traffic deep into the networks of public electronic communication network

---

[48] Mobile and fixed broadband prices vary widely across the EU not only in nominal terms but also at power purchasing parity. See European Commission, Directorate-General for Communications Networks, Content and Technology, Mobile and fixed broadband prices in Europe 2021 – Final report and executive summary, Publications Office of the European Union, 2022, available at https://data.europa.eu/doi/10.2759/762630.

[49] 2023 Report on the state of the Digital Decade, available at https://digital-strategy.ec.europa.eu/en/library/2023-report-state-digital-decade.

[50] Directive (EU) 2022/2555 of the European Parliament and of the Council of 14 December 2022 on measures for a high common level of cybersecurity across the Union, amending Regulation (EU) No 910/2014 and Directive (EU) 2018/1972, and repealing Directive (EU) 2016/1148 (NIS 2 Directive), OJ L 333, 27.12.2022, p. 80.

[51] BoR (23) 214, Draft BEREC Report on the general authorization and related frameworks for international submarine connectivity.

operators. Consequently, traffic transits mostly on private networks, which are largely unregulated, rather than on public ones.

Another distinction made in the Code is between the kind of service provided; for example, most obligations apply to providers of internet access services and of number-based interpersonal communications services (NBICS) while providers of number-independent interpersonal communications service (NIICS) are subject to only a few obligations and are exempt for instance from contribution to the funding of the Universal Service or the financing of sector regulation. Whilst both NIICS and cloud computing services are within the scope of the Digital Markets Act[52], those rules only apply to gatekeepers designated for these specific core platform services.

2.3.5. Sustainability challenges

The ICT sector accounts for between 7 and 9% of global electricity consumption (forecast to rise to 13% by 2030)[53], around 3% of global greenhouse gas emissions[54], and increasing amounts of e-waste. Yet, if properly used and governed, digital technology can help cut global emissions by 15%[55], outweighing the emissions caused by the sector. For instance, smart building design has the potential to generate energy savings of up to 27%[56] and smart mobility applications have been shown to be able to reduce transport emissions by up to 37%[57]. Connected and Automated Mobility is expected to be one of the main drivers to decarbonise the transport sector and 5G is expected to be one of its main enablers. However, significant further efforts are needed to apply digital technology systematically and make sure it powers solutions carefully designed according to circular, regenerative principles.

The "softwarisation" and "cloudification" of the next generations of electronic communications networks hold the promise of efficiency gains for all sectors, but also present new challenges in terms of energy consumption (e.g. Open Radio Access Network - RAN - in cellular networks). Increased energy consumption due to step changes in traffic load has a cost in itself that has significantly increased in recent years with rising energy prices. At the same time, high energy costs could incentivise investments into more energy-efficient and low-carbon network operations and technologies with less e-waste.

Modern digital networks can contribute significantly to sustainability. Concrete examples include the deployment and adoption of new and more efficient technologies such as fibre, 5G and 6G, and the phasing out of legacy fixed and mobile networks. Also, the use of more efficient codecs (coders-decoders)[58] for data transmission is essential. Newer generation video codecs are inherently more sustainable by minimising outgoing energy and power at the same video quality. At the same time, proper attention and investments, including sustainable financing, need to be ensured so that connectivity can accelerate and deliver on the digital enablement to green other sectors, through smart digital solutions that reduce the climate and environmental

---

[52] Regulation (EU) 2022/1925 of the European Parliament and of the Council of 14 September 2022 on contestable and fair markets in the digital sector and amending Directives (EU) 2019/1937 and (EU) 2020/1828 (Digital Markets Act), OJ L 265, 12.10.2022, p. 1.

[53] Strategic Foresight Report 2022; EU Action Plan on Digitalising the Energy System.

[54] The Shift Project, "Déployer la sobriété numérique", October 2020, p. 16; World Bank 2022.

[55] World Economic Forum 2019.

[56] https://www.buildup.eu/en/news/overview-smart-hvac-systems-buildings-and-energy-savings-0.

[57] TransformingTransport.eu, EU-funded Horizon 2020 Big Data Value Lighthouse project.

[58] A codec is a process that compresses large amounts of data – most commonly a video stream - before their transmission and decompresses them after the reception.

footprint across industrial processes, energy systems, buildings, mobility, and agriculture and support the efforts towards climate neutral and smart cities.

2.4. Need for security in the supply and in the operation of networks

2.4.1. Challenge of trusted suppliers

In a geopolitical environment increasingly marked by tension and conflict, the growing requirement for security and resilience of key enabling communications technologies and critical infrastructure highlights the need to rely on diversified and trusted suppliers, to prevent vulnerabilities and dependencies, with potential knock-on effects on the entire industrial ecosystem. The EU 5G Cybersecurity Toolbox[59] for example put forward a set of recommended measures to mitigate the risks to 5G networks, notably the assessment of the risk profile of suppliers and the application of restrictions for suppliers considered as high risk, including necessary exclusions from key assets. In this respect, in its Communication of 15 June 2023 on the "Implementation of the 5G Cybersecurity Toolbox"[60] the Commission considered that Huawei and ZTE present in fact materially higher risks than other 5G suppliers and confirmed that decisions adopted by Member States to restrict those suppliers are justified and compliant with the 5G Toolbox.

Gaps left by these high-risk vendors in the supply chain require the development of new capacities provided by existing or new actors. In this context, Research & Innovation (R&I) efforts in key technologies relevant for secure communications networks will have to be stepped up to ensure that a sufficient level of intellectual property and production capacity remains available across the entire EU supply chain, at all times. The objective is not only to ensure that the EU remains among the global leaders in communications systems, but also to achieve leadership in the development of new capabilities in related areas such as edge cloud, radio frequency identity chips technology, quantum communications, quantum resilient cryptography, non-terrestrial connectivity, and submarine cable infrastructures.

2.4.2. Security standards for end-to-end connectivity

To achieve the highest security and resilience, the EU should also lead the development of security standards covering the entire value stack, from end-to-end and from the hardware layer up to the service layer (e.g. secure messaging and videoconferencing standards). The challenge for the EU is to ensure that such developments result in common and interoperable security standards for all key infrastructural elements underpinning sensitive communications infrastructures. The Commission is working with Member States to establish the EU Critical Communication System (EUCCS) to connect communication networks of all public law-enforcement, civil protection and safety responders in Europe by 2030 to allow for seamless critical communication and operational mobility across the Schengen area[61]. The related setting of mission critical standards will enhance strategic autonomy in a particularly sensitive segment of the communication sector.

---

[59] https://digital-strategy.ec.europa.eu/en/news/connectivity-toolbox-member-states-agree-best-practices-boost-timely-deployment-5g-and-fibre.

[60] C(2023) 4049.

[61] EUCCS is based on projects funded by the EU security research programme and the Internal Security Fund. The current rollout of testbeds in Member States will also establish the link to EU connectivity assets in Space, in line with the EU Space Strategy for Security and Defence.

The new digital era will be based, among others, on quantum technologies for secure connectivity and quantum computing. Communication networks and the way data are protected will experience a paradigm shift as a direct consequence of advances in quantum computing. As safeguarding our data and securing communication are vital for our society, economy, infrastructure, services, and prosperity, as well as our political stability, we need to anticipate threats coming from potential malicious use of future quantum computers, which could put our traditional methods of encryption at risk.

The Cyber Resilience Act (CRA), which is set to enter into force later this year, will contribute significantly to securing EU's digital infrastructure. It places security-by-design obligations on the manufacturers of hardware and software products, covering the entire life cycle of such products from their design and development to their maintenance. The CRA not only covers many of the products deployed in digital infrastructures, such as routers, switches or network management systems, but also requires the manufacturers of connectable hardware and software products at large to protect the confidentiality and integrity of data by state-of-the-art means. This could entail, where appropriate, the use of quantum-resistant cryptography. To support manufacturers in their implementation, the Commission will request the development of European standards by the European Standardisation Organisations. In addition, the recently adopted European Cybersecurity Scheme on Common Criteria (EUCC) will allow manufacturers of technological components, such as chips, to provide security assurance in a harmonised manner under the EU's Cybersecurity Act.

2.4.3. Secure and resilient submarine cable infrastructures

A precondition for secure communications is a higher level of resilience and integration of all communication channels: terrestrial, non-terrestrial and, importantly, submarine. In the current context of increased cybersecurity and sabotage threats, governments in all regions are paying particular attention to their reliance on critical submarine cables. Indeed, over 99% of intercontinental data traffic is carried through submarine cables, and three insular EU Member States, Cyprus, Ireland and Malta, as well as a number of islands in other Member States and outermost regions are highly dependent on them.

In particular, Russia's war of aggression against Ukraine has had a significant impact on awareness about the security of communications networks, including submarine cables, given its potential capability to disrupt cables and suspicious monitoring activities of Russian vessels.

Europe has global leaders in fibre production. However, since 2012, large non-EU providers have been increasingly investing in own infrastructures, which is already leading to strategic dependencies, which may be further exacerbated going forward.

In the EU, there have been repeated calls to strengthen the security and resilience of submarine cable infrastructures, including increasing public funding to support private investment in a challenging environment. For instance, the Nevers Call of March 2022[62] recognised the utmost importance of critical infrastructure, such as electronic communications networks and digital services, to many critical functions, and the fact that the latter are a prime target for cyberattacks. The Council, in its Conclusions on the EU's Cyber Posture of 23 May 2022 and on the EU Policy on Cyber Defence of 22 May 2023, requested risk evaluations and scenarios to be undertaken. In its Critical Infrastructure Resilience Recommendation on a Union-wide

[62] https://presse.economie.gouv.fr/08-03-2022-declaration-conjointe-des-ministres-de-lunion-europeenne-charges-du-numerique-et-des-communications-electroniques-adressee-au-secteur-numerique/.

coordinated approach to strengthen the resilience of critical infrastructure of 8 December 2022, the Council set out targeted actions at EU and Member States' level for enhanced preparedness, enhanced response and international cooperation. These actions focus on critical infrastructure, including those with significant cross-border relevance and in the identified key sectors energy, transport, space, and digital infrastructure.

In the State of the Digital Decade report 2023, the Commission underlined the importance of making progress towards more resilient and more sovereign networks and in particular to limit the vulnerability of the EU's key infrastructure, including submarine networks. It also issued a clear recommendation to Member States to boost the investments necessary for the security and resilience of such infrastructures. Member States have also committed to reinforce Internet connectivity between Europe and its partners, in the Ministerial Declaration on "European Data Gateways as a key element of the EU's Digital Decade".

Moreover, the EU-NATO Task Force on the resilience of critical infrastructure discussed submarine infrastructure on several occasions. Its Final Assessment Report includes a recommendation for EU and NATO staffs to "*[e]xplore possibilities for exchanges on how to improve the monitoring and protection of critical infrastructure in the maritime domain by relevant authorities and discuss ways to enhance maritime situational awareness*". Staff exchange have intensified in the context of the Structured Dialogue on Resilience, including in light of the establishment of the NATO Critical Undersea Infrastructure Coordination Cell to address the security of inter alia submarine cables.

Incidents such as in the Baltic Sea[63], following which Finland activated the EU Hybrid Toolbox mechanism[64], have however demonstrated that elements of submarine cable infrastructure remain vulnerable, even if the system itself is resilient due to multiple redundancies. This underlines the need to further advance and coordinate work at EU level to foster cable infrastructure security and resilience. Consequently, the European Council on 27 October 2023 consequently stressed "*the need for effective measures to strengthen the resilience and ensure the security of critical infrastructure"*, while underlining *"the importance of a comprehensive and coordinated approach*."

As mandated by the 2022 Council Recommendation as regards submarine cable infrastructures, the Commission carried out studies and consulted relevant stakeholders and experts on appropriate measures in relation to possible significant incidents regarding submarine infrastructure. The results of the study will be shared with Member States at the appropriate confidentiality level.

A key conclusion is that the current framework in the EU cannot fully address the challenges identified. Concrete elements currently lacking include an accurate mapping of existing cable infrastructures informing a consolidated EU-wide assessment of risks, vulnerabilities and dependencies, a common governance of cable technologies and cable-laying services, ensuring rapid and secure repair and maintenance of cables, as well as the identification and funding of critical intra-EU and global cable projects.

---

[63] A submarine gas pipeline (between Finland and Estonia) and electronic communications cables (between FI and EE, and between SE and EE) were damaged.

[64] Council conclusions of 21 June 2022 on a Framework for a coordinated EU response to hybrid campaigns.

3. MASTERING THE TRANSITION TO THE DIGITAL NETWORKS OF THE FUTURE - POLICY ISSUES AND POSSIBLE SOLUTIONS

3.1. Pillar I: Creating the "3C Network" - "Connected Collaborative Computing"

As described in earlier sections, people and devices communicating with each other, doctors caring for their patients at a distance, buildings becoming intelligent through sensors, and other future applications facilitating business and improving the lives of citizens depend on the availability of high-performing digital infrastructures.

The advancement of on-device edge technology is expected to facilitate the presence of significant computational capacity, especially those equipped with AI processors, in a wide range of devices, including robots, drones, medical devices, wearables and self-driving cars. Computation is no longer bound to dedicated computing environments such as data centres. Instead, it has become embedded and ubiquitous in almost everything. This will allow to combine on-device edge with the rest of the broad range of edge computing categories and different types of cloud services in collaborative computing environments[65]. However, the integration of these different computing resources with various network capacities will require intelligent orchestration, that also allows optimisation for security and sustainability considerations.

As section 2.2 describes, just as connectivity and computing are converging, the companies in these different segments of the value chain also need to work together, including chips manufacturers, electronic communications network equipment providers, edge and cloud service providers. But the different sectors are fragmented and, as well as lacking scale, they do not have a common approach to the innovation necessary to deliver next generation connectivity and computing. Thus, as well as orchestration in the technical sense, these sectors require close collaboration in order to succeed.

We need to ensure that these innovations are implemented in the EU and safeguard our economic security and prosperity. In particular, it is of key importance that EU industry has sufficient technology capacity in key parts of the digital supply chain and is able to reap economic benefits in the most attractive parts of the digital value chain. The goal is to foster a vibrant community of European innovators, creating the "Connected Collaborative Computing" Network ("3C Network"), an ecosystem that spans semiconductors, computational capacity in all kinds of edge and cloud environments, radio technologies, to connectivity infrastructure, data management, and applications.

3.1.1. Capacity building through open innovation and technology capabilities

As hybrid networks, edge computing, and full cloud migration change the architecture of connectivity infrastructure, the historical strength of Europe in the network equipment and service industry is at risk. It is therefore important to safeguard EU global leadership in electronic communications network equipment and facilitate the build-up of further industrial capacities in this transition towards interoperable cloud-based networks and the integration of telco-edge infrastructures and services. Next to industrial capacity, it is equally important for the EU to strengthen its technological innovation capabilities as well as developing the necessary knowledge and skills.

---

[65] Collaborative computing environments have also been referred to in literature as Swarm computing, Ambient Computing, and Tactile internet, among other additional terms.

EU businesses increasingly partner with non-EU players, both within the electronic communications services ecosystem but also in the supply industry. While such partnerships with actors from like-minded countries can generate synergies and benefits, a potential dependency on a small number of suppliers of critical infrastructures and services, such as cloud, edge or AI tools, or submarine cable infrastructures, bears the risk of new bottlenecks or lock-ins[66]. The goal must be to create an equally strong dynamic for partnership between businesses within Europe.

In the area of semiconductors, the EU has reacted to reverse this trend: with the Chips Act[67], the EU has put forward an ambitious programme which has already mobilised more than EUR 100 billion of public and private investments. But when it comes to connectivity infrastructures, an industrial policy of similar magnitude to incentivise investments by EU players and catalyse the 3C Network to enable future applications is currently missing.

Nevertheless, in the equipment sector, the EU has a solid base that it can build upon. Today, it is the home of two of the three largest suppliers of digital network equipment, both as regards global sales market share and share of standard essential patents. Following decades of success in shaping mobile communication standards and driving innovation in the EU and globally, the challenge is to build on this leading position and leverage it to the broader supply and value chain, such as in the area of edge and cloud computing but also chips, where Europe starts from a weaker position. This extends to complementary infrastructures, such as submarine cables or even non-terrestrial connectivity.

As for production, deployment, and operational capacities, Europe can also build on its strength when it comes to R&I in the upstream part of the digital value chain. The EU already hosts a solid R&I base for networks, with globally renowned scientific excellence on which future R&I ecosystems can build. The geopolitical context and the trend towards ever more critical applications, such as blockchain in finance, connected trucks in logistics, or telemedicine, call for infrastructure security and resilience by design. These design criteria therefore need to be placed at the forefront of our R&I efforts.

However, the transformation of the EU's connectivity industry requires significant investment capacities, in particular when compared to the massive investments made by large cloud providers into cloud, edge, and AI capacities. There are a number of EU funding instruments and programmes that already support private investments in R&I in relation to the communications sector. These include the Smart Networks and Services Joint Undertaking (SNS JU) under Horizon Europe, but also InvestEU, the Digital Europe Programme (DEP), and the Connecting Europe Facility (CEF) Digital.

The SNS JU is the current EU platform for R&I funding towards 6G systems in cooperation between industry and public actors. One of its main objectives is to leverage the EU's strength in network supply towards the broader value chain including cloud and software as well as devices and components. The SNS JU already addresses several industry-led R&I needs (mostly in anticipation of 6G): research on concepts, architectures and core components of 6G systems, large-scale trials and pilots, standardisation, virtualisation of networks, cloud software, as well as AI-enabled radio access networks. This current scope is, however, too narrow to

[66] Commission study on 5G Supply Market Trends, August 2021, available at https://digital-strategy.ec.europa.eu/en/library/commission-publishes-study-future-5g-supply-ecosystem-europe.

[67] Regulation (EU) 2023/1781 of the European Parliament and of the Council of 13 September 2023 establishing a framework of measures for strengthening Europe's semiconductor ecosystem and amending Regulation (EU) 2021/694 (Chips Act) (Text with EEA relevance), OJ L 229, 18.9.2023, p. 1–53.

address the challenges identified. Moreover, the existing budget of EUR 900 million for 2021-2027 is focused on R&I activities. This represents a small amount in the face of those challenges, compared to what would be required to catalyse the next generation connectivity ecosystem covering the entire computing continuum.

In December 2023, the Commission approved up to EUR 1.2 billion of State aid by seven Member States for an Important Project of Common European Interest (IPCEI) in Next Generation Cloud Infrastructure and Services (IPCEI CIS), which is expected to unlock additional EUR 1.4 billion in private investments[68]. Already in June 2023, the Commission approved another IPCEI to support research, innovation and the first industrial deployment of microelectronics and communication technologies across the value chain (IPCEI ME/CT), involving 14 Member States, counting with EUR 8.1 billion in public funding, unlocking EUR 13.7 billion in private investments. Leading chip suppliers and network equipment vendors participate, to develop advanced chips for electronic communications networks.

3.1.2. Way forward

To ensure a more efficient use of resources, the EU needs to establish a coordinated approach to the development of integrated connectivity and computing infrastructures, making sure that today's connectivity providers become tomorrow's providers of collaborative connectivity and computing, capable of orchestrating the different computing elements that this ecosystem requires. To do so it is not only necessary to develop a synergetic ecosystem between actors in the different sectors, but also to rethink the interplay and synergies that can be established between existing EU funding programmes. This is necessary in order to maximise the impact of R&I in communications and computing networks, but also capacity building and pre-deployment, especially given the convergence of technologies and services (cloud-edge continuum, AI, connectivity). These programmes could be built around the overall objectives of improving the EU's industrial capacities, of contributing to a secure and resilient connectivity and computing infrastructure, and of bolstering Europe's competitiveness. Ultimately, this could provide the environment for future networks and applications being developed, tested, deployed, and integrated in the EU.

A key step towards the 3C Network could be taken by proposing for consideration in forthcoming work programmes a number of large-scale pilots that set up end-to-end integrated infrastructures and platforms and bring together players from different segments of the connectivity value chain and beyond. These could be considered for funding under the Horizon Europe programme or its successors.

If pursued, these pilot infrastructures would be used to test innovative technologies and applications (including demos, proof of concepts and early deployment of technologies). They could be attached, where appropriate, to the European network of competence centres in semiconductors, which are maximising synergies with the European Digital Innovation Hubs. Initial pilots could focus on 5G corridors, e-health and smart communities. These initial, up to three large-scale pilots would not only promote exchanges between players from the traditional electronic communications value chain and players along the broader computing continuum, but also with non-digital sectors, ensuring emphasis on concrete applications. The integrated infrastructures and platforms would bring together not just the key technologies from startups to large businesses but also researchers and attract talent to develop knowledge and skills.

[68] https://ec.europa.eu/commission/presscorner/detail/en/ip_23_6246.

Europe can build again on existing initiatives to scale up innovative technologies and applications. One example is the development of 5G corridors, funded under the CEF Digital programme, where the corridors can be used for testing and piloting new technologies and applications, in particular connected and autonomous driving but also advanced logistics and IoT applications. Another example is the smart communities, where pilot architectures could be used to trial AI systems and applications funded under the EU's AI flagship, in order to maximise synergies and ensure that computing at the edge serves as a fuelling station for AI-powered algorithms. As well as urban agglomerations, a smart communities pilot could account for specific challenges of rural surroundings, so that any solutions are 'rural ready'.

To succeed, Europe must mobilise all the relevant actors into a collaborative computing ecosystem. As well as the 6G Industry Association, the key private sector partners in the SNS JU, the European Alliance for Industrial Data, Edge and Cloud (the Cloud Alliance) brings together actors in the cloud and edge environment. Concretely in the next few years, the SNS JU could coordinate the creation of immediate synergies with relevant programmes and IPCEIs. Following the publication of this White Paper, the Commission will shortly start developing with stakeholders the specifications of this task, building notably on the ongoing work to further develop and deploy European Telco Edge Cloud capacities, as envisaged by the Industrial Technology Roadmap developed by the Cloud Alliance.

The existing IPCEIs, in particular in the area of microelectronics and connectivity as well as next generation cloud infrastructure and services, could be used to structure innovation and accelerate market take-up. In October 2023, the Commission launched a Joint European Forum for Important Projects of Common European Interest (JEF-IPCEI) to focus on identifying and prioritising strategic technologies for the EU economy that could be relevant candidates for future IPCEIs. As part of the JEF-IPCEI, and drawing from the experience under the Chips Joint Undertaking (Chips JU), CEF2, DEP, and relevant national and regional funds, the possibility of supplementing these measures with a new IPCEI to tackle the need for large scale infrastructure deployment together with the exploration of integration of additional target areas along the computing continuum such as chips in order to respond adequately to the massive future compute demands of artificial intelligence could be discussed.

In addition, the Strategic Technologies for Europe Platform (STEP) will boost investments in critical technologies in Europe including deep and digital technologies. STEP also introduces the Sovereignty seal – the EU quality label for sovereignty projects.

In the longer term, to further leverage EU technology capacities, it would need to be determined whether and how related areas that are crucial for future networks could be brought under a single cooperative governance. The appropriate mix of budget sources at Union, national and industry levels would also need to be determined, including the role of different possible EU programmes. Inspiration could be taken from the examples of the recent AI innovation package[69] and the Chips Act, which extended the mandates of respective current Joint Undertakings on European High Performance Computing and Chips (EuroHPC JU and Chips JU). Future research priorities could include security solutions in critical hardware and software modules, interoperability and federation between edge and cloud infrastructures supported by open-source activities, diversified supply chains for products, components, and materials, while strengthening know-how in the EU, and sustainability solutions covering various aspects of the

[69] COM/2024/28 final.

networking domain ("Sustainable 6G") and a variety of the vertical industries, such as manufacturing, transport, energy, and agriculture (i.e. "6G for sustainability").

Increased and better aligned R&I activities that are embedded into an industrial strategy could strengthen Europe's technology capacity, create synergies, ensure coherence, and leverage the multiplier effect of EU actions for private investments. It could also provide the means of ensuring the EU's security and resilience in this domain as well as improve cooperation among European players in an ecosystem that spans the whole computing continuum, supporting them to compete on an equal footing with global competitors. The goal would be to ensure the availability of European solutions able to establish a single entry point for EU funding across the whole continuum from radio frequency to chips to software to algorithms to edge and cloud compute capacity, so that Networks-as-a-Service are not an end in themselves but an enabler of orchestration, fuelling actual services and applications 'made in Europe'.

3.1.3. Summary of possible scenarios

- *Scenario 1: The Commission may consider proposing large-scale pilots that set up end-to-end integrated infrastructures and platforms for telco cloud and edge. In a second step these pilot infrastructures would be used to orchestrate the development of innovative technologies and AI applications for various use cases.*

- *Scenario 2: The possibility of following-up the accomplishments of IPCEI CIS by a new infrastructure-focussed IPCEI could be discussed by the Commission's Joint European Forum for Important Projects of Common European Interest (JEF-IPCEI), which is tasked with identifying and prioritising strategic technologies for the EU economy that could be relevant candidates for future IPCEIs.*

- *Scenario 3: Massive investments in connectivity capacity are required to support the creation of a collaborative connectivity and computing ecosystem. The Commission may consider different options in order to frame these investments into a simplified and coordinated support framework for a truly digital single market drawing on European and national, public and private investments.*

    - *This should streamline procedures and improve synergies between existing instruments and programmes (including based on the experience with the Chips Joint Undertaking, Important Projects of Common European Interest, the Connecting Europe Facility and the Digital Europe Programme), possibly tasking as a pilot under the current Multiannual Financial Framework the Smart Networks and Services Joint Undertaking (SNS JU) to adopt a more coordinating role, and by liaising with stakeholders such as the European Alliance for Industrial Data, Edge and Cloud as appropriate).*

    - *This should explore means to ensure strengthening coherence, simplification and clarity of future support action, without prejudice to institutional programme design and budget allocation prerogatives under the next Multiannual Financial Framework.*

3.2. Pillar II: Completing the Digital Single Market

3.2.1. Objectives

One of the main objectives of the Code is to promote connectivity by putting in place a regulatory framework conducive to more investment in very high-capacity networks. With this objective in mind, a number of legal provisions in the area of access regulation and spectrum management were designed to facilitate investment, and to cut red tape. However, despite a number of new provisions introduced in the Code, the results have not been satisfactory (e.g. joint authorisation process to grant individual rights of use for radio spectrum, co-investment and wholesale only provisions had not been much used in practice). This is due not only to the delayed transposition by several Member States, but also because of the complexity of the framework and its procedures.

While reinforcing investment objectives, the Code also aims at promoting competition (both at infrastructure as well as at services level), contributing to the development of the internal market and promoting end-user benefits. The assumption is that competition drives investment based on market demand and is beneficial to consumers and businesses. All these principles remain valid but in addition due to recent technological developments and new global challenges, it should be considered whether incorporating wider dimensions such as sustainability, industrial competitiveness, and economic security into the policy framework, would be appropriate.

Whatever measures might be taken in the future to address said new challenges, end-users' protection, including consumers, will continue to carry important weight among the objectives. Ultimately, the stable bedrock of any future regulation should be the "European Declaration on Digital Rights and Principles for the Digital Decade" of 15 December 2022, according to which people are at the centre of the digital transformation in the European Union and all businesses, including SMEs, should benefit from it.

3.2.2. Scope of application

In light of the developments described above (see section 2.3.4), and in particular the quick progressing of convergence between electronic communications networks and cloud, a rethinking of the scope of application of the electronic communications regulatory framework could be considered. Currently, an end-user sends or receives data that "travel" via different networks or network segments (ranging e.g. from submarine cables to local access networks) and that are subject to different applicable rules. It is difficult to justify the rationale for such difference in the applicable rules (for instance, as regards lawful interception).

At the same time, the recent technological changes create an opportunity for alignment of the operations of electronic communications and cloud services with the development of pan-European core network operators. For example, the cloudification of 5G networks can provide significant benefits to the electronic communications network providers and allow them to leverage the same economies of scale of cloud providers by, *inter alia*, unifying the core network functionality of several national electronic communications networks in the cloud. However, when it comes to electronic communications networks, this integration of functionalities in centralised cloud data centres that provide cross-border core network functionalities currently faces several legal barriers due to non-harmonised legal frameworks in the Member States, *inter alia*, in the area of authorisation.

On the service side, a consistent provision of NaaS-based applications relying on standalone 5G core networks, network slicing, and spectrum resources available across Member States could provide a new business case for cross-border operations.

On the network side, it is to be recalled that - in contrast to voice traffic (which is billed according to the "calling party's network pays" principle) - IP interconnection currently appears to rely on transit and peering agreements usually based on a “bill-and-keep” approach where the Internet Service Provider (ISP) does not receive payments at the wholesale level for terminating traffic. According to the model generally attributed to the IP interconnection market, the ISP normally recovers its costs at the retail level by selling internet connectivity to its end-users, who generate internet traffic when retrieving data/content offered by CAPs. For supplementary paid peering and for transit, typically payment is made on the basis of the capacity provided at the point of interconnection. The main recent changes in the overall global architecture of the internet and of interconnection are caused and driven by the expansion of own backbone and delivery infrastructures by the CAPs. This has shifted the relation of interconnection in the form of transit and peering[70], with “on-net” exchange now predominating[71], with the CDNs' dedicated local storage servers (cache servers) collocated directly in the ISPs' networks. This leads to a very direct and cooperative interaction between CAPs and ISPs as they have to agree on technical and commercial conditions for transit and peering bilaterally (e.g. on the locations of traffic handover, the level of transit prices, on the question of settlement-free or paid peering or on quality and efficiency aspects).

There are very few known cases of intervention (by a regulatory authority or by a court) into the contractual relationships between market actors[72], that generally functions well and so do the markets for transit and peering. There has been nonetheless a vivid debate on this topic[73]. Moreover, it cannot be excluded that the number of cases in the future will increase. Should this be the case, subject to careful assessment, policy measures could be envisaged to ensure swift resolution of disputes. For example, the commercial negotiations and agreements could possibly be further facilitated by providing for a specific timeline and by considering the possibility for requests for dispute resolution mechanisms, in case commercial agreements could not be found within a reasonable period of time. In such case, NRAs or (in cases with a cross-border dimension) BEREC could be solicited, as they have the necessary technical knowledge, and important experience in dispute resolution and in assessing market functioning.

3.2.3. Authorisation

The general authorisation regime established in 2002 and maintained in the Code replaced the previous regime of individual licenses/authorisations, by pre-establishing generally applicable conditions for the provision of electronic communication networks and services (ECNS). Yet, given the local character of the physical networks, and the fact that spectrum is deemed to be a

[70] See e.g. WIK-consult: Final study report “Competitive conditions on transit and peering markets”, Bad Honnef, 28.02.2022.

[71] Only a few ISPs do not allow on-net data exchange, continuing instead to exchange traffic across network boundaries and point of interconnection.

[72] For an overview of known cases see WIK-consult: Final study report “Competitive conditions on transit and peering markets”, Bad Honnef, 28.02.2022.

[73] For an overview of the various arguments raised in this debate, see e.g. also the responses to the relevant section of the exploratory consultation available at https://digital-strategy.ec.europa.eu/en/news/consultation-electronic-communications-highlights-need-reliable-and-resilient-connectivity.

national resource (see section 3.2.5), authorisations are subject to conditions established by the Member States' competent authorities and granted and implemented at national level.

Nonetheless, due to cloudification and softwarisation, network provision is less and less linked to location. Furthermore, coverage of wireless networks, such as satellite networks, can extend beyond national – and even EU – borders. While there are still clear benefits in keeping the implementation of authorisation regimes at national level, in particular for local access and retail services, assigning radio spectrum under conditions which differ between Member States may not always be the most efficient approach, in particular for satellite communications. There could therefore be an economic and technical justification for a more European approach.

One of the elements explaining the fast development of information society services has been the fact that they could be provided to the entire EU simply by complying with the legislation of the Member State of establishment ('so called 'country of origin' principle), without the need to comply with the legislation of each Member State in which services are provided. While network virtualisation may technically allow the provision of cross-border core networks and create a market for core network services, the business case cannot develop if there is insufficient scale, or if different regulatory regimes hinder such business case. To develop the business case, setting out a single set of rules by enabling authorisation based on the 'country of origin' principle for providers of core networks and core network services could balance the approach to all types of providers of digital networks and services, putting them on a more equal level. In the converging ecosystem, where a boundary between the "traditional" providers of digital networks and services on the one hand and the providers of e.g. cloud services on the other hand becomes increasingly blurred, the regulatory treatment of those services should be more holistic. It could also lessen the administrative burden by bringing in potential rationalisation of reporting obligations of different actors.

The application of a single set of rules based for instance on a 'country of origin' principle for core networks and core network services would enable EU core network operators to leverage the full potential of the internal market to reach critical size, take advantage of scale economies, and reduce capital expenditure and operating costs, thus solidifying their financial position, attracting more private investments and ultimately contributing to EU competitiveness. In this scenario, the applicable legislation and the competent authority to regulate access to networks and retail services provided to end-users would remain the same and the one closest to the end-users, i.e. those of the Member State of the provision of the access network and of the retail service. This would also ensure that the specificities of local markets are adequately taken into account when defining appropriate access remedies and when guaranteeing the highest level of protection of end-users.

3.2.4. Addressing barriers to core network centralisation

In addition to the sector-specific regulatory barriers mentioned above, contributors to the exploratory consultation listed other regulatory barriers to the establishment of a true Digital Single Market such as different obligations across the EU with regard to network/service incident reporting or security vetting requirements, building lawful interception capabilities, data retention regimes, privacy and reshoring requirements or cybersecurity and reporting obligations[74].

[74] The results of the exploratory consultation were published in October 2023 and are available at https://digital-strategy.ec.europa.eu/en/news/consultation-electronic-communications-highlights-need-reliable-and-resilient-connectivity. For this specific point see page 12 under point ii. Obstacles to the Digital Single Market.

Having due regard to Member States' sovereignty as well as their competence on security issues, it is worth reflecting on whether and how those other barriers could be addressed to allow achieving scale and enhance innovation. For example, in relation to security incidents or security vetting to further improve harmonisation and a high level of security, different measures could be envisaged, such as introducing close cooperation between those Member States where a core network spans, guaranteeing core network operators the right to request all competent authorities of the Member States in which they provide networks to agree on a set of conditions and requirements to be consistently applied throughout the network and be verified at a one stop shop; defining security requirements for core network operators through EU level guidance etc. As regards law enforcement obligations such as lawful interception, one option could be that core network operators identify in each Member State where they operate a point of contact for competent national law enforcement authorities. Soft law measures, such as an EU recommendation or guidelines, could help identify and specify such solutions on security and law enforcement.

3.2.5. Radio spectrum

Spectrum plays a pivotal role in wireless connectivity and should be managed in the best coordinated way possible among all Member States to fulfil the Union objectives of sustainable development, balanced economic growth, economic, social and territorial cohesion, and solidarity among Member States. Earlier attempts to establish greater EU coordination in spectrum management were not fully successful, and, in parallel, discrepancies and delays have been observed in authorising spectrum for 5G deployment across the Member States. As a consequence, today Europe is lagging behind its international competitors on the uptake of 5G. The observations in Section 2 indicate that there is scope to further improve spectrum policy across the EU and make spectrum management fit for the Digital Decade needs and targets.

3.2.5.1. Adapting spectrum management to Digital Decade needs: lessons learned from earlier legislative efforts

A number of proposals by the European Commission to better harmonise the release and licensing of radio spectrum for mobile services have faced considerable resistance in the past 10 years. In view of the delays, fragmentation and in certain instances artificial scarcity that led to very high prices paid for spectrum, it is worth considering whether solutions that were proposed in earlier legislative efforts, but eventually not retained by the co-legislators, could have avoided some of the negative effects that are now evident given the delayed 5G deployment. Considering the necessity to complete 5G roll-out and timely 6G deployment, a more cooperative approach between the national and European level is of vital importance for EU competitiveness. In this context, areas that deserve to be considered and possibly lead to relevant actions include: (i) EU level planning of sufficient spectrum for future use cases, (ii) strengthening EU level coordination of auction timing, and (iii) considering more uniform spectrum authorisation landscape.

No wireless service can be deployed without the availability of sufficient spectrum resources. This would include evolving and new areas such as vertical use cases, 6G, IoT applications, WiFi, local spectrum use. Also, this includes rapidly developing satellite communications, ensuring secure government and commercial applications, including direct-to-device satellite connectivity, using spectrum allocated for mobile satellite and, if appropriate, terrestrial services. In this context it should be considered whether, to ensure that new technology advancements are rolled out across the EU at the same time, an EU spectrum roadmap towards 6G should be enshrined in the law and enforced in a coordinated way by all Member States.

Coordinated release and refarming would be crucial in this context. Key example is the coordinated switch-off of 2G and 3G networks (with release of the relevant spectrum for other uses) while, in parallel, implementing solutions for continuous support of important legacy services such as emergency and critical communications (e.g. eCall[75]).

At the same time, efficiency in spectrum use should be further enhanced to meet the fast growing needs of existing and future wireless applications. For example, stricter conditions attached to spectrum usage rights could be considered, where appropriate, including the principle of 'use it or lose it' so as to avoid the creation of barriers to market entry and inefficient allocation of scarce resources. Efficiency could also be achieved whenever possible through shared and flexible use of spectrum with innovative and dynamic solutions or new forms of licensing and methods using, for example, databases and licensed-shared access, geolocation and artificial intelligence. Parallel to enabling new services, spectrum efficiency can significantly enhance consumer experience, quality of service, competitiveness, and environmental sustainability. At the same time the needs of end-users, such as persons with disabilities who rely on assistive technologies that require adequate and stable spectrum availability, should be taken into account.

Moreover, looking at the deployment of the next wireless communications technologies or renewal of existing licenses for broadband wireless communications, Europe cannot afford yet another spectrum authorisation process for the next generation mobile technology spreading over almost a decade, with huge disparities in timelines of auctions and network infrastructure deployment between Member States. To avoid that the same problems appear in the future, it should be considered how to better coordinate timing of auctions and ensure it is tighter across the whole EU.

The single market could benefit from better coordinated spectrum authorisation and usage conditions and rights including their appropriate duration to promote efficient investment across the whole EU. In this context, to date, the voluntary spectrum authorisation peer review mechanism that was adopted under the Code has not proven to be effective. Therefore, as an alternative, a notification mechanism similar to that used for market analysis as implemented under Article 32 of the Code could be considered to reinforce the coordination of authorisation procedures and conditions regarding the use of spectrum in the internal market.

3.2.5.2. New challenges in spectrum management

In the context of the reflection on core networks (discussed in 3.2.4), it is worth exploring the possibility, on the spectrum management side, for operators of EU core networks and pluri-national operators to request competent authorities to seek better aligned national authorisation processes and conditions so as to increase their communications capacities. This could primarily apply with regard to the existing spectrum usage rights or general authorisations, notably with regard, in particular, to the duration of licenses, spectrum usage conditions, such as quality of service objectives/obligations in the context of the 2030 connectivity targets, as well as the possibility to integrate satellite and terrestrial networks into new hybrid networks. These could be aligned to allow pan-EU or plurinational operators to operate in a more harmonised environment across borders. Such alignment could increase efficiency and ensure

[75] Regulation (EU) 2015/758 of the European Parliament and of the Council of 29 April 2015 concerning type-approval requirements for the deployment of the eCall in-vehicle system based on the 112 service and amending Directive 2007/46/EC, OJ L 123, 19.5.2015, p. 77–89.

legal certainty for operators of EU core networks and pluri-national operators, while respecting the rights already granted.

In addition, in particular the fast development of the satellite sector and its cross-border nature invite new reflections regarding enhanced or common licensing regimes (even EU-level selection and authorisation, if appropriate), to promote the emergence of cross-border or genuine pan-EU operators, while leaving spectrum revenues to the Member States. Such approach would complement the upcoming proposal for a Union legislative act for safe, resilient and sustainable space activities in the Union (EU Space Law) laying down the foundation for safe, resilient and sustainable space activities, and aiming at achieving consistency for all operators of space infrastructure.

Spectrum efficiency and investment incentives should be considered a priority, subject to competition considerations, in market shaping measures for example as regards reservation for new entrants or spectrum caps and overall design of auction processes. In this respect, it should be noted that, while auction prices for 3G and 4G were even higher, 5G auctions implemented in Europe between 2015 and 2023 still raised around EUR 26 billion[76], not to mention the administrative charges due to national authorities for spectrum management. This amount was paid by operators, in addition to the investments necessary for the deployment of the network infrastructure. The consequence thereof (particularly in cases of artificial increase of the spectrum price without adequate market justification) has been roll-out delays and suboptimal network quality and performance to the detriment of consumers and businesses. To help bridge the significant investment gap in the deployment of advanced communications networks, the financial burden could be alleviated by adopting bidding processes geared towards infrastructure investments.

Considering the potentially enlarged scope of the tasks that will need to be developed at EU level regarding radio spectrum, in particular with regard to coordinated, harmonised or common selections or authorisations, a more integrated spectrum governance mechanism at EU level should be considered.

From an international perspective, a more coherent spectrum management approach should be developed to ensure the EU's digital sovereignty and to defend EU interests externally. In this regard, the EU should retain full control over EU spectrum usage decisions especially when confronted with geopolitical and security challenges to guarantee the cybersecurity, independence and integrity of EU communications networks. This includes, in particular, the preparation of technical harmonisation measures for the use of spectrum in the Union[77] and of international negotiations such as World Radiocommunication Conferences. Member States, if appropriate at Council level, should be able to take positions regarding spectrum management in full independence from non-EU actors. This means reconsidering the role of the European Conference of Postal and Telecommunications Administrations (CEPT) in EU decision making, given the representation of non-EU Member States in this international body. Going forward, while continuing to rely on the technical expertise of CEPT, the Commission could be

[76] More than EUR 109 bn for 3G and more than EUR 40bn for 4G. ETNO, 2024 State of the Digital Communication Report.

[77] Under the 676/2002/EC Radio Spectrum Decision, with a view to the adoption of technical harmonisation measures to ensure the availability and efficient use of radio spectrum, the Commission is cooperating with the CEPT gathering experts from national authorities responsible for radio spectrum management from 46 European countries, including the 27 EU Member States.

assisted by an ad hoc group composed solely of the Member States' representatives whenever issues linked to EU sovereignty might be at stake.

EU and Member States' interests should also be defended at the EU external borders and globally through common actions adopted by all Member States and the EU in full spirit of solidarity. Harmful radio interference affecting Member States and originating in third countries should therefore be addressed through strong and efficient action not only by the Commission but also, by all Member States acting jointly in support of bilateral negotiations and in multilateral negotiations with third countries including in international fora such as the International Telecommunication Union.

Better alignment of existing and future spectrum usage rights, clarity in the policy orientations for the coming decade and more certainty in spectrum management throughout the Union could promote investments and boost EU competitiveness and scale, eliminate remaining barriers caused by the fragmentation induced by national practices. In turn, this would promote the development of the internal market of converging high-speed wireless broadband communications and enable planning and provision of integrated multi-territorial networks and services and economies of scale, thereby fostering innovation, economic growth and the long-term benefit of end users.

3.2.6. Copper switch-off

The migration from legacy copper to newly deployed fibre networks is a key process to facilitate the transition towards the new connectivity ecosystem and contributes to the EU's green objectives[78]. At the same time, it will promote the take-up of the new services and thus contribute to increasing the return on fibre investment and support the achievement of the Digital Decade target whereby, by 2030, all end users at a fixed location should be covered by a gigabit network up to the network termination point[79].

While the decommissioning of copper networks has the potential to decrease the OPEX costs for operators providing at the same time a more sustainable infrastructure due to lower energy consumption, the process requires coordination of all stakeholders. Predictable and balanced measures are necessary to avoid the migration reversing competitive gains, including competitive infrastructure roll-out, under the current regulatory regime. The needs of end-users, in particular vulnerable groups and end-users with disabilities, should also be carefully addressed. While the Code already contains provisions on migration processes and the new Gigabit Recommendation[80] aims at providing updated guidance to regulators, a clear path towards migration would send a strong signal to the sector further incentivizing investment.

The copper switch-off process requires close monitoring. NRAs should ensure that the design of the switch-off process by the operator with significant market power (SMP), in particular as

---

[78] Currently, the process of copper switch-off varies considerably in the EU. By 2023 the leading fixed line operators had announced plans for switching off their copper network in 16 Member States (BE, EE, EL, ES, FI, FR, HU, IE, IT, LU, MT, PL, PT, SE, SI, SK), while actual decommissioning has already commenced in 10 Member States (BE, EE, ES, FI, LU, MT, PL, PT, SE, SI). However, the progress within these Member States varies significantly. See also BEREC summary report on the outcomes of the internal workshop on the migration from legacy infrastructures to fibre-based networks, 5 Dec. 2019, BoR (19) 23.

[79] Another possible scenario is that copper networks would be at least partially replaced by fixed wireless access products (based on 5G). Moreover, significant differences in fibre deployment pace may lead to smaller, localized markets, not allowing a truly single market to emerge.

[80] Commission Recommendation of 6.2.2024 on the regulatory promotion of gigabit connectivity, C(2024) 523 final.

regards its timing and agenda, does not allow strategic behaviour that would risk weakening competition at wholesale or retail level. Some operators, at least initially, would not switch off copper (in particular, if it is supplemented by vectoring, which enables higher quality of broadband services – though falling significantly below VHCN performance). It cannot be excluded that some operators try to switch over customers from copper to fibre via lock-in strategies that would undermine the business case of FTTH alternative operators. Operators would lower FTTH wholesale prices in view of competing FTTH entry in order to keep wholesale customers. Therefore, the regulatory incentives for the switch-off, in particular on temporary copper price increase during the switch-off phase as proposed in the Gigabit Recommendation, should be accompanied by sufficient safeguards to preserve competition (similar to those provisionally agreed under the Gigabit Infrastructure Act[81] (GIA) and described in next section). Furthermore, lighter access regulation on very high-capacity networks could be imposed by applying pricing flexibility, subject to safeguard mechanisms as provided in the new Gigabit Recommendation.

In light of the above, setting a recommended date for achieving the copper switch-off would provide for planning certainty throughout the Union and would offer end-users opportunities of fibre connections under similar timeframes. Considering the national circumstances and the connectivity targets set in the Digital Decade, achieving a copper switch-off for 80% subscribers in the EU by 2028 and the remaining 20% by 2030 seems appropriate. Such a clear roadmap for copper switch-off would support the 2030 connectivity targets and send a strong signal for investors that there is a clear path towards a return on investment in fibre networks.

3.2.7. Access policy in a full fibre environment

The objective of liberalisation of the EU electronic communications sector was, following the global trends, to bring competition into a sector characterised by legal/statutory monopoly and to combat historical negative consequences of such monopoly (e.g. resulting inefficiency, lack of innovation, low quality, monopoly rents) etc. However, from its very inception, the ultimate goal was to limit sector specific regulation over time and - after a transition period and subject to competition developments - to migrate in the sector to a market-based environment subject only to competition rules.

Ex-ante regulatory intervention has been broadly successful in lifting barriers to competition in the national market for fixed legacy networks. The emergence of competition after regulatory intervention made it possible to reduce the number of markets that national regulators need to assess ex-ante from 18 to 2 between 2003 and 2020[82]. As the markets subject to ex-ante regulation and the number of operators designated as having SMP have diminished[83] in view of the progressing deployment of competing network infrastructures, it is right time to explore the possibility of not recommending at the EU level any market for ex-ante regulation. The possibility of leaving electronic communications networks to ex-post control alone could have merit in certain circumstances, as we observe infrastructure competition developing notably in many densely populated areas where end customers benefit from a variety of competing

---

81 https://ec.europa.eu/commission/presscorner/detail/en/ip_24_669.

82 Commission Recommendation (EU) 2020/2245 of 18 December 2020 on relevant product and service markets within the electronic communications sector susceptible to ex ante regulation in accordance with the Code (the 2020 Recommendation on Relevant Markets, OJ L 439, 29.12.2020, p. 23-31.

83 In the key "bottleneck" market for wholesale local access, in Bulgaria, Romania, the Netherlands the regulation was phased out due to the existing competition. In Czechia, Denmark, Hungary and Poland the markets are partly deregulated. In Austria, no operator is designated as having SMP and wholesale access products are provided based on commercial terms.

services based on at least two independent fixed broadband networks (e.g. coaxial cable and fibre).

Despite this progress, some barriers still persist (and may continue to persist in the near future) in some geographical areas (in particular rural/remote), and the need for ex ante intervention in such cases remains. However, with the objective to foster the progressive deployment of alternative fibre networks and with legacy networks of former incumbents to be ultimately replaced by Gigabit networks, the Commission and the NRAs will need to further adjust their intervention to keep pace with the market evolution and ensure investment incentives which are currently reduced by the perspective of overbuilding. In particular, NRAs should monitor the degree of infrastructure competition, potentially defining separate geographic markets and limiting ex ante regulation to the areas where it is still needed or applying differentiated remedies, ensuring their appropriateness and proportionality[84].

To foster pan-European network roll out, the development of a more EU-level access regulation toolkit could be envisaged to complement or replace, when necessary, the national/local approach. Indeed, in a full-fibre environment, access products can be provided more centrally and at the higher network level without altering the capacity of access seekers to compete in terms of the services and quality as offered to the end-users. Such EU-wide remedies already exist in the current framework and they have been very successful in tackling common issues across the EU (e.g. introduction of single Union-wide mobile termination rates or roaming). They led to less burdensome albeit effective regulation reducing fragmentation. A decade later after the first Commission proposal of harmonised access remedies[85], the lack of cross-border provision of electronic communications products and services persists. Therefore, time appears ripe for considering the introduction some EU-wide access remedies. While broadband access networks will remain predominantly of local character (due to demand and supply patterns), such unified and standardised access product could in turn facilitate the further integration of the single market. This tool should support the emergence of pan-European operators. For example, the provisional agreement on the GIA introduces symmetric regulation for access to civil engineering assets, including specific provisions aimed at protecting the business case of FTTH operators (although in some cases optional for Member States to implement). Operators investing in new fibre networks will be able to refuse access to their (newly deployed) physical infrastructure if they provide wholesale access, such as dark fibre, fibre unbundling, or bitstream under certain conditions, suitable for the provision of very high capacity networks under fair and reasonable terms and conditions[86]. At the same time, while phasing out ex ante regulation to foster investment incentives for the deployment of physical fibre networks across

---

84 See recital 172 of the Code.

85 Proposal for a Regulation of the European Parliament and of the Council laying down measures concerning the European single market for electronic communications and to achieve a Connected Continent, and amending Directives 2002/20/EC, 2002/21/EC and 2002/22/EC and Regulations (EC) No 1211/2009 and (EU) No 531/2012, Brussels, 11.9.2013, COM(2013) 627 final.

86 Member States could allow network operators and public sector bodies to refuse access to physical infrastructure by offering active access, such as bitstream as an alternative to physical access, under conditions, i.e. the deployment project of the requesting operator addresses the same coverage area, there is no other fibre network connecting end-user premises (FTTP) serving this coverage area, and the same or an equivalent refusal possibility is applied at the date of the entry into force of the regulation, in the Member State in accordance with national law complying with Union law. Also, networks deployed by undertakings owned or controlled by public sector bodies in rural or remote areas and operated on a wholesale only basis could receive an extra protection from competition if a Member State allows them to refuse requests to coordinate civil works.

the whole of the EU, competition can be still preserved by providing for virtual access to lower the barriers for rolling out pan-European networks on a virtual basis.

In particular, where symmetric and harmonized regulation offered by standard remedies would not be sufficient and market failures would still persist, a safety net allowing continued ex-ante local regulation could be maintained. For this purpose, the "3 Criteria Test"[87] should allow NRAs to determine (sub-national) markets where ex ante regulation is still necessary to address persistent market failures. In such (limited) geographic areas the SMP regulation could ensure that local access seekers remain in the market and prevent re-monopolisation of less densely populated areas or more generally in absence of competitive pressures. The limited SMP-based regulation could be ancillary or replaced to more general, harmonised symmetric rules addressing access to civil engineering infrastructure with safeguards providing investment certainty, e.g. in view of risk of unreasonable overbuild.

3.2.8. Universal service and affordability of digital infrastructure

The availability of adequate broadband internet services, of the quality that is needed to perform basic tasks on-line, such as eGovernment services, social media, browsing or performing video calls, is ubiquitous throughout the EU. Hence, in most of the Member States, Universal Service obligations are focused on consumers with low income or special needs.

However, in the future, a different kind of social exclusion may emerge, that of weaker end-users not being able to benefit from the best available networks due to their localisation (for example rural/remote areas) or due to the price of services. It is important to ensure that this does not lead to a social digital divide, and that all end-users may reap the benefits of very-high speed connectivity. It is hence important to ensure that Member States take measures to support such end-users and ensure appropriate geographical coverage.

The importance of ensuring Universal Service in the future has also been acknowledged by the European Parliament, the Council and the European Commission in the "European Declaration on Digital Rights and Principles for the Digital Decade". According to its principle 3 "*Everyone, everywhere in the EU, should have access to affordable and high-speed digital connectivity"* and they commit to "(…) *ensuring access to high-quality connectivity, with available Internet access, for everyone wherever in the EU, including for those with low income"*.

Sector-specific universal service obligations have relied on two modes of financing: state financing and sector financing, the latter being the predominant form. Sector financing has so far been limited to electronic communications providers, while providers of NIICS have been excluded.

In addition to the Universal Service, a number of Member States have tried to ensure the affordability of networks through state financing in the form of connectivity vouchers with the view to boosting the take-up of high-speed offers. The latest Broadband State Aid Guidelines have clarified the conditions under which such connectivity vouchers may comply with EU

[87] In accordance with Article 67(1) of the Code and Recital 22 of the 2020 Recommendation on Relevant Markets, the national regulatory authorities can also define other relevant product and service markets, not recommended for ex-ante regulation, if they can prove that in their national context, the markets meet the "three criteria test". A market may be considered to justify the imposition of regulatory obligations if all of the following criteria are met: (a) high and non-transitory structural, legal or regulatory barriers to entry are present; (b) there is a market structure which does not tend towards effective competition within the relevant time horizon, having regard to the state of infrastructure-based competition and other sources of competition behind the barriers to entry; (c) competition law alone is insufficient to adequately address the identified market failure(s).

State aid rules and the General Block Exemption Regulation now exempts from notification certain types. Vouchers, financed by the Member States, may be used to prevent or remedy any divide in access to very high -capacity networks.

3.2.9. Sustainability

A focus on environmental sustainability aspects of the digital transformation of the economy and society is a key requirement of the Digital Decade Policy Programme. The recent COP28 drew on EU proposals and actions in the field and launched a Green Digital Action in an effort to reinforce the role of digital in reaching international goals on climate change (such as on global warming, e-waste, fossil fuels) with a key involvement of the mobile electronic communications and satellite industry sectors. These developments reinforce and give an international dimension to European efforts in integrating sustainability in digital standards by design.

Another important aspect is to create more awareness on the issue of sustainability in digital networks. In this respect, in its Communication "*Shaping Europe's digital future*"[88] the Commission raised the possibility of introducing 'transparency measures for electronic communications operators on their environmental footprint' at EU level. In the EU Action Plan for Digitalising the Energy System[89], the Commission announced that it will work, in consultation with the scientific community and stakeholders, towards defining common EU indicators for measuring the environmental footprint of electronic communications services. Furthermore, the Action Plan foresees the development, by 2025, of an EU Code of Conduct for the sustainability of electronic communications networks to help steering investments towards sustainable infrastructures. Following this announcement, the Commission in 2023 launched a survey to collect input on sustainability indicators from stakeholders involved in the design, development, deployment and operation of telecommunications networks providing communications services to both commercial and residential customers[90]. The results of the work on the sustainability indicators will be published in the coming weeks.

Beyond pursuing sustainability public policy objectives, such transparency efforts could be the basis to create incentives to attract investments in the electronic communications sector to make ICT greener ('green ICT') and have it enable the greening of other sectors ('ICT for green'), particularly where investment funds are increasingly directing capital to green and sustainable infrastructures. The Commission will engage with the industry to further improve the usability and potential scope of the EU Taxonomy for green investment in electronic communications networks ensuring it is based on robust and credible science-based metrics. In this regard, the Commission could also assess the metrics to estimate the net carbon impact of digital solutions in climate critical sectors such as energy, transport, construction, agriculture, smart cities and manufacturing, as developed by the European Green Digital Coalition[91]. The aim should be that these metrics can be used by industrial actors, procurers and financial entities to measure the net gains in emission reduction, enabling sustainable finance to deploy and scale digital solutions including the necessary digital infrastructures.

Nonetheless, to ensure success in achieving sustainability objectives, it is essential that all players of the digital network ecosystem, including CAPs, cooperate towards an efficient use

---

88 COM(2020) 67 final.
89 COM(2022) 552 final.
90 https://joint-research-centre.ec.europa.eu/scientific-activities-z/green-and-sustainable-telecom-networks/sustainability-indicators-telecom-networks_en.
91 See, greendigitalcoalition.eu.

of resources while meeting energy needs. Beyond concrete actions to reduce carbon footprint, these players could also contribute to increasing transparency on the emissions related to the usage of their services, such as codecs' performance labels .

3.2.10. Summary of possible scenarios

- *Scenario 4: In order to address the converged electronic communications connectivity and services sector and to ensure that its benefits reach all end-users everywhere, the Commission may consider broadening the scope and objectives of the current regulatory framework to ensure a regulatory level playing field and equivalent rights and obligations for all actors and end-users of digital networks where appropriate to meet the corresponding regulatory objectives; given the likely global magnitude and impact of the technological developments and of any possible regulatory changes, a reform of the current framework needs to be properly assessed in terms of the economic impact on all actors as well as debated broadly with all stakeholders;*

- *Scenario 5: In order to address technological and market developments and the resulting need to change the regulatory paradigm and ensure less burden for companies and more efficient service delivery, while continuing to protect vulnerable end-users and promote territorial coverage, the Commission may consider:*

    - *measures to accelerate copper switch-off (such as a target in 2030, aligned to the Digital Decade target for Gigabit connectivity, and support for copper-fibre switch-over from 2028);*

    - *a change to access policy in view of full fibre environment, by proposing a European wholesale access product and recommending no markets for presumptive ex ante regulation while maintaining a safety net for NRAs to keep regulation if the "3 Criteria Test" is met (reverse burden of proof). In the alternative, only markets for civil infrastructure might be considered for regulation ex ante (as the most persistent bottleneck), combined with the implementation of lighter access regulation (no price regulation or pricing flexibility) along the lines of the recently adopted Gigabit Recommendation.*

- *Scenario 6: In order to facilitate the single market and building scale for activities of all players, the Commission may consider:*

    - *a more integrated governance at Union level for spectrum that would allow, where necessary, for greater harmonisation of spectrum authorisation processes and thereby create the conditions for market scale necessary for pan-EU operators to attain larger investment capacity; the Commission may also consider solutions for more aligned authorisation and selection conditions, or even single selection or authorisation processes, for terrestrial and satellite communications and other innovative applications that make clear cases for fostering the development of the single market;*

    - *a more harmonized approach to authorisation (through the possible establishment of "country of origin" principle for certain activities less connected to consumer retail markets and local access networks).*

- *Scenario 7: The Commission may consider facilitating greening of digital networks through promoting the timely switch-off of copper networks and the move to a full fibre environment and a more efficient use of networks (codecs) throughout the Union territory.*

3.3. Pillar III: Secure and resilient digital infrastructures for Europe

To protect the value of the massive investments that Europe is to undertake to build the cutting-edge infrastructure that it needs to deliver economic growth and societal benefits, it is important to ensure that such infrastructure is secure. Given the threats outlined in Section 2 above, adequate attention should be given to physical security, notably in relation to the backbone infrastructure, as well as to the transmission of data from end to end of the network.

3.3.1. Towards secure communication using quantum and post-quantum technologies

Advances in quantum computing come with implications for existing encryption methods, which play a crucial role in ensuring end-to-end security in digital networks, including electronic communication networks and the critical infrastructures they are underpinning. Although quantum computers capable of breaking current encryption algorithms are not yet a reality, the first operational quantum computers are being deployed world-wide. Therefore, the EU needs to anticipate the maturing of quantum computers and start developing transition strategies towards a quantum-safe digital infrastructure now, i.e. secure against attacks from quantum computers. Short of this, the effort and investment in cutting-edge digital infrastructure to deliver applications of critical societal relevance, such as in the field of mobility or healthcare, could be compromised.

Post-Quantum Cryptography (PQC) is a promising approach to make our communications and data resistant to quantum attacks, as it is based on mathematical problems hard to solve even by quantum computers. As a software-based solution, for which new dedicated hardware is not necessary, PQC allows for a swift transition to higher protection levels.

PQC is already high on the agenda of many countries. National authorities, as well as the European Union Agency for Cybersecurity (ENISA) have published reports on preparing for the implementation and deployment of PQC[92]. The US Cybersecurity and Infrastructure Security Agency (CISA) established a PQC Initiative to unify and drive agency efforts to address threats posed by quantum computing[93].

However, the current framework in the Union cannot fully address the challenges posed by the migration to a quantum-safe digital infrastructure. Addressing these challenges requires a coordinated effort at EU level, involving mainly government agencies. For an effective transition towards PQC, efforts should be synchronized ensuring the roadmaps are aligned at Union level, with concrete timelines for every transition step. Assessment of the implementation of the transition plans will be beneficial not only to gather information on

[92] See, ANSSI Avis scientifique et technique de l'ANSSI sur la migration vers la cryptographie post-quantique, available at anssi-avis-migration-vers-la-cryptographie-post-quantique.pdfanssi-avis-migration-vers-la-cryptographie-post-quantique.pdf; BSI. Migration zu Post-Quanten-Kryptografie. Migration zu Post-Quanten-Kryptografie - Handlungsempfehlungen des BSI (bund.de)Migration zu Post-Quanten-Kryptografie - Handlungsempfehlungen des BSI (bund.de) ; Post-Quantum Cryptography: Current state and quantum mitigation — ENISA (europa.eu); Post-Quantum Cryptography - Integration study — ENISA (europa.eu).

[93] https://www.cisa.gov/news-events/news/cisa-announces-post-quantum-cryptography-initiative.

practical challenges and gaps, but also to anticipate needs for future EU regulatory requirements.

It is therefore important to encourage Member States to develop a coordinated and harmonized approach, ensuring consistency in the development and adoption of EU PQC standards across Member States. This consistency would promote interoperability, allowing systems and services to function seamlessly across borders, preventing fragmentation, different levels of efficiencies in the transition, and ensure a European approach to PQC. Measurable effects of the transition are expected to appear around 2030. This step appears to be compelling and needed to preserve future policy options in an evolving technology landscape. That is why the Commission will set out recommendations to this effect in due course.

In the long-term, Quantum Key Distribution[94] (QKD) will offer additional security to our communications, at the physical network layer. Hybrid implementation schemes PQC/QKD are part of guidelines issued by different National Security Agencies and enter discussions about the design of coordinated actions at EU level. The combination of QKD and PQC will allow for full end-to-end security in our digital communications. QKD represents a hardware-based solution which is based on the unique properties of quantum physics, rather than on mathematical functions, and it is in principle inherently robust against brute-force attacks, as well as against new mathematical discoveries that are the underlying weakness of classical cryptography. Intense research is ongoing on different fronts to overcome the current practical challenges of this technology, and first deployment test-beds are at present being delivered under the EuroQCI initiative[95] funded by the DEP and SAGA[96]. EuroQCI will be gradually integrated under IRIS^2. In principle, QKD will represent a full paradigmatic shift of the digital infrastructure ecosystem, and constitutes already now a forward-looking, highly competitive technology of high interest also for future applications such as the Quantum Internet.

3.3.2. Towards security and resilience of submarine cable infrastructures

As described in Section 2.4 above, the security and resilience of the EU's network and computing infrastructure is an essential element of our digital autonomy. In particular, it is clear that the security of submarine cable infrastructures is a particularly pressing issue of EU sovereignty and poses a challenge to EU resilience.

To overcome the identified challenges and protect the European interests, structural measures need to be considered. While the exact scope of these measures would need to be defined, a focus area should be the reinforcement of advanced R&I activities to strengthen the economic security of the EU, particularly in support of new fibre and cable technologies as part of the strengthening of the EU's technical capacity as laid out in Section 3.1 above.

Another key area to be addressed in the long term concerns the financing of new strategic submarine cable infrastructures and the increase of security and resilience of existing ones. In this respect, an amendment by Delegated Act of the Annex Part V of the CEF Regulation could

---

[94] The Commission is working with all 27 EU Member States, and the European Space Agency (ESA), to design, develop and deploy the European Quantum Communication Infrastructure (EuroQCI). It will be an integral part of IRIS², the new EU space-based secure communication system.

[95] The European Quantum Communication Infrastructure (EuroQCI) Initiative | Shaping Europe's digital future (europa.eu)

[96] The space-based component for EuroQCI, known as SAGA (Security And cryptoGrAphic mission), is developed under ESA's responsibility and consists of satellite quantum communication systems with pan-European reach.

be considered in order to establish a CPEI list and related labelling system of strategic Cable Projects of European Interest (CPEIs) that would address identified risks, vulnerabilities and dependencies. CPEIs could be conceived to comply with the most advanced technological standards, such as sensor capabilities for their own monitoring and to support EU policies in the field of security, sustainability, or civil protection.

More generally, it will be important to ensure appropriate funding of CPEIs and pool together EU and national funding instruments, and explore the feasibility and potential leverage effect of financial instruments as possible implementing modes to ensure synergies and sufficient financing of CPEIs. Where appropriate, the Member States may decide also to design Cable IPCEI(s) in compliance with the criteria set in the IPCEI Communication[97]. Member States may also explore if the deployment and operation of certain CPEIs require further public support in line with State aid rules, or if it can be supported through the purchase of capacity for public use.

As a result, a joint EU governance system on submarine cable infrastructures could be envisaged, including: (i) additional elements to consider for mitigating and addressing risks, vulnerabilities and dependencies under a consolidated EU-wide assessment, and priorities for increasing resilience; (ii) revised criteria to upgrade existing or to fund new cables; (iii) an update of the co-created priority list of CPEI, both intra-EU and international, based on strategic importance and respect for the above criteria; (iv) pooled funding from various sources for such projects, including potentially through equity funds in which the Union could participate with Member States to de-risk private investment and (v) further actions to secure supply chains and avoid dependency on high-risk third-country suppliers.

Point (iv) could include specific action regarding the reinforcement of maintenance and repair capacity at EU level, which would mitigate the impact of any attempts to sabotage submarine cable infrastructure. This work stream could learn from the experience gained under the Union Civil Protection Mechanism and RescEU, particularly regarding firefighting, with a view to building up an EU-funded fleet of maintenance and repair vessels.

Finally, the need to work towards harmonised security requirements should also be addressed and promoted in international fora, including through the identification of best-in-class standards that harness the latest developments in security and self-monitoring capacities for cables and associated routing and relay equipment, which could be recognised through a dedicated EU certification scheme.

While safeguarding the space for future policy options, in the current geopolitical context described above and responding to the Council Recommendation as regards submarine cable infrastructures, it is necessary to take action to ensure the basis for a coordinated EU response. Therefore, alongside this White Paper, the Commission recommends to Member States certain immediate actions to prepare measures in the longer term. These possible actions are specifically related to submarine cable infrastructure that Member States can adopt in the implementation of the Council Recommendation on resilience of critical infrastructure concerning submarine cable infrastructure. The Commission Recommendation will ensure that Member States and the Commission work together to implement a coordinated and robust approach as a precursor to the identification of the appropriate level of EU funding of relevant

[97] Communication on the criteria for the analysis of the compatibility with the internal market of State aid to promote the execution of IPCEIs, OJ C 528, 30.12.2021, p. 10–18.

R&I activities, in light of the scale of the challenge, and eventually a more centralised governance framework in the longer term.

3.3.3. Summary of possible scenarios

- *Scenario 8: The Commission will promote the reinforcement of advanced R&I activities across the EU in support of new fibre and cable technologies.*

- *Scenario 9: The Commission may consider establishing a CPEI list and related labelling system by a Delegated Act under the Connecting Europe Facility.*

- *Scenario 10: The Commission may conduct a review of available instruments, in particular grants, procurement, blending operations under InvestEU and grant blending facilities, with a particular focus on leveraging private investment to support CPEIs, including the possibility of an equity fund.*

- *Scenario 11: The Commission may consider proposing a joint EU governance system on submarine cable infrastructures.*

- *Scenario 12: The Commission may consider harmonising security requirements in international fora, which may be recognised through a dedicated EU certification scheme.*

4. CONCLUSION

As we are at the crossroads of major technological and regulatory developments, it is of tantamount importance to debate these developments broadly with all stakeholders and like-minded partners. Hence, with this White Paper the Commission launches a broad consultation of Member States, civil society, industry, and academics, to collect their views on the scenarios outlined in this White Paper and provide them with an opportunity to contribute to the Commission's future proposals in this domain.

These ideas put forward include both policy means to ensure secure and resilient digital infrastructures and possible scenarios for key elements of a future regulatory framework. This consultation will allow a comprehensive dialogue with all concerned parties that will inform the next steps of the Commission.

The Commission invites comments on the proposals set out in the White Paper through a public consultation available at https://ec.europa.eu/info/law/better-regulation/have-your-say_en. The consultation is open for comments until 30.06.2024.