BEREC
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# BEREC Report on the 5G Ecosystem

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# EXECUTIVE SUMMARY

The technical features of 5G-based services aim to meet the specific needs of vertical industries bringing new use cases and customized solutions. It also implies changes at the network layer such as the virtualization of some of its elements. All these developments may entail significant changes in the dynamics of both the supply chain and on the demand side. In this report, BEREC addresses the 5G ecosystem with a twofold objective: analysing some fundamental elements of the 5G provision and identifying the potential impact on regulation of the 5G ecosystem. Namely, BEREC has focused its analysis in three fundamental elements: the main players in the 5G ecosystem, the 5G value propositions, and the cost structures and revenue streams.

BEREC underlines the role of traditional market players in the rollout of 5G networks and fostering verticals demand of 5G based products. However, the merge between IT and telecommunications competences needed for the delivery of 5G products may entail new roles undertaken by new players as 5G evolves and reaches maturity. These new roles in the 5G ecosystem include new equipment suppliers, system integrators and managed service providers (MSPs), cloud network providers and 5G verticals. In such a scenario, a possible outcome could be that new players may specialize in the provision of platform operation as traditional players undertake the network domain operation. Additionally, the design of specialized products for verticals is expected to lead to different combinations of partnerships among all players.

The 5G value propositions take into consideration, on the one hand, the benefits that 5G technical features bring to the provision of new and/or enhanced products. These include improved electronic communications services (ECS); 5G private networks; multi-access edge computing (MEC); enhanced network functionalities relying also on a cloud-native architecture; Open RAN; and system integration. On the other hand, the value proposition considers the demand side with the growth of Business to Business (B2B) products and the solutions for verticals.

BEREC has looked over the costs in the deployment and operation of the network as well as the costs for the verticals to adopt the new technology. With regard to the revenues, two main sources are identified: enhanced user ECS, especially Internet Access Services (IAS), and digital transformation of vertical industries.

At the present early stage of the development and the uptake of the 5G ecosystem, most NRAs have not received formal complaints specifically related to 5G regulatory issues. Nevertheless, as a response to the calls for input for the elaboration of this report, stakeholders pointed out several potential concerns for the attention of regulators. These are mainly related to the return of the investments needed for the deployment of 5G and ways to ensure competition. BEREC notes that the 5G ecosystem is still at an early stage and considers that it is still too early to conclude which specific 5G regulatory measures should be taken. BEREC recommends that regulators monitor the developments in the market and keep a steady and constant communication with stakeholders, this report being part of this effort by NRAs.

# 1. INTRODUCTION

The technical features of 5G aim to meet the specific needs of vertical industries bringing new use cases and customized solutions as well as changes at the network level such as the virtualization of some of its elements. All these developments entail the emergence of new roles for the provision of the services ultimately leading to added complexity in the 5G ecosystem and the potential entry of new players to the 5G ecosystem.

In this report, BEREC addresses the 5G ecosystem with a twofold objective: analysing some fundamental elements of the 5G provision and identifying the potential impact on regulation of the 5G ecosystem. Namely, the following elements have been explicitly considered:

a) Main players in the 5G ecosystem (key partners and customer segments)
b) The 5G value propositions
c) The cost structures and revenue streams

Finally, the market players' views on the diverse regulatory implications of the 5G ecosystem are gathered.

For the preparation of this report, BEREC issued three calls for input:

- A general call, addressed to all players in the 5G ecosystem inquiring about the selected business case elements
- NRAs were requested to provide information on their regulatory experience and possible complaints received regarding wholesale access to 5G and 5G Standalone, spectrum management and other regulatory aspects.
- A specific questionnaire for verticals, system integrators/ Managed Service Providers (MSPs) and cloud providers.

The report is mainly based on the feedback received from all these actors. It is relevant to note, however, that most responses received come from traditional ECS providers and fewer from new players and verticals.

Promoting full connectivity, including 5G, is one of the BEREC's strategic priorities set out in the BEREC strategy for 2021 – 2025[1]. Therefore, BEREC has published a number of relevant reports in this field of study, include the BEREC Report on the impact of 5G on regulation and the role of regulation in enabling the 5G ecosystem[2]; the2018 BEREC Report on infrastructure sharing[3] and the common position on infrastructure sharing[4]; the 2021 BEREC workshop on 5G focused on new business models and value chains and innovation[5] whereby the BEREC report on the diversification of the 5G ecosystem was delivered[6]; 2021 BEREC Workshop on

[1] https://www.berec.europa.eu/en/document-categories/berec/berec-strategies-and-work-programmes/berec-strategy-2021-2025
[2] https://www.berec.europa.eu/en/document-categories/berec/reports/report-on-the-impact-of-5g-on-regulation-and-the-role-of-regulation-in-enabling-the-5g-ecosystem
[3] https://www.berec.europa.eu/en/document-categories/berec/reports/berec-report-on-infrastructure-sharing
[4] https://www.berec.europa.eu/en/document-categories/berec/regulatory-best-practices/common-approachespositions/berec-common-position-on-infrastructure-sharing
[5] Video available: https://www.berec.europa.eu/en/events/berec-events-2021/berec-workshop-on-5g
[6] https://www.berec.europa.eu/en/document-categories/berec/reports/report-on-the-diversification-of-the-5g-ecosystem

NRA experiences with 5G[7]; 2022 BEREC Workshop on Open RAN[8] or the BEREC Opinion for the evaluation of the application of Regulation (EU) 2015/2120 and the BEREC Net Neutrality Guidelines[9] which analyses the impact of the Open Internet Regulation (Regulation (EU) 2015/2120) in the development of 5G services. BEREC also organised a workshop on mobile infrastructure sharing[10].

The present report complements the BEREC report on the Internet Ecosystem[11], analysing in more detail also the part of the Internet ecosystem that is supported by 5G technologies. Finally, BEREC has recently published a High-level Opinion on the Data Act proposal[12],addressing issues such as switching between data processing services. Taking all this previous work into consideration, BEREC refers to these reports for in-depth analysis of some 5G related issues such as Open RAN or Open Internet.

# 2. 5G STAKEHOLDERS

5G is the first generation of a telecommunications technology designed with the intent of catering for the needs of the vertical industries. Vertical industries encompass a group of companies and customers that are all interconnected around a specific niche or specialized industry. Some examples of verticals are the automotive, transport, healthcare, manufacturing, logistics, agriculture, smart cities or media and entertainment industries.

This new technology entails significant changes in dynamics in both the supply chain and the demand side of the mobile telecommunications ecosystem. The mobile ecosystem will no longer mainly consist of the traditional equipment suppliers and Electronic Communication Networks and Services (ECN/S) providers. The 5G Infrastructure Association (5GIA)[13] has systematized the integration of traditional and new roles in the provision side of 5G as follows:

[7] https://www.berec.europa.eu/en/document-categories/berec/reports/summary-report-on-berec-workshop-on-nra-experiences-with-5g-23-september-2021
[8] https://www.berec.europa.eu/en/events/berec-events-2022/berec-workshop-on-open-ran
[9] https://www.berec.europa.eu/en/document-categories/berec/opinions/berec-opinion-for-the-evaluation-of-the-application-of-regulation-eu-20152120-and-the-berec-net-neutrality-guidelines
[10] Virtual workshop on mobile infrastructure sharing | BEREC (europa.eu)
[11] https://www.berec.europa.eu/en/document-categories/berec/public-consultations/draft-berec-report-on-the-internet-ecosystem
[12] https://www.berec.europa.eu/system/files/2022-07/BoR%20%2822%29%20118_BEREC%20H-L%20Opinion%20on%20the%20ECs%20proposal%20for%20a%20Data%20Act_0.pdf
[13] "5G Ecosystems," 5G IA, Sept. 2020, source: https://5g-ppp.eu/wp-content/uploads/2021/09/White_paper_5G-Ecosystems_1-0-final.pdf

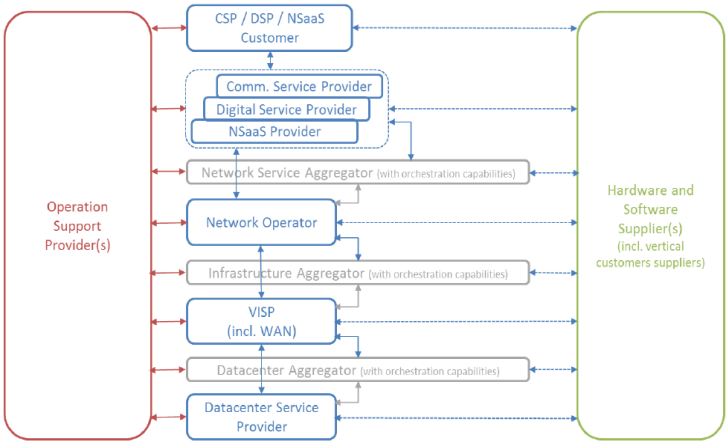


*Figure 1 Roles in the 5G ecosystem. Source: View on 5G Architecture. 5G PPP Architecture Working Group*

In addition to the provision of electronic communications networks (ECN)[14], the 5GIA roles proposition includes the category of service providers (slashed square in figure 1) encompassing:

a) Communications Service Provider (CSP), providing traditional telecommunications services[15],

b) Digital Service Provider providing digital services to verticals such as enhanced mobile IAS and IoT, and

c) Network Slice-as-a-Service Provider (NSaaS) providing network slice and the necessary support and configuration.

The 5GIA also introduces the roles of Virtualisation Infrastructure Service Provider (VISP), which offers virtualised network or cloud/edge computing resources available through APIs, and Data Center Service Provider offering raw computing resources.

Those roles may be provided jointly or separated by different, traditional or new, stakeholders. In addition, it is expected that the diverse players provide end-to-end solutions to vertical industries by means of partnerships and that the provision of 5G based services will be facilitated by system integrators and MSPs.

For the time being, 4G/LTE and 5G technologies will coexist in the short to medium term. The development and provision of new 5G services may increase the number of entities operating in the 5G ecosystem or transform the role of the existing players. The main stakeholders at this stage and their current and the potential evolution of their roles within the 5G ecosystem are described below.

[14] Depicted as “network operator” in figure 1.
[15] The classification and the definitions of the roles issued by the 5GIA are not equivalent to the classification of services provided by the EU regulatory framework. Those are used for analysis purposes in this report.

## 2.1. Traditional Stakeholders

Traditional market players include ECN/S providers and equipment suppliers. They provide electronic communications services, software and hardware services. For the past years those have been active participants in the 5G ecosystem, playing an important role in the rollout of 5G and the development of new 5G use cases by participating in a number of 5G pilots throughout Europe. In doing so, traditional market players have also been stimulating the interest of the 5G verticals by demonstrating how 5G can realise the necessary digital transformation.

It is expected that the maturity of 5G will require further adaptation of traditional providers to changes associated with the provision of new services based on enhanced quality of service requirements and tailoring of combined network and IT services or massive machine-type communications (mMTC) to remotely manage the increasing volume of connected devices to meet vertical-specific needs of end-users. At network level, 5G network *softwarisation*[16] requires the integration of multiple domains and resources that result in service providers operating in open, flexible platforms and services provisioned on top of them.

The expansion of the IT industry into infrastructure and services entails an increased need of specific competencies and skills of personnel of the traditional stakeholders. According to the 5GIA[17], the role of telecom operators is shifting towards operating a programmable network infrastructure including the management of virtual resources. It may be expected that some telecom operators, in particular the ones that already provide integrated IT and cloud computing services to verticals, may evolve into assuming the role of VISP and Data Centre Service Provider, in addition to providing the network itself. To this end, they would require additional expertise in fields such as IT management of network and software, IT network and software integration supporting the design or the development of end-to-end orchestration platforms at network and application level. A possibility could be outsourcing the operation of cloud/IT/edge infrastructure. Such option has the advantage of allowing multitenant use of costly network infrastructure and, thus, reduce CAPEX. The traditional mobile communications value chain will meet the vertical specific ecosystem potentially leading to a number of different context specific combinations of stakeholders and partnerships. The collaboration of legacy players with verticals, cloud and edge providers, and service aggregators may be essential to unlock new areas for revenue.

When it comes to network building and maintenance, legacy players can take an important role in the operation of local private networks. At the same time, other stakeholders emerge taking over some roles traditionally carried out by ECN/S providers. This is the case, for instance, of neutral hosts offering connectivity to MNO.

## 2.2. New Stakeholders

New actors emerge in the 5G Ecosystem offering new services, taking over services provided by traditional players or complementing their services. The need for 5G platforms can create new opportunities for specific solution providers. These new players may develop product

[16] Softwarisation or virtualization refers to the migration of traditional hardware-based elements of the networks to software-based ones.
[17] https://5g-ppp.eu/wp-content/uploads/2021/09/White_paper_5G-Ecosystems_1-0-final.pdf

offerings using location specific and usage specific expertise that other market players do not have. Some of the new players will bring their experience in areas such as cloud computing, artificial intelligence (AI), or vertical industries into the 5G ecosystem.

### 2.2.1. New vendor suppliers and software developers

One relevant concept that BEREC is aware of, and has held a workshop on, is Open Radio Access Network (Open RAN). The development of Open RAN specifications may impact the traditional mobile market in a number of ways, including creating opportunities for MNOs to pick and choose different RAN components from different suppliers. Barriers to entry may be lowered by reducing the upfront investment necessary to enter the market and different parts of a 5G network may be bought “as a service” from different stakeholders. Consequently, Open RAN facilitate new entrants to compete with incumbent players. The new 5G architecture is expected to facilitate supply-chain diversification and, as a result, further increasing competition at various levels of the 5G ecosystem. At the same time, challenges regarding system integration and end-to-end quality assurance may arise.

### 2.2.2. Neutral hosts

In the last years, MNOs have tended to reduce their CAPEX by disposing of their passive infrastructure (e.g., towers, masts), outsourcing these assets to infrastructure providers. The 5G business development requires investment in new infrastructure elements, such as small cells in smart cities, enhanced indoor connectivity and specific coverage of spaces or venues with a high volume of users and devices (DAS – Distributed Antenna System), fibre backhauling and edge computing resources, particularly in connected factories. This network infrastructure expansion can be offered by infrastructure providers of wholesale services, acting as neutral hosts.

As a result, several neutral host models are emerging, evolving from pure passive infrastructure services (towerco model) towards upper layers of the network value chain, by adding emission and transmission services (antennas, fibre), as well as IT network functions and resources (data centres, edge computing), partnering with technology vendors and integrators. These multi-tenant services are offered to traditional stakeholders but also target new players in the 5G ecosystem, in particular the verticals, with specific local connectivity needs and service requirements, such as ports, energy plants or smart cities.

### 2.2.3. Mobile Virtual Network Enabler

Mobile virtual network enablers (MVNEs) provide services for Mobile Virtual Network Operators (MVNOs) acting as intermediaries between them and the MNOs. In addition to the access to the network infrastructure, they typically provide related services, such as business support systems, administration or operations support systems. In the context of the deployment of certain 5G solutions, vertical industry players may be interested in becoming MVNOs relying on MVNEs. In some cases, traditional MVNO may act as MVNEs for these vertical industry players.

### 2.2.4. System Integrators and Managed Services Providers

System integrators combine hardware, software, networking and storage products from multiple vendors to build computing systems for clients. System Integrators are emerging as important intermediaries in the 5G ecosystem as they can provide the necessary coordination and translation between the needs of the vertical sectors and the technical design and deployment of the 5G networks and features to deliver those needs. They collaborate with verticals interested in private 5G networks providing such networks "as-a-Service" by planning, designing, deploying and managing the private 5G networks. System Integrators may also play a critical role in enabling the integration of the 5G network with the other IT processes of the vertical industry players.

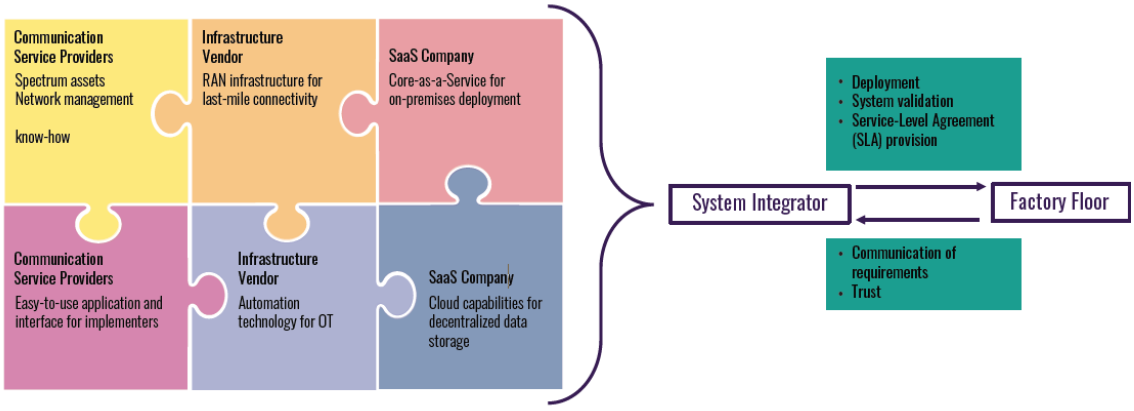


*Figure 2 Example of system integrator services. Source: The Role of System Integrators for Enterprise 5g Deployments. ABIresearch.*

MSPs allow the outsourcing of some of part of their IT or infrastructure services management. Thus, as system integrators, MSP also help businesses with end-to-end planning, design, deployment and private network management.

### 2.2.5. Cloud Service Providers

5G will be a key enabler for the development of advanced cloud services to designed customised services for vertical industries. Services like edge computing will benefit from the 5G advances such as increased speeds, network capacity and reliability or lower latency. 5G can also support a dense and distributed-access architecture. This helps move data storage and processing to the edge of the network to support edge computing and IoT.

In turn, cloud services will also act as an enabler for all the benefits that a fully fletched 5G network can deliver. Network virtualisation and automation will lead to the use of cloud native solutions as well as an increased emphasis on software capabilities. The "network as a service" cloud solutions will significantly simplify the deployment and operation of services and new models based on a "pay-as-you-use" principle can emerge. As a result, the investment required for verticals could be reduced while Cloud Service Providers may expand towards other parts of the supply chain, such as the edge. Cloud Service Providers may also assume

the role of cloud capacity providers to host virtual and cloud native network functions and even full solutions to Private Networks[18].

MNOs are investing in the necessary resources and it is perceived that the cloud native nature of 5G is an opportunity for traditional service providers to move into adjacent industries[19]. However, some providers of over-the-top (OTT), cloud and CDN services could be also well placed to assume the role of cloud service network providers taking into account their experience and market position for those services as well as the possibility to benefit from economies of scale.

### 2.2.6. Verticals (new "end-user")

Verticals encompass a heterogeneous group of end users. The verticals' needs will differ significantly from one to another, in terms of level of QoS, security, privacy, coverage requirements and level of control over the network. Verticals are meant to play a critical role in the 5G ecosystem. Given the high cost of 5G deployment, developing and stimulating the uptake of 5G vertical use cases is necessary and should be done in tandem with the actual 5G roll-out.

## 2.3. Role of Partnerships

Partnerships will play a paramount role for the success of 5G. 5G has a much more complex objective than the previous generation of mobile technology, seeking to enable all the digitalization needs of the verticals which are quite vast. This will thus require experts in the development of applications and services to cater for the needs of the verticals taking as well into account the different standards which the verticals adhere to in their line of work. Moreover, 5G requires a significant investment to further stimulating the need for more partnerships. Therefore, partnerships will be necessary to pool together both the necessary expertise and monetary investment to deliver the complex end-to end (E2E) services demanded by the vertical industries. BEREC identified different types of partnerships expected in the 5G ecosystem.

| PARTNERSHIP | DESCRIPTION |
|---|---|
| **ECN providers, system integrators and vendors** | System integrators may act as intermediaries between the operators and the verticals for the provision of solutions tailored to the needs of the vertical. Other partnerships will be driven by the need to integrate new technologies such as AI, cloud computing and quantum technology. Thus, traditional market players including ECN providers and equipment suppliers may collaborate with system integrators to deliver 5G applications integrating new emerging technologies. |
| **Verticals and ECN providers or System Integrators / MSPs** | Verticals interested in deploying their own stand-alone non-public network (SNPN) may not necessarily have the in-house expertise to design, deploy and manage their private networks. For those verticals, it could be more |

[18] For example, https://aws.amazon.com/private5g/.
[19] "Edge computing – introduction in phases," Ericsson, source: https://www.ericsson.com/en/edge-computing

| | |
|---|---|
| | economically and technically feasible to resort to other entities such as ECN/S providers or System Integrators / MSPs to deploy their private network. Some examples are the BASF Schwarzheide GmbH and Vodafone[20] partnership for the deployment of a private 5G network in Schwarzheide production site or the partnership between Volvo and Ericsson leading to the first cross-border 5G network vehicular handover, involving the constant update of high-quality maps across borders. Also in the area of mobility, Ericsson, Einride and Telia work to develop power sustainable, self-driving trucks using 5G[21]. |
| **Equipment suppliers and System Integrators/MSPs** | This kind of partnerships focuses on the development of private 5G solutions covering all the technical aspects of a 5G network that system integrators and MSPs can offer to the verticals. These partnerships do not involve ECN/S providers but are limited to technology vendors and integrators. |
| **ECNs providers** | Given the significant investment necessary for the roll-out of 5G, partnerships between MNOs, tower companies, fixed network operators and satellite operators focusing on the network deployment can also emerge. |
| **Equipment suppliers, ECN providers and cloud service providers** | MEC and the cloud-native nature of 5G is also another driver of a new type of partnership unique to the 5G ecosystem. This involves equipment suppliers, ECN providers and cloud service providers. One example is the partnership between Google Cloud, Ericsson and TIM to pilot 5G cloud solutions for telco edge enterprises use cases in automotive, transportation and other sectors[22] or the partnership between Vodafone and Amazon Web Services to offer MEC[23]. |
| **Equipment vendors, chipset providers, software companies, cloud providers and system integrators** | Equipment vendors, chipset providers, software companies, cloud providers and system integrators may also reach agreements for the development of Open RAN and open and disaggregated solutions. |

# 3. 5G VALUE PROPOSITION

There are significant high expectations for the digital transformation that the 5G service portfolio promises. 5G is designed in such a manner that it is not only seeking to connect people but connect everything, taking into account three different use cases:

- Enhanced Mobile Broadband (eMBB);
- Ultra-Reliable and Low Latency Communications (URLLC);

[20] "BASF Schwarzheide GmbH nimmt 5G-Campus-Netz in Betrieb", Jan 2022. Source: https://www.basf.com/global/de/who-we-are/organization/locations/europe/german-sites/Schwarzheide/press-and-media/press-relations-Schwarzheide/2022/basf-schwarzheide-gmbh-nimmt-5g-campus-netz-in-betrieb.html

[21] https://www.ericsson.com/en/press-releases/2018/11/ericsson-einride-and-telia-power-sustainable-self-driving-trucks-with-5g

[22] Source: https://www.ericsson.com/en/press-releases/2021/6/google-cloud-and-ericsson-partner-to-deliver-5g-and-edge-cloud-solutions-for-telecommunications-companies-and-enterprises

[23] "Vodafone uses AWS Wavelength to launch first Multi-access Edge Computing services in European region" Vodafone Press Office, Jun. 2021, Source: https://newscentre.vodafone.co.uk/press-release/partnership-aws-wavelength-launch-first-multi-access-edge-computing-services-in-europe/

- Massive Machine Type Communications (mMTC);

These three types of use cases aim to address the diversified demand that the vertical industries have. This new generation of mobile communications will thus support the digital transformation of different vertical sectors transforming how services and products are produced and delivered to end-users resulting in optimised production levels whilst attaining better quality. The uptake of 5G use cases is expected to deliver a number of socio-economic benefits such as enabling safer mobility, remote medical intervention, connected ambulances, enhanced fixed wireless access and increased environmental sustainability via for example smart and green transport and smart grids. Since 5G is meant to cater for the needs of the vertical sectors, it is impossible to identify one unique selling point of 5G as different vertical industries will prioritize different KPIs such as capacity, reliability, latency, security etc.

In order to extract the maximum digitalisation potential of 5G, there is a need for 5G standalone deployment**,** however there are concerns about whether this deployment is slow[24]. The advantages of deploying 5G standalone and thus 5G's strongest value proposition are:[25]

- It enables E2E network slicing and thus new business opportunities including applications that rely on time critical communications.
- It enhances the end-user experience by providing instant access to 5G and better uplink coverage – the augmented uplink coverage is resulting from the elimination of the power split between user equipment using 4G and 5G.
- It improves network efficiency by extending the 5G coverage and enable LTE offload.
- It results in lower complexity both at the network side and the device side.

In order for 5G to enable the resulting digital transformation, it will not only require a number of new partnerships, as discussed in the previous section, but it will also drive the market players to develop various new value propositions in order to deliver the new 5G services and use cases. The different 5G value propositions are described in the following subsections.

## 3.1. Electronic Communications Services – Enhanced IAS

As expressed in the BEREC report on the Internet Ecosystem, IAS is a key element in the user experience. Market players are seeking to offer better electronic communications. eMBB was one of the first use cases which was offered commercially. 5G Fixed Wireless Access takes advantage of 5G's eMBB to quickly and economically offer a wireless solution that competes with wired IAS. In addition to eMBB and the stable low latency and network reliability (URLLC) or the possibility of IoT communications involving a massive number of sensors (mMTC), other aspects of the 5G value proposition to differentiate the IAS offerings in the market, include enhanced secure communications and positioning accuracy including indoor positioning.

[24] "Is the Industry Moving Fast Enough on Standalone 5G?" GSMA Intelligence, July 2022, source: https://www.gsmaintelligence.com/wp-content/uploads/2022/07/GSMAIntelligence_Standalone5G_Presentation.pdf

[25] "Why Standalone is vital for reaching 5G maturity," Ericsson, Dec 2021, source: https://www.ericsson.com/en/blog/2021/12/why-standalone-is-vital-for-reaching-5g-maturity

## 3.2. Network Slice-as-a-Service

Network slicing, whereby logically independent network slices are provisioned on the same physical infrastructure, is unique to 5G. The attractive advantage of this is that the same infrastructure can be used to provide diversified service requirements according to established Service Level Agreement (SLA). One of the value propositions of network slicing is a guaranteed level of reliability according to the agreed SLA between the customer and the ECS provider at most probably a lower capital and operational expenditure than that of private 5G network under the control of the vertical.

Moreover, the Cloud Native E2E Network Architecture enables the automatic network slicing service generation, maintenance and termination reducing operational expenditure. This also means that it may be easier to integrate future innovative solutions when opting for the deployment of a private network via 5G network slices. Another differentiator of 5G network slicing is that, since this relies on a public network, it is especially suitable for those use cases that require national geographic coverage such as connected cars.

## 3.3. Standalone Non-Public Networks (SNPN)

There seem to be various advantages that an enterprise can benefit from by opting for this kind of private 5G networks. These include: guaranteed QoS; improved data privacy and protection (as the network is completely disassociated from the MNO's 5G core); enhanced security (as access to the network is limited to authorised devices only), strict KPIs (for example: faster connection speeds, higher throughput and ultra-low latency), better network control and avoidance of network congestion (since a limited number of devices can access the private network)[26]. Therefore, SNPN are considered particularly suitable for mission or safety critical applications and services deployed within a specified parameter. In addition, 5G private networks could also offer the added advantage of creating an environment fully customised to meet the needs of the specific use-case. This supports and facilitates the development of new services which could – at a later stage - then be even rolled out using a public network and network slicing.

MNOs[27], MVNOs, System Integrators and MSPs can all play a role and offer their own unique value proposition to the vertical player interested in the deployment of a private 5G network. Some verticals may not have the in-house expertise to plan, design, deploy and manage their own private 5G network. Moreover, verticals may also require the development and/or deployment of a platform from which they can monitor the state-of-play of their private 5G network.

## 3.4. Cloud Computing

Cloud Computing offers to market players the opportunity to enhance their own business model by providing large scale, open interfaces, enhanced security and resilience and the possibility to transform processes and operating models. The use of cloud technology at the

[26] "5G Non-Public Networks: Standardization, Architectures and Challenges," J. Prados-Garzon et al., IEEE Access, Nov. 2021, source: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9611236

[27] Example of Private 5G Networks offered by an MNO: "Ireland's first standalone 5G MPN will unlock some truly exciting possibility for manufacturing," Anne O-Leary, Vodafone Ireland, Mar 2021 source: https://www.vodafone.com/business/news-and-insights/blog/gigabit-thinking/irelands-first-standalone-5g-mpn-will-unlock-some-truly-exciting-possibilities-for-manufacturing

core and/or at the edge of the network enables the connection of billions of devices. This is thanks to the distributed and on-demand processing power which the cloud can offer whilst maintaining the same performance and latency parameters. Besides, offering an increase in compute resources, the cloud can provide storage resources, where vast volumes of data can be accessed from anywhere connected to the network. Thus, the compute and storage performance the cloud offers can enhance the operational efficiencies available to various market players resulting in furthering their digital transformation.

Cloud Computing is closely linked to MEC which places the compute and storage resources necessary for the 5G use cases closer to the end users. This is paramount to guarantee that stringent requirements such as ultra-low latency, higher capacity and handling of data from an IoT consisting of a massive amount of connected devices are possible. Market players focusing on cloud technologies have claimed that the cloud-native architecture can reduce the cost of communications services, whilst being able to provide more advanced services.

## 3.5. Service diversification

5G opens up opportunities for ECN/S providers to diversify their portfolio tapping into new revenue opportunities in the B2B segment. MVNOs can also take on the role of MVNEs and/or system aggregators to help businesses wishing to have their own mobile offer or wish to integrate mobile communications in their own offerings to Business to Consumer (B2C) and B2B markets.

Cloud Services Providers may profit from the cloudification of the network and the anticipated increase in data generation. In fact, the 5G use cases are expected to generate a lot of data - both from sensors and consumers - which will be highly beneficial also for the further development of AI solutions.

## 3.6. System Integration and Consultation Services

Given the considerable difference between the 5G network architecture and the previous generations of mobile technology, resulting in integrating various specialisations not limited to those of traditional players enabling advanced 5G uses, system integration and consultation services are key to the 5G Value Proposition. Such entities can offer different value-added services including consultation services related to the interoperability of components, integration of the 5G network with the other IT systems of vertical industry players, cloud-based services, as well as the transition from in-house to cloud digitisation solutions. Moreover, system integrators may offer additional layers of security to the user plane and/or control plane, that goes beyond the 5G default security level, using solutions from specialised vendors.

## 3.7. Verticals' demand

There are high expectations of the added value that 5G can offer to the vertical sector. For example, it is expected to deliver an increase in maintenance efficiency via 5G Industrial Augmented Reality (AR), in Quality Control using 5G Machine Vision, in reliability using 5G Automatic Guided Vehicles and in productivity using 5G Programmable Logical Control enabling unmanned production. Another example of how the enhanced KPIs, 5G offers can

lead to added value to the vertical sector is the improved positioning accuracy which can enable more advanced applications for logistics, smart factories, autonomous vessels and vehicles, localized sensing, digital twins, augmented and virtual reality.

However, most verticals are still experimenting with 5G communications. The verticals which have garnered experience in 5G use case through collaboration with various consortia include manufacturing, transport, automotive, health, education and energy. Pilot trials of 5G use cases remain key to ensure that the developed 5G use cases deliver the level of safety and KPIs defined by the verticals' own standards. Some stakeholders state that verticals are cost-conscious resulting in some showing more interest in the use of public networks to reduce costs. SMEs may be more open to the deploy a 5G use case using public 5G networks using network slicing or a hybrid private network rather than deploying their own private 5G network. There is, in any case, significant interest in private 5G networks from verticals seeking certain level of autonomy and control over their network.

# 4. COST STRUCTURES AND REVENUE STREAMS

## 4.1. Cost Structures

Building a cellular network requires CAPEX to invest in the necessary infrastructure including Spectrum, Radio Access Network, Transport, and Core Network, and a significant OPEX to implement and maintain the services. It is estimated that the total 5G deployment cost across the European Union could reach 400 billion Euro[28]. The GSMA estimated that only 35% of all mobile connections in Europe will be based on 5G by the year 2025, which contrasts with the projections for the US and Canada that amount to 51%[29]. Various challenges could be observed such as the mobile communications revenue being well below their level before 5G was introduced to the point that, as claimed by the MNOs, that the return on capital is materially below the cost of capital.

### 4.1.1. Capacity expansion and coverage extension

5G use cases require enhanced network infrastructure that provides increased capacity - both downlink capacity for eMBB and uplink capacity for URLLC applications such as advanced automotive use cases. Ubiquitous coverage and enhanced KPIs such as low latency and ultra-reliability are also mandatory characteristics of 5G networks which results in another cost element. Thus, part of the cost of 5G deployment is related to capacity expansion and coverage extension.

[28] "5G roll-out in the EU: delays in deployment of networks with security issues remaining unresolved," European Court of Auditors, 2022, source: https://www.eca.europa.eu/Lists/ECADocuments/SR22_03/SR_Security-5G-networks_EN.pdf

[29] "The Mobile Economy 2021", GSMA

### 4.1.2. Spectrum

Availability of sufficient spectrum is relevant for both capacity and coverage[30]. The use of mmWave bands may result in small cell deployment and thus a densification of network sites. A study by NGMN[31] states that the economics of small cells are such that stakeholders will need to seek ways to reduce building, operation and maintenance costs per cell. According to the study, this can be achieved by sharing the physical site among a number of operators either by collaborating to acquire sites or via leasing agreements, sharing active equipment via a Multi-Operator Radio Access Network or via a neutral host model. In line with competition law, stakeholders also consider sharing spectrum and passive and active components to address costs. This is in line with statements made by the participants in BEREC's call for input which remarked on the importance of network sharing and leasing of spectrum.

Spectrum availability (type and amount of) and network densification are two elements which depend on each other. Lack of spectrum may result in the need for a greater amount of small cell deployments. However, this may be subject to other issues such as interference, site availability etc. [32]

Albeit the increased demand for more capacity, which has been an observed trend preceding 5G, the price of mobile retail data packages has been decreasing and thus finding ways how to increase capacity and coverage in an efficient and more cost-effective manner is necessary for 5G. This could be achieved either by leasing of spectrum, infrastructure sharing or rental costs saving.

Stakeholders also considered that different Electromagnetic field exposure limits set in Member States could be a barrier to efficient use of radio spectrum (and thereby giving rise to costs). Harmonization of limits could improve efficient use of spectrum and result in cost savings.[33] In this regard, Member States are implementing the best practices of the Connectivity Toolbox – and accelerating the deployment of high-capacity networks[34].

### 4.1.3. Wholesale access

MVNOs have to factor in the costs of wholesale access to 5G and 5G standalone. However, 5G could make it possible to adopt new pricing regimes, whereby bandwidth usage or off-peak usage hours could determine the price of wholesale access. Moreover, wholesale access to small cell deployments may also be necessary.

### 4.1.4. Service-Based Architecture

Service-Based Architecture will not only enable advanced 5G use cases relying on low latency and ultra-reliability but will also result in greater automation, enhanced network and service

[30] E.g. "Vision 2030 – Insights for Mid-band Spectrum Needs," GSMA, July 2021, source: https://www.gsma.com/spectrum/wp-content/uploads/2021/07/5G-mid-band-spectrum-needs-vision-2030.pdf

[31] "Small Cell Cost Sharing," NGMN, Dec. 2019, source: https://ngmn.org/wp-content/uploads/Publications/2020/Small-cell-economics-external-full-report-v1_1-clean.pdf

[32] "Vision 2030 – Insights for Mid-band Spectrum Needs," GSMA, July 2021, Source: https://www.gsma.com/spectrum/wp-content/uploads/2021/07/5G-mid-band-spectrum-needs-vision-2030.pdf

[33] BEREC and RSPG published a joint position on EMF: https://www.berec.europa.eu/system/files/2022-07/9462-berec-rspg-position-paper-on-spectrum-re_0.pdf

[34] Overview of Member States' progress on implementing Connectivity Toolbox measures | Shaping Europe's digital future (europa.eu)

orchestration and network slicing. The implementation of Service-Based Architecture will result in the use of a software and cloud-based platform and thus move towards a cloud-native deployment using containerized network functions decomposed into microservices. This contrasts with the traditional approach using monolithic virtualized network functions. It is anticipated that this would lead to the management of traffic growth with enhanced CAPEX efficiencies, reduction in OPEX and operational inefficiencies.

### 4.1.5. Deployment of Private 5G Networks

A vertical industry interested in deploying private 5G networks must first decide whether it will opt to rely on the ECN/S provider[35] to provide the spectrum (dedicated or not), equipment and technical know-how to deploy and manage such a network.

If on the other hand, it opts for an SNPN, the vertical must incur the cost of 5G equipment such as base stations and other networking devices and it will also require access to spectrum. One possibility is acquiring spectrum on a local basis if such a local licensing framework is available or else through the secondary market, i.e. spectrum trading or leasing from other spectrum licensee. They must also factor in the cost of designing and managing the network.

When verticals lack the necessary expertise to plan, design and deploy a private network, they must also factor in the cost of outsourcing such services. MSP may undertake the planning, design, deployment and management of the private 5G network on behalf of the vertical providing private 5G network-as-a-service. Private 5G networks-as-a-service frequently also rely on the use of a cloud-based network management portal and troubleshooting applications to simplify the management of these networks once they are deployed. The benefit an enterprise may gain in contracting the services of an MSP is that it will not dedicate in-house resource commitment to non-core functions. In addition, the verticals can benefit from cost-efficient models such as pay-as-you-go-and-grow pricing or coverage or annual subscription fees.

### 4.1.6. SIM cards

SIM cards or eSIMs will be necessary irrespectively of the terminals access or not to public networks. If the device is interacting with both a public network and the private 5G networks, solutions could vary from handover between the public and private network or roaming. For the former, the mobile carrier of the private network must be the same as the one for the public network. For the latter, one would require multiple roaming agreements and multiple interconnections between the private network and the public networks which may result in costly roaming fees and is time-consuming to implement[36]. A solution could be the use of SIM cards which allows seamless switching between private 5G networks and public network connectivity[37]. The switch can be either automatic or manual and can be triggered by SIM location, NFC detection, vocal command, specific application usage or time.

[35] I.e by means of a 5G Public Network Integrated Non-Public Network (PNI-NPN)

[36] "Private 5G/LTE: Dual Sim, Dual IMSI, eSIM or Roaming?" Athonet, Nov. 2020, source: https://athonet.com/blog-post/private-5g-lte-dual-sim-dual-imsi-esim-or-roaming/

[37] "Transatel announces private LTE/5G extension solution enabling connected devices to seamlessly switch between private and public cellular networks worldwide," Transatel, Feb 2022, Source:

### 4.1.7. Other issues related to cost

Increased cost-effective solutions are anticipated with the emergence of open, disaggregated multi-vendor solutions relaying on softwarization and virtualization. This will open up the market to new suppliers, resulting in an increased competition. Market players active in the field of cloud technology stated that the combination of radio access networking with cloud technology will diversify the ecosystem vertically and horizontally enhancing vender selection and offering new options to accessing modernized and secure 5G networks.

Another cost is the cost of 5G capable devices, including the royalty fees. This could be a source of concern especially for the use cases relying on mMTC. Other costs given the trend in application and services development, relate tothe costs of data access.

## 4.2. Revenue Streams

Challenges related to the monetization of 5G-based ECS is one of the major concerns of MNOs. The demand for higher data allowance will continue to grow but this might not result in a higher ARPU, according to MNOs. Since 5G aims to go beyond connecting humans seeking to connect everything, solutions to businesses could be one important driver of new revenue streams and thus special attention is paid by market players to B2B markets. However, since this will not solely rely on the traditional mobile network infrastructure (core, access, network), but it will include new domains such as cloud or edge computing partnerships, it will be crucial to reap all the benefits from the new possibilities enabled by 5G standalone as reported previously in this report. The two of 5G revenue streams are private market ECS, including enhanced mobile IAS and the digital transformation of vertical industries.

### 4.2.1. Enhanced ECS for consumers

Enhanced ECS for consumers may encapsulate everything related to 5G ECS to the consumer including mobile IAS, TV and video services, smart home communications and the necessary innovative devices and technologies such as augmented reality and virtual reality, configuring provided-specific ecosystems comprising a large number of elements[38].

A study undertaken by Ericsson and Omdia[39], reports that by 2024, the consumer business will generate 81% of the overall mobile IAS revenues. This would mean that albeit the attention given to enterprise ECS in order to realise the 5G advanced use cases, the provision of enhanced IAS for the consumer ECS segment will still generate the majority of the core mobile revenues for service providers. It has been noted that the past trend whereby consumers expect higher data rates at cheaper prices will remain.

https://www.transatel.com/news-and-insights/press-releases/transatel-announces-private-lte-5g-extension-solution-enabling-connected-devices-to-seamlessly-switch-between-private-and-public-cellular-networks-worldwide/

[38] See draft BEREC report on the Internet ecosystem regarding provider-specific ecosystems.

[39] "Harnessing the 5G consumer potential – The consumer revenue opportunity uncovered," Ericsson, source:https://www.ericsson.com/4ac9d8/assets/local/reports-papers/consumerlab/reports/2020/harnessing-the-5g-consumer-potential.pdf

### 4.2.2. Digital Transformation of Vertical Industries

The digital transformation of vertical industries will result in generating new revenue streams not only to existing stakeholders in the cellular networks value chain but also new ones. As discussed in the previous sections, Private 5G Networks are likely to be deployed for a significant number of enterprises. Whilst the option of relying on in-house resources remain, offloading the planning, design, deployment and management of these networks on other third parties offers a number of benefits. This option will result in new partnerships and revenue streams. It has been reported that when it comes to the Private 5G network, networks vendors are being directly involved even through partnerships with system integrators[40]. The different types of revenue streams associated with Private 5G Networks are:

- Sale of or leasing of equipment to enterprises;
- Design and deployment of the private 5G network;
- Management and monitoring of the private 5G network - This could include the use of a cloud-based network management portal and troubleshooting applications as well as the packaging with cloud-based IT services (business analytics, AI services, etc.)

### 4.2.3. Network slicing

When it comes to B2B Solutions, network slicing will also result in new revenue opportunities. Since a 5G Core may logically divide the 5G infrastructure into a number of end-to-end network slices; each slice having unique characteristics serving a particular type of use case, different tenants and offering specific quality of service guarantees, it will be possible to adopt different pricing schemes according to the network slice offered. An understanding of the new innovative pricing and business models is paramount, including the commercial models which network slicing will offer[41]. Stakeholders have stated that it is too early to assess the cost elements to be included in the pricing scheme for network slicing. The benefit of network slicing in terms of revenue generation to MNOs stems also from the opportunity that MNOs have to monetise excess capacity through network slicing.

### 4.2.4. Revenues related to Open RAN provision

New equipment suppliers offering open and disaggregated hardware, software developers and cloud solution providers forming part of the Open RAN value chain diversifying the supply-chain will also see an increase in revenue streams. Analysys Mason reports that the global market of supplier revenues may be worth EUR 36.1 billion by 2026[42]. Other revenue streams related to the open and disaggregated approach can result from providing services needed to create better interoperability between hardware and software from different vendors and the validation and trial runs of new solutions.

[40] "Private 5G Here and Now: Perspectives on industry adoption" Economist Impact
[41] "5G Market Disruption demands pricing innovation from the Get-Go," Source: https://www.csgi.com/insights/5g-market-disruption-demands-pricing-innovation-from-the-get-go/
[42] "The economic impact of open and disaggregated technologies and the role of TIP," D. Abecassis et al., Analysis Mason, May 2021, source: https://telecominfraproject.com/economic-impact-of-open-and-disaggregated-technologies-and-the-role-of-tip-in-sub-saharan-africa/

### 4.2.5. Data

Stakeholders have also highlighted the anticipation of new revenue streams stemming from the data generation for both the public sector and enterprises. These markets players claimed that there are risks that these new streams may be subject to a lack of level playing field that could impede exploiting data generation revenues.

# 5. MARKET PLAYERS' POLICY CONSIDERATIONS

A stable and predictable regulatory environment is important for companies to invest in the 5G ecosystem. As a general consideration, BEREC notes that the 5G ecosystem is still a developing one. It is still too early to conclude on 5G specific measures to further promoting connectivity, competition and citizens' interest, support innovation and to contribute to development of the internal market. Considering this, regulators must monitor the developments in the market and keep a steady and constant communication with stakeholders, this report being part of this effort by NRAs.

In the responses of the surveys circulated by BEREC for this report, market players expressed some 5G policy considerations as follows:

**Profits distribution across the 5G ecosystem**

For some respondents, the significant investment that 5G entails from specific players contrasts with the wider distribution of revenues across the entire 5G ecosystem lowering the expected return of investment. Various respondents claimed that albeit being a prerequisite for the development of the ecosystem, ECS are bottoming out in terms of value. Not solely because of the demand for increased capacity at a lower price but also because 5G has facilitated new market players to also play a role in electronic communications. An example provided is the private 5G networks that facilitate the entry of new players in electronic communications such as -but not limited to- vertically integrated cloud service providers. Tower companies are also expanding their role in electronic communications, especially to serve verticals who acquire dedicated spectrum.

Albeit the opposing concerns expressed by traditional players and new entrants such as those focusing on the development of open and disaggregated networks, all agree on the importance of policy makers supporting fair competition.

**Regulatory level playing field between traditional and new players**

A concern expressed by various stakeholders is the risk that different players offering similar services may face different regulatory obligations.

One example provided is the different coverage obligations related to spectrum assignment that national MNO and new entrants or verticals deploying campus networks face. Well established MNO may be legally expected to cover even less profitable rural areas while new entrants may have less stringent license obligations. Other regulatory conditions, which, according to some stakeholders, new entrants and verticals may not necessarily be facing, include network security obligations and net neutrality.

Facilitating a level playing field between players that are not active in the same layer of the ecosystem such as ECS providers and OTTs was requested by some market players,

justifying that connectivity related costs are distributed in a proportionate manner among all players in the 5G ecosystem. According to some stakeholders, MNO are facing both additional costs and additional competition from new players who often have lower costs.

Regulators and Policy Makers were encouraged to monitor and assess the role that for example Big Tech companies will play in the 5G ecosystem especially since further development of applications relying on artificial intelligence (AI) will sustain further the role and resulting growth of cloud computing in the future of mobile communications.

**Regulatory level playing field between MNOs**

Policy makers were urged by some stakeholders to analyse the 5G ecosystem to ensure that the regulatory frameworks result in a level playing field also among MNOs. These respondents underline the importance of encouraging long-term investment and incentivise nationwide 5G network roll-out to attain the Digital Decade[43] goals**.**

Some stakeholders indicated that in order to avoid market failure and potential monopolies, public sector entities should act in a pro-competitive way also when granting permits, organizing tenders, granting state aid, or even acting as an operator themselves. They underlined the need to take into consideration, when designing these policies, various parameters such as retail prices, profit margins, service penetration rates, to determine whether new entrants are discouraged to compete due to the market dynamics caused by the incumbents.

Some stakeholders called for NRAs and policy makers to seek to strike a balance between increasing competition and the resulting investment potential by the stakeholders involved.

**Conditions for voluntary network sharing agreements, access to small cells and leasing of spectrum**

In order to further encouraging investments by traditional and new players, regulators were urged to establish the right conditions for voluntary network sharing agreements including RAN sharing, access to small cells and leasing of spectrum. Network sharing, trading and leasing of spectrum can be beneficial to a number of stakeholders including MNOs. Enhanced legal certainty of the national and EU policies concerning these aspects may reduce the costs of 5G deployment including small cell deployment[44]**.** Policy makers were urged to pay attention to small cell deployment as this too may be susceptible to market distortions given the dependence on the incumbents' fixed networks.

**5G revenues uncertainty**

Some stakeholders claimed that ECS have bottomed-out in terms of value. A balance between capable 5G nationwide networks and the fulfilment of the goals stipulated in the EU Digital Decade may require a better understanding of the challenges resulting from the revenue generated from ECS, particularly IAS. In line with the previous point regarding revenues distribution, some stakeholders warn that 5G services can generate significant new revenue

[43] EC Communication: "2030 Digital Compass: the European way for the Digital Decade" https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0118&from=en

[44] Small cells relying on mmWave play a unique role in 5G networks.

streams, which also involve new stakeholders but those may not necessarily be investing in the deployment of 5G nationwide networks.

**Cloud providers switching**

Other aspects to be taken into account are the cost and ability to migrate from one cloud provider to another and whether customers are resorting to multi-cloud strategies. This could be further extrapolated to other players in the 5G ecosystem such as migration from one MSP to another in the case of a campus network.

**5G wholesale access**

MVNOs participating in BEREC's survey claimed that they were not in a position to join the appropriate partnerships to delivering E2E solutions over 5G networks either because MNOs do not allow 5G wholesale access or such access is subject to challenging economic conditions. Some respondents urged NRAs to ensure that wholesale access conditions to 5G and 5G standalone do not act as a barrier to MVNOs role as enablers delivering advanced 5G use cases to various verticals.

They indicated that establishing pricing models for wholesale access determined at European level could serve as a basis for discussions between MNOs and MVNOs at a national level. The monitoring of wholesale access to 5G and 5G stand alone networks including network slicing taking also note of the underlying network costs and any unclear significant discrepancies in wholesale prices between countries, with the aim of minimizing risks of margin squeeze was also recommended by market players.

**Spectrum management**

Spectrum is considered a key but scarce resource necessary for the realisation of the 5G value proposition. Traditional and emerging players have opposing views about the assignment of spectrum for new players and verticals.

MNOs consider that reserving and assigning mid-band spectrum to verticals could undermine the MNOs' needs for macro cellular coverage, further increasing spectrum scarcity and also leading to market fragmentation. Moreover, the digital transformation of verticals is driven by a mix of public and private network solutions. Thus, policy makers were urged to develop regulatory frameworks that do not result in artificial scarcity as these would in turn increase the cost of deployment which will be transferred onto the end-users.

Various stakeholders expressed their preference to the possibility of trading and/or leasing spectrum to verticals from MNOs, especially in the case of mid-bands that can be used to provision high-capacity wide-area macro-cellular mobile coverage across urban/suburban areas. However, other stakeholders recommended that policy makers should explore ways to support business models that do not necessarily rely on MNOs.

On the other hand, regulators and policy makers were also urged to continue to prioritize the efficient and effective use of spectrum, managing spectrum using a service neutral approach. Those respondents underlined the need to take into account that the needs of 5G verticals differ significantly from one another and from the needs of the consumer, with some use cases requiring the deployment of SNPNs.

**Cross-border applications**

Regulators and policy makers are considered to have a critical role for cross-border applications, particularly since this type of applications require increased cooperation between neighbouring countries on a number of regulatory and technical matters.

A recommendation made to policy makers in this regard is the synchronization of 5G Time Division Duplex (TDD) networks between countries. Stakeholders are of the view that this will necessitate effective cross-border coordination, agreeing on a common phase clock reference and also developing the appropriate spectrum licenses.

Another aspect pointed out which may negatively impact cross-border ECS is the differing licence obligations for QoS stipulated in neighbouring countries.

Finally, stakeholders indicated that roaming for network slices for cross-border use cases may also pose a challenge especially since no specific network slice has been defined for this kind of applications.

**Monitoring interconnection, interoperability and roaming**

Monitoring of the development of ECS, interconnection, interoperability, 5G roaming both for generic and customized services and the market developments in network slicing including cross-border network slicing is considered key to ensure that if new bottlenecks arise, proper and timely intervention is taken.

Regulators and policy makers were also urged to take into account that roaming from private to public networks may be necessary for certain use cases and user needs and thus assess the existing frameworks to determine whether roaming scenarios should be supported by public MNOs.

**Support to strategic sectors and technologies enabled by 5G**

Policy makers were also urged to support the strategic sectors and technologies that 5G will enable or incorporate such as virtualization, open and disaggregated infrastructures, software defined networks, edge computing, hybrid clouds and network slicing. Promotion of interoperable digital and data infrastructure projects such as edge computing, cloud computing and open interfaces were also recommended by the stakeholders as these could lead to better economies of scale. Moreover, respondents believe that in doing so, the strategic capacities to reinforce the European Digital Sovereignty will be enhanced and the Digital Decade 2030 targets will be attained.

Market experts in the development of open and disaggregated RAN and core networks have urged policy makers to both support further R&D in this field through funding schemes and also incentivise investment by market players in software and hardware from new vendors.

**Cybersecurity**

Regulators are urged by some stakeholders to consider the impact of the zero-touch virtualised networks[45] in a cloud-native network architecture on cyber-security, energy efficiency and supply markets.

Stakeholders also urged policy makers to facilitate an ongoing dialogue with emerging vendors in order to ensure that regulatory frameworks reflect the impact of new technologies including open and disaggregated technologies. According some stakeholders, any reduced vendor diversity resulting from cybersecurity mitigating approaches intended to eliminate high-risk vendors from the European supply chain can be addressed via adequate support to Open RAN based solutions.

**Social welfare**

Finally, regulatory focus on end-user protection including social well-being, safeguarding competition and encouraging continuous economic development, promoting innovation and ensuring sustainability in the long-term is also encouraged by stakeholders.

# 6. CONCLUSIONS

The maturity of 5G will bring significant changes in the mobile ecosystem with changing roles of traditional ECS providers and the emergence of new players adding complexity in the mobile ecosystem. These developments may entail new competition dynamics, both from the supply and demand side, as well as regulatory challenges.

The analysis of the key stakeholders' position in the 5G ecosystem implies that new 5G solutions, in particular the ones designed for verticals, may not be necessarily provided by traditional players alone but they may result from partnerships and agreements between different types of stakeholders. This could imply that, in the future, traditional ECS providers may not be the main players in the provision of some of the 5G services.

The development of 5G will allow the provision of new and/or enhanced products by means of improved electronic communications, 5G private networks, MEC, enhanced network functionalities, Open RAN and system integration. Also, 5G will bring value for the demand side with the growth of B2B products and the solutions for verticals. However, the pace for the adoption of this technology will strongly depend on the costs, both for the deployment of the infrastructure and for the verticals, and revenues and benefits expected.

In this regard, uncertainty on how the role of the different players may evolve may risk slowing down the adoption of 5G. For instance, although traditional ECS providers are currently well placed to bring 5G solutions to their customers, the possibility that in the future other players may step in and be better placed to provide specialized products could potentially hinder current investments from these players. On the other hand, it could take more time for other players to be able to provide fully-fledged solutions without the traditional operators' support.

[45] Zero touch networks are autonomous networks able to adjust themselves, based on the signals in the data they collect and analyse.

For the time being, it is expected the increased growth of partnerships among all the types of providers.

Another source of uncertainty could be the willingness to pay for 5G solutions by the verticals. Most verticals are still on an experimental phase and there are diverse degrees of maturity for the adoption of 5G across the different sectors. Furthermore, the willingness to pay for the enhanced connectivity is also still to be determined. However, for previous generations mobile networks the rich supply of content and applications available over the open internet has been a strong driver for demand for mobile IAS capacity.

Although at this early stage of development and uptake of the 5G ecosystem, most NRAs have not received formal complaints specifically related to 5G. BEREC takes note of the concerns expressed by the stakeholders and shares the aim to facilitate the deployment and adoption of 5G.

Some of the issues put forward by the stakeholders are not specific to the 5G ecosystem and have been[46] or may be addressed by BEREC in other context and documents. Other proposals may be source for future BEREC work. The cooperation for the development of 5G cross-border applications or the collaboration and competition between ECS and IT providers, are topics that could need BEREC's attention. BEREC recommends that regulators continue to monitor 5G developments.. In this regard, BEREC thanks the stakeholders for the extensive input provided for the elaboration of the report.

[46] The introduction chapter lists the relevant BEREC document related to this report.

**Annex I – Acronyms**

5GIA – 5G Infrastructure Association

AI – Artificial Intelligence

B2B – Business to Business

B2C – Business to Consumer

BBS - Business Support System

CAPs - Content and Application Providers

CAPEX – Capital Expenditure

CSP – Communications Service Provider

DAS – Distributed Antenna System

ECN/S – Electronic Communication Networks and Services

E2E – End-to-End

eMBB – Enhanced Mobile Broadband

GSMA – Global System for Mobile Communications Associations

IoT – Internet of Things

KPI – Key Performance Indicator

MEC – Multi-Access Edge Computing

mMTC – Massive Machine Type Communication

MNO – Mobile Network Operator

MSP – Managed Service Provider

MVNO – Mobile Virtual Network Operator

MVNE – Mobile Virtual Network Enabler

NPN – Non-Public Network

NRA – National Regulatory Authority

Open RAN - Open Radio Access Network

OPEX – Operational Expenditure

OTT – Over-the-Top

OSS - Operations Support System

PNI-NPN – Public Network Integrated-Non Public Network

SLA - Service Level Agreement

SME – Small and Medium Enterprises

SNPN – Standalone Non-Public Networks

URLLC – Ultra-Reliable and Low Latency Communications

VISP - Virtualisation Infrastructure Service Provider