From 5G to 6G: How can Europe stay ahead in the 6G race?

Booster Europe' Digital Sovereignty in global 6G

Table of Content

Foreword

Unlike other areas of the digital economy, Europe is one of the leaders in the world's telecommunications equipment market. Thanks to world class-companies, innovative research projects platforms, as well as varied vertical industry ecosystems, Europe has a strong voice when it comes to defining the future of mobile communications.

The new sixth generation of mobile communications (6G) is already on the horizon. Research and development programs are launched all over the world and 6G standardization is debated in international forums.

Europe must aspire to maintain its leadership in mobile telecommunications. In a world where geopolitical tension interferes with economical decision-making, it is crucial for our continent to adopt a strategy that will allow us to preserve a leading position. To do so, Europe should maintain a strong focus on innovation dynamic.

European policy should promote an approach that is based on open and global research and development cooperation. While we can observe that other world regions, closing in on themselves, we advocate the reverse.

Innovation and research, finds its origin in the exploration of ideas and concepts. We observe/believe that innovation benefits those who embrace and encourage the widest possible cooperation.

Therefore, the EU 6G R&D strategy should be as open as possible in order to converge and crystallize the best innovation available worldwide. EU 6G R&D tools should be open to all companies, European and non-European, to allow entrepreneurs to speed up their innovation process and create economic, societal and environmental benefits.

IDATE, July, 2023

1. 5G digital sovereignty: 5G shifting the global competition landscape

1.1. 5G promise to create new value for industries and society

The rapid deployment of 5G network is ongoing across the world. 5G is not only about wireless connectivity, but also have a systemic impact for industries and our societies. 5G promises to accelerate the digital transformation as well as create significant economic and social value for our society. According to a report by the GSM Association (GSMA), 5G technology is expected to contribute an estimated total economic value of USD 1 trillion[1] to the global economy in 2030. This economic value will be generated by the increased productivity and efficiency enabled by 5G, as well as the creation of new jobs and industries that leverage the technology.

The rollout of 5G has a massive impact on B2C market. With 5G's high bandwidth and low latency connectivity, new applications such as 8K high-quality video streaming, augmented and virtual reality applications, online gaming and video calling can be achieved to customers. By enabling "network slicing", operators can also introduce speed tiering internet services for various target markets. In certain remote areas, 5G rollouts have also driven the adoption of fixed wireless, given that 5G promise to provide high-speed connectivity to customers in underserved areas by existing fixed network.

5G is an accelerator of innovation for various industry markets, such as the healthcare industry, manufacturing, transport, smart cities, and many other areas. The 5G network will enable many industries worldwide to carry out digital transformation projects. Combined with artificial intelligence, big data and robotics, 5G is seen as the main enabler to accelerate industry digital transformation and essential to remain competitive in the future.

Following 3GPP approved NSA in December 2017 and 5G SA in January 2018, major economies around the world, including US, South Korea, and China, Europe, are building and deploying 5G network. The mobile 5G race is officially at the starting block. 5G trials and pilots were carried out in the leading countries.

1.2. Global 5G development and ecosystem landscape

Status of 5G development in major regions

Since 2018, telecom operators have made massive investments in 5G networks, which are now approaching adolescence three years after their launch. These operators are under immense pressure to provide seamless, fast, and reliable 5G connections and are continuing to invest heavily to meet the demands of consumers. As of January March 2023, 5G services have been launched by 249 operators across 97 countries worldwide[2].

In the US, there are more than 100,000 5G base stations[3], covering more than 77% of the population[4]. The number of 5G subscribers is approximately 150 million, accounting for 30% of the total number of mobile connections[5].

China's government put 5G at a top priority in the 13th Five-Year Plan and the "Made in 2025" initiative. China's commercial 5G launch happened in November 2019. With the

[1] GSMA, The Mobile Economy 2023

[2] https://www.3gpp.org/news-events/partner-news/2023-04-gsa-lte-5g

[3] https://5gobservatory.eu

[4] TeleGeography estimation

[5] Idate, World 5G Market Database

government support, the country targets to build 2,38 million 5G base stations by March 2023. More than 20000 5G based business applications have been launched in various areas, including education, transportation, and healthcare, etc.

Europe is an important global hub for 5G development and investments. During the 2014-2020 period, the EU supported 5G development with over €4 billion. Many EU cities strongly engaged in 5G development, trials, and pilots. Operator Telia in Finland was the first company to launch 5G in Europe in 2019. In terms of 5G base station density, Europe ranked in the middle range, trailing behind South Korea and China.[6] Almost 70% of the population covered by 5G in EU-27 with approximately 250,000 base stations. Over 200 private 5G networks have been deployed throughout Europe. By 2027, 5G connections in Europe are expected to reach 812 million, accounting for approximately 48% of all mobile connections. [7]

Comparison of 5G rollout in international markets

	China *	South Korea	Japan	USA	EU
Approximate number of 5G base stations	2,290,000	215,000	50,000	100,000	310,000
Total country population	1,402,000,000	51,780,000	125,800,000	329,500,000	447,706,000
5G base stations per 100,000 inhabitants	163	415	40	30	69
Indicative 5G subscribers	357,000,000	25,000,000	14,190,000	79,000,000	31,000,000
Indicative 5G subscribers per 100,000 inhabitants	25,464	48,281	11,280	23,976	6,924

Source : 5gobservatory.eu

* The number of China 5G base stations reached 3 million by July 2023, according to Chinese government.[8]

5G adoption is outpacing previous generations, and IDATE forecasts that by the end of 2027, there will be over 5.6 billion 5G subscriptions worldwide. The Asia-Pacific region is expected to account for the majority of these subscriptions and more than 40% of 5G revenues in 2027. Thanks to the large populations of China and India, the number of 5G subscriptions in the Asia-Pacific region is set to exceed 1 billion by 2023[9].

[6] 5G Observatory, European 5G scoreboard

[7] IDATE, World 5G Markets - 2H 2022-report

[8] https://www.cnii.com.cn/tx/202308/t20230824_498369.html

[9] IDATE, World 5G Markets - 2H 2022 - Report

Telecom equipment: Europe's last stand in the digital market

Europe continues to hold a strong position in the global telecom equipment market. The success of European companies in telecom equipment sector is crucial for Europe's ability to remain competitive in the global digital market. This sector plays a critical role in the digital ecosystem by enabling high-speed internet and mobile connectivity, which is essential for digital innovation.

In global digital technologies market large Asian and US companies have established dominance in virtually every digital sector, leveraging their powerful domestic markets to expand their international footprint. In the US, companies such as Google, Facebook, Amazon, and Microsoft are leaders in their respective segments. Similarly, companies such as Baidu, Alibaba, Tencent, and Xiaomi have emerged as dominant players in China, facing no significant European competition.

Despite Europe's historical prominence in IT services and software, European companies have gradually lost ground to their digital competitors. One of the reasons for Europe's lag in the digital market is its highly fragmented nature. The European Union consists of multiple countries with differing laws and regulations, making it difficult for companies to operate seamlessly across borders. Additionally, Europe's digital market is its highly fragmented nature. The European Union is made up of multiple countries with differing laws and regulations, making it difficult for companies to operate seamlessly across borders.

While telecom equipment market is dominated by several large equipment vendors that invest heavily in research and development to compete, EU vendors still account for almost half of the global telecom mobile equipment market, with its leading players Ericsson and Nokia. EU vendors still account for almost half of the global telecom mobile equipment market. Nevertheless, the adoption of Open RAN technology poses a significant threat to Europe's leadership position in the telecom equipment sector, potentially opening the door for new entrants into the market and disrupting the existing market landscape.

In conclusion, 5G technology is the foundation of digital ecosystem development and has the potential to boost social and economic growth. While almost all countries are making efforts to deploy and adopt 5G, the EU lags behind in terms of deployment and adoption. This highlights the challenges that the EU faces in comparison to its global competitors in the digital ecosystem. However, the EU still maintains a strong position in the telecom equipment sector.

To ensure a strong competitive position of European vendors globally, the EU must create a market and innovation ecosystem. This requires strong cooperation with public authorities and the creation of a favorable environment for research and development. European players are calling for regulations to attract players from outside Europe to invest in research and development in Europe. By doing so, Europe can maintain its expertise and remain at the forefront of innovation in the digital ecosystem.

1.3. Impact of Open RAN on EU's leading position in telecom equipment sector

The emergence of the Open Radio Access Network (Open RAN) was driven by geopolitical concerns that limited the number of vendors that could deploy 4G and 5G networks in certain regions. Open RAN is a concept that disaggregates the hardware and software components of the radio access network and modularizes them through open interfaces, virtualization, and AI. This approach enables RAN functions to be built entirely in the cloud, leveraging virtualization and AI to enable the deployment of hardware from a variety of vendors, including commercial-off-the-shelf (COTS) hardware. While Open RAN is not a new technology, it represents a significant step forward in creating a more open and flexible ecosystem for deploying wireless networks.

Open RAN 5G network architectures seem to offer a compelling alternative to traditional networks. With a focus on open, modular, and interoperable interfaces, Open RAN aims to reduce operators' technological dependencies on big equipment vendors, while also addressing security concerns associated with 5G deployment. Additionally, Open RAN target to reduce deployment costs and increase the flexibility of the network infrastructure for mobile operators. For governments, Open RAN represents an opportunity to increase the competitiveness of local 5G supply ecosystems, while also guaranteeing trust in network management by replacing untrustworthy foreign vendors.

Two major Open RAN industry associations

There are a variety of Open RAN groups and advocacy organizations seeking to unify an ecosystem of supply chain partners and advance open RAN Research and development. Prominent Open RAN industry organization include:

- O-RAN Alliance is formed in February 2018 by a group of mobile operators and vendors. AT&T, China Mobile, Deutsche Telekom, NTT Docomo and Orange were the initial founding operators. It is now comprised of close to 30 operators and more than 200 vendor companies. The goals are to create specification for new radio architecture, enabling an open and interoperable supply chain ecosystem. In February 2019, ORAN published the first open standard specification for the fronthaul interface between the RUs and BBUs.
- OpenRAN project group is a subgroup of Telecom Infrastructure Project (TIP), which is created in in early 2016 by Facebook. Today TIP has more than 500 members and 12 project group. Its main objective is to develop fully programmable RAN solutions based on disaggregated software running on General Purpose Processors (GPP) using COTS hardware. In addition, it also focuses on building white-box baseband and radio unit designs based on O-RAN Alliance architecture and interfaces.

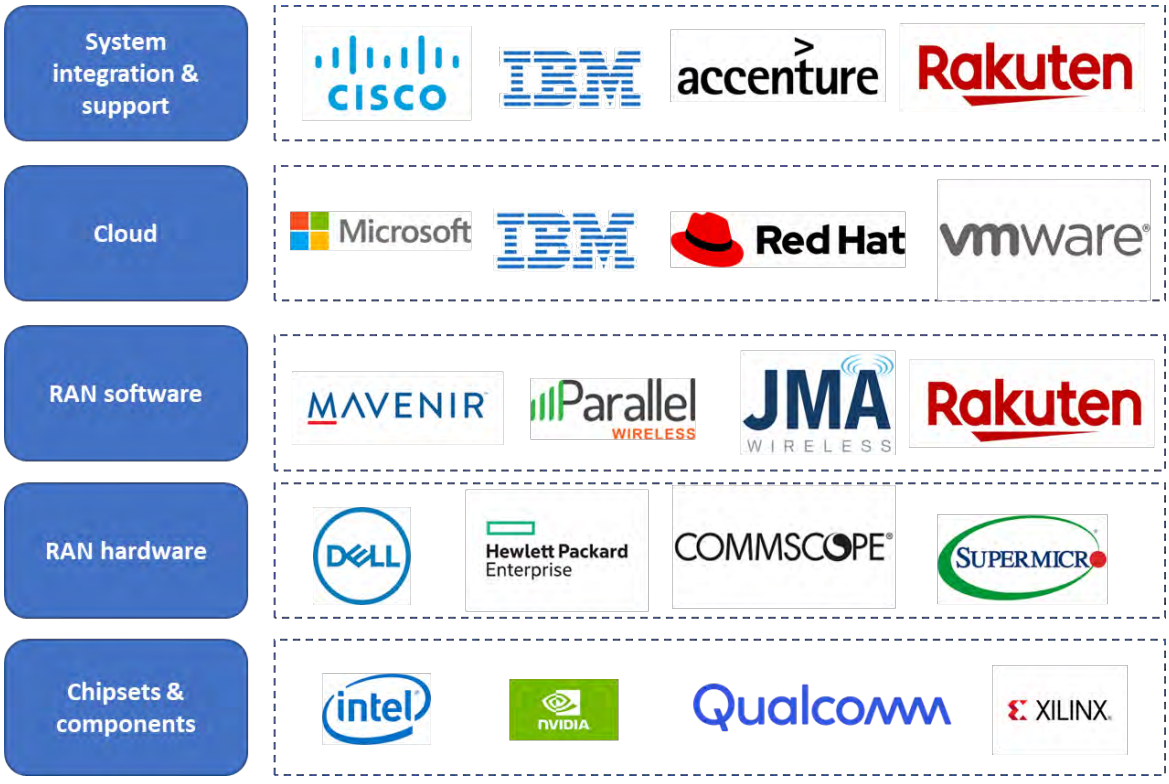
Global Open RAN trials and deployments Jan. 2023[10]

[10] telecominfraproject.com, TIP: Facilitating, Accelerating and Enabling Open RAN

Open RAN will shift RAN value chain and vendor landscape

Open RAN is changing and challenging the traditional telecom equipment vendor value chain landscape. Different from current RAN value chain, the Open RAN value chain is divided into five major categories as below. Cloud and Chipset are the main components across Open RAN value chain.

Open RAN Ecosystem



Source: IDATE, *From 5G to 6G: How can Europe stay ahead in the 6G race?*

The Open RAN ecosystem will attract new software and hardware suppliers, but the main players are currently dominated by non-EU companies from OTT/Software/Chip sectors. IT companies could utilize their enterprise expertise and infrastructure to enter the market. For cloud giants, this presents an opportunity to become a crucial part of the networking infrastructure, especially for open cloud platform-based networks. Cloud giants with a global infrastructure, strong brand recognition, and AI capabilities are particularly well-positioned to take advantage of this.

European telecom equipment vendors have been dominating the telecom equipment market for a long time. However, the EU's Open RAN ecosystem is currently lagging behind its international peers and is still fragmented. Without a strong presence of EU companies in the Open RAN ecosystem, EU telecom infrastructure companies risk losing their leading position in the market.

Challenges and risk of Open RAN

Currently, the Open RAN model is still in its early rollout and is not mature yet. The new architecture will raise faces several challenges:

- Lack of maturity: According to studies, there are concerns about the maturity of Open RAN. The Body of European Regulators for Electronic Communications (BEREC) found that Open RAN is not yet extensively deployed in commercial networks, and its implementation may take time due to a lack of maturity[11]. Additionally, the European Union Agency for Cybersecurity (ENISA) has reported that Open RAN is still lacking in maturity, and cybersecurity is a significant challenge. The report highlights those technical specifications, such as those developed by the O-RAN Alliance, are not secure enough by design[12]. As a result, investing in such an immature technology could be risky.
- Cybersecurity challenge: Multiple safety assessment reports from government regulators highlight open RAN security concerns, including those from Germany's Federal Office for Information Security (BSI), the European Union's "5G supply market trends" report, and the Body of European Regulators for Electronic Communications (BEREC) report titled "An overview of the BEREC work on the Open Radio Access Network (RAN),)." Additionally, the NIS Cooperation Group(CG)'s "Report on the cybersecurity of Open RAN" highlights 16 security risks related to Open RAN. Furthermore, The decentralization of functions with Open RAN increases the attack surface. The ENISA 's report state that in the short term, by increasing the complexity of networks, Open RAN would exacerbate a number of security risks. Those risks include a larger attack surface and more entry points for malicious actors, an increased risk of misconfiguration of networks and potential impacts on other network functions due to resource sharing. Additionally, Open RAN does not implement any mechanism for guarantee the trustees of vendors.
- Unproven power efficiency: There is no clear evidence that Open RAN consume less energy than traditional RAN system. The EU Commission's report on the future 5G supply ecosystem in Europe suggests that integrated stand-alone solutions may be better for energy efficiency. Open RAN's increased heterogeneity may make it more difficult to measure and control energy consumption in each part of the network, and energy consumption may increase due to optimization for flexibility

[11] BEREC, An overview of the BEREC work on the Open Radio Access Network (RAN)

[12] ENISA, Report on the cybersecurity of Open RAN

and interoperability. In addition, Open RAN uses generic chips, such as Intel X86 processors, which consume more power than specific chips used in traditional RAN systems. Some proponents claim that Open RAN promotes energy efficiency for a fully cloudified mobile network infrastructure, but traditional telecom infrastructure companies are also moving their RAN solutions to the cloud. The energy efficiency of Open RAN's cloudification has yet to be proven to be better than that of traditional RANs.

- **Low performance:** Since open ran models include a wide range of components from a wide range of vendors, it is more difficult to optimize the control plane. This includes identifying bottlenecks that reduce performance and coordinating various software roadmap. Additionally, operators need carefully coordinate the responsibility of vendors. When a problem arises on an Open RAN network, operators are needed to work with multiple vendors to resolve the issues. Otherwise, an ineffective troubleshooting process will negatively affect the quality of networks.
- **Complex integration**: Open RAN require integration between different software modules or between software and hardware solutions, thus maximizing the complexity of system integration. Based on the study of BEREC, ensuring interoperability is essential for the successful implementation of Open RAN. However, SRL's Open RAN report show that the combined use of products and services from multiple vendors makes it easier for mistakes and misconfigurations to occur, increasing the number of clues for hacking[13].
  Unclear cost efficiency: Open RAN total ownership cost may be high, constrains from replacing a proprietary model to an open model may include hidden costs that are overlooked. The BEREC's Open RAN report states that the impact that Open RAN will have on CAPEX and OPEX is not yet clear. There is scant evidence that open RAN is cheaper, and no one rates it ahead of traditional RAN on performance[14].

Additionally, Open RAN will generate new risks that will not only impact EU companies' dominant position in telecom infrastructure sector, but also disrupt current telecom infrastructure landscape by create new dependencies on cloud giants and lead market fragmentation for the future generation of mobile technologies.

- **New dependences on cloud and chipset**: Open RAN's reliance on cloud services and chipset development could lead to increased critical dependencies, such as on a small number of dominant non-EU cloud/chipset service providers. For instance, Intel holds a near-monopoly position in the market for open and virtualized radio access network (RAN) technology. Approximately 99% of commercial vRAN deployments currently rely on Intel's solutions[15]. The ENISA's report states that Open RAN could lead to new or increased critical dependencies, for example in the area of components and cloud[16]. There is a risk of MNOs becoming dependent on a small number of cloud/chipset service/infrastructure providers, which are dominated by non-EU companies and could also lead to supplier lock-in. In that case, Open RAN therefore brings the risk for Europe telecom operators of swapping one dependence for another one: either towards legacy vendors in the

[13] Security Research Labs(SRL), OpenRAN – 5G hacking just got a lot more interesting

[14] https://www.lightreading.com/open-ran/open-ran-mania-for-systems-integration-could-end-badly/a/d-id/780921

[15] https://www.lightreading.com/open-ran/intel-boasts-open-ran-monopoly-as-nokia-turns-to-others/d/d-id/783384

[16] ENISA, Report on the cybersecurity of Open RAN

proprietary RAN model, or towards large OTT/Software/Chip companies in the Open RAN model[17].

- **Service integrator lock-in**: In the Open RAN model, operators are expected to work with multiple open RAN suppliers. However, operators prioritize the smooth operation of their networks over handling the integration and support of the RAN system. Therefore, some operators rely on service integrators to supply components for their radio access network, which allows system integrators to leverage their own Open RAN ecosystem resources for radio access networks. However, this approach may limit the freedom of operators to choose the best-of-breed products from multiple vendors as multi-vendor interoperability is not always guaranteed. In addition, the prominent Open RAN system integrators include Rakuten, 1&1, and Dish. The expanding ecosystem of system integrators, such as Rakentu's acquisition of Altiostar Networks in 2021, may also lead to another form of vendor lock-in.
- **Risk for the market fragmentation**: Both O-RAN alliance and 3GPP defines a number of Open RAN internal interfaces specifications. The specifications should complement and extend 3GPP specification but should never contradict or overlap the work in 3GPP to avoid market fragmentation of 5G and future mobile standards[18].

National governments' positions towards Open RAN

Several governments worldwide are taking measures to support Open RAN development, including US, Japan, and UK, through legislation, grants, tax incentives, and funding competitions.

EU hold a balanced approach towards Open RAN. European Union prioritizes the deployment of secure 5G networks and developed a concerted approach with EU member to the cybersecurity of 5G networks. In 2020, jointly assessed the main risks related to 5G networks and defined a comprehensive and risk-based approach in the form of the EU 5G Toolbox adopted in January 2020. the European Union Agency for Cybersecurity (ENISA) published in November 2019 a "toolbox" providing a detailed assessment on the general threat landscape for future 5G networks. In early 2020, the EU adopted a toolbox on 5G cybersecurity on 5G cybersecurity to mitigate cybersecurity risks related to the rollout of 5G networks. In Mai 2022, ENISA published another report on the cybersecurity of Open Radio Access Networks (Open RAN), which analyze security implications of Open RAN architecture. These documents do not endorse nor oppose Open RAN as a safer alternative solution.

While Open RAN is an appealing technology for promoting supply chain diversity, experts warn that it failing to address the original security issue and facing numerous challenges and risks. These challenges include immaturity, cybersecurity risks, power inefficiency, complex integration, low performance, high cost, and new risks such as dependency on cloud and chipsets, reliance on service integrators' ecosystems, and market fragmentation.

Ericsson and Nokia, have established themselves as leading incumbents in 5G research, development, and deployment, giving European companies a technological edge in the global market. However, the emergence of Open RAN could undermine their power by shifting control from equipment vendors to cloud providers, many of which are non-European. This shift could jeopardize the EU's path to digital sovereignty, making Open RAN a contentious issue.

[17] The Political Hijacking of Open Networking. The Case of Open Radio Access Network

[18] https://www.ericsson.com/en/blog/2020/9/ran-what-policy-makers-need-to-know

The dominant players in Open RAN are currently non-EU companies in the OTT, software, and chip industries. Without the participation of EU companies, the EU's telecom equipment industry risks losing its foothold in the market. EU policymakers should take a cautious approach to Open RAN and prioritize the security and autonomy of the EU's 5G supply chain ecosystem by addressing potential software and integration vulnerabilities.

1.4. Concluding remark on 5G eco-system trends

5G is crucial for digital ecosystem development and has the potential to accelerate social and economic growth.5G is viewed as a strategic technology for Europe to maintain its competitiveness in the global market. While US and Asian companies dominate the leading digital markets, European telecom equipment players remain strong in 5G space. By investing in research, promoting innovation, and supporting the deployment of 5G networks, Europe can maintain its competitiveness in the global market and secure its position as a leader in technology development.

Open RAN presents a new challenge to telecom infrastructure by aiming to diversify 5G suppliers and reduce deployment costs. However, hidden costs, environmental and security issues could be underestimated, posing a threat to European major telecom vendors' position . This transition could cause European companies to lose their lead position to non-European companies, leading to 6G fragmentation.

In conclusion, the European telecom industry must collaborate to overcome challenges and maintain a competitive position in the 5G ecosystem. This includes addressing challenges posed by Open RAN, investing in 5G infrastructure and deploying new service and business models. EU policymakers must be cautious with Open RAN, prioritizing the security and autonomy of the EU's 5G supply chain ecosystem by addressing potential software and integration risks.

2. 6 GHZ paves the way for network evolution beyond 5G

2.1. Increasing spectrum resource is needed to realize 5G promise between 2025 and 2030

Today, the majority of countries have deployed their 5G networks in frequency bands such as 3.5 GHz and mmWave range (above 24 GHz). However, with the exponential increase in data traffic, the current 5G spectrum resources are expected to face saturation by 2025. As a result, it is imperative to acquire additional frequencies to fully release the potential of 5G and gradually evolve towards the vision of 6G.

Recent research by GSMA indicates that each country needs an additional 1-2 GHz frequency band in urban areas by 2025-2030 to meet the rising demand for data traffic and network quality. Without additional spectrum resources, there is a risk that 5G networks in busier areas will not be able to deliver reliable download speeds of 100 Mbps. The mobile industry is actively seeking new spectrum resources that would enable the evolution of 5G to continue while delivering comparable performance.

2.2. Leveraging Mid-Band Spectrum for Sustainable 5G Deployment and Beyond

As the world continues to embrace the transformative potential of 5G technology, the importance of leveraging the right spectrum bands cannot be overstated. While low-band spectrum offers wider coverage and mmWave spectrum provides greater capacity and speed, mid-band spectrum offers an attractive balance between coverage and capacity.

Mid-band spectrum, with its higher bandwidth and capacity compared to low band, and broader coverage than mmWave frequencies, plays a critical role in bridging the gaps between low-band and mmWave. In urban areas, mid-band can significantly improve network capacity to meet the increasing demand for data traffic, while in rural areas, it can be used to provide high-speed fixed wireless access (FWA) broadband, increase available capacity along major transport routes, and help address the connectivity needs of industrial use cases.

Mid-band spectrum is considered as a crucial enabler for achieving the full potential of 5G and meeting the growing demand for data traffic and network quality. Globally in excess of 200 operators in more than 100 countries/territories have started their commercial 5G deployments in mid-band spectrum[19]. its importance cannot be overlooked. However, to fully realize the potential of 5G and beyond, additional mid-band spectrum is required.

Leveraging mid-band spectrum not only improves connectivity and reduces the digital divide in Europe but also has the potential to achieve economic value and support sustainable development goals. Mid-band spectrum in 5G and beyond can contribute to achieving carbon emission goals by enabling more efficient and sustainable use of resources, such as energy, and reducing the need for additional base stations and antennas. Moreover, the use of mid-band spectrum can facilitate the development of smart cities and industries, enabling new use cases and business models that promote sustainable development.

[19] GSA, Mid-band spectrum and the 5G opportunity

Comparison of low band, mid band and mmWave[20]

Low bands	Mid bands	Mmwave
Wide covergae area	City-wide coverage area	Small area/hotspot coverage
Limited capacity	High capacity	Ultra-high capacity

2.3. 6 GHz is key resource to offers complementary capacity to 3.5 GHz

The 6 GHz band has the potential to play a crucial role in the development of both wider area public mobile networks relying on licensed/auctioned spectrum and wireless local area networks including Wi-Fi using unlicensed spectrum, both essential for inclusive universal connectivity in the future.

In June 2021, the European Commission announced its decision to make the lower part of the 6 GHz band (480 MHz) available for unlicensed use by Wi-Fi. The remaining upper part of the 6 GHz band (700 MHz) is currently under examination by the competent ministries and national regulatory authorities within the EU Member States.

The allocation of the entire 6 GHz band for unlicensed use by Wi-Fi, largely driven by the US technology industry, raises concerns for EU telecom industries. This potential allocation of the entire 6 GHz band for unlicensed use would have serious implications for the future development of mobile networks in Europe. A detailed cost-benefit analysis conducted by GSMA Intelligence clearly demonstrates that a balanced utilization of spectrum in the 6 GHz band, catering to both licensed mobile and unlicensed Wi-Fi services, would yield optimal socio-economic benefits for Europe.

If the remaining 700 MHz of the 6 GHz band are not made available for mobile use, our forecast indicates that certain European cities will encounter limitations on 5G network capacity well before the end of this decade. The insufficient availability of reasonably priced 6 GHz spectrum undermines the feasibility of economically viable network investments by European operators. Furthermore, it creates hurdles in realizing Europe's vision for the digital decade, placing Europe at a disadvantage compared to other countries and regions.Moreover, it is worth noting that Europe lags behind other leading countries in terms of mid-band spectrum allocation. There is a nearly 1 GHz gap to meet the required 2 GHz, which is larger than the gaps observed in other countries.

[20] GSMA, Mid-band 5G spectrum benefits

Gaps to required 2 GHz mid band spectrum of selected region/countries

	Total Mid-band allocated frequencies	FDD	TDD	Gaps to required 2 GHz mid-band spectrum by 2025-2030
European Union	1050 MHz	600 MHz	450 MHz	950 MHz
China	1735 MHz	470 MHz	1265 MHz	265 MHz
US	1600 MHz	500 MHz	1100 MHz	400 MHz
Japan	1740 MHz	490 MHz	1250 MHz	260 MHz
South Korea	1320 MHz	590 MHz	730 MHz	680 MHz

Source : IDATE based on various internet sources , From 5G to 6G: How can Europe stay ahead in the 6G race?

2.4. WRC 23 Opportunity for harmonization of licensed 6 GHz

The World Radiocommunication Conference 2023 (WRC-23) in Dubai from November to December 2023 will presents a significant opportunity for the harmonization of licensed 6 GHz spectrum allocation. While some countries have allocated the full 6 GHz band for unlicensed use, others have reserved it for licensed 5G use. There are also countries that have adopted a hybrid approach, splitting the band between licensed and license-exempt technologies.

International spectrum harmonization through WRCs can lead to a larger ecosystem for technologies, resulting in more affordable mobile services and handsets. The decisions on the future spectrum allocation of the upper 6 GHz spectrum (U6G, 6425-7125 MHz) will be taken at WRC 23, and this presents an opportunity for countries to align their approaches and enable a more cohesive and efficient use of the spectrum.

According to the "Opinion on the ITU-R World Radiocommunication Conference 2023" from the Radio Spectrum Policy Group (RSPG), which was approved in December 2022 after public consultation, the recommended EU position is to accept an International Mobile Telecommunications (IMT) identification at WRC-23 for all or a portion of the 6 425-7 125 MHz band.

Furthermore, the supplementary spectrum at 6 GHz provides the opportunity to expand 5G spectrum resources to meet the additional 2 GHz goal. Therefore, it is essential that regulators and policymakers work together to ensure a harmonized approach to licensed 6 GHz spectrum allocation at WRC 23, which will support the sustainable development of industries and economies, and benefit consumers and society as a whole.

2.5. Allocating Upper 6 GHz for EU's Sustainable Digital Agenda with 5G and Beyond

The deployment of 5G is a crucial step in achieving sustainable socio-economic development. To achieve this, governments and regulators must ensure that 2GHz of mid-band spectrum is available, and the use of the Upper 6 GHz band for licensed mobile systems will play a critical role in achieving Europe's "Digital Decade" objectives. The WRC-23 meeting will be important to discuss the use of mid-band spectrum, and international collaboration and support will be necessary to make informed decisions on the future identification of Upper 6 GHz for 5G and beyond.

The EU has launched the Digital Europe Program to achieve digital transformation targets by 2030, with 5G being a key enabler of this transformation. 5G technology provides enhanced and reliable connectivity, enabling new advanced services and applications to support sustainable development in industries and economies. The allocation of Upper 6 GHz spectrum must be prioritized to ensure that Europe remains competitive in the digital economy, meet the growing demand for data traffic, and contribute to achieving sustainable development goals.

Furthermore, according to the GSMA, 5G can drive 0.68% of global GDP growth by 2030, and mid-band range will drive nearly 65% of the overall value created by 5G. Additionally, the spectrum requirements for 6G will be even higher than those of previous generations, making Upper 6 GHz spectrum essential for coping with emerging services and applications such as large-scale metaverse and holographic in future 6G networks while providing reasonable wide area coverage. Moreover, it is worth noting that making additional mid-band spectrum available to meet future capacity targets can help reduce the carbon footprint of future 5G mobile networks. By avoiding a significant densification of macro sites and outdoor small cells, the environmental impact of network infrastructure can be minimized[21].

In conclusion, the allocation of Upper 6 GHz spectrum for licensed use is crucial for achieving the promise of 5G and beyond, and policymakers and industry players must prioritize this to support sustainable development and ensure that Europe remains competitive in the digital economy.

[21] https://www.analysysmason.com/5g-mid-band-carbon-impact

3. Moving forward to 6G

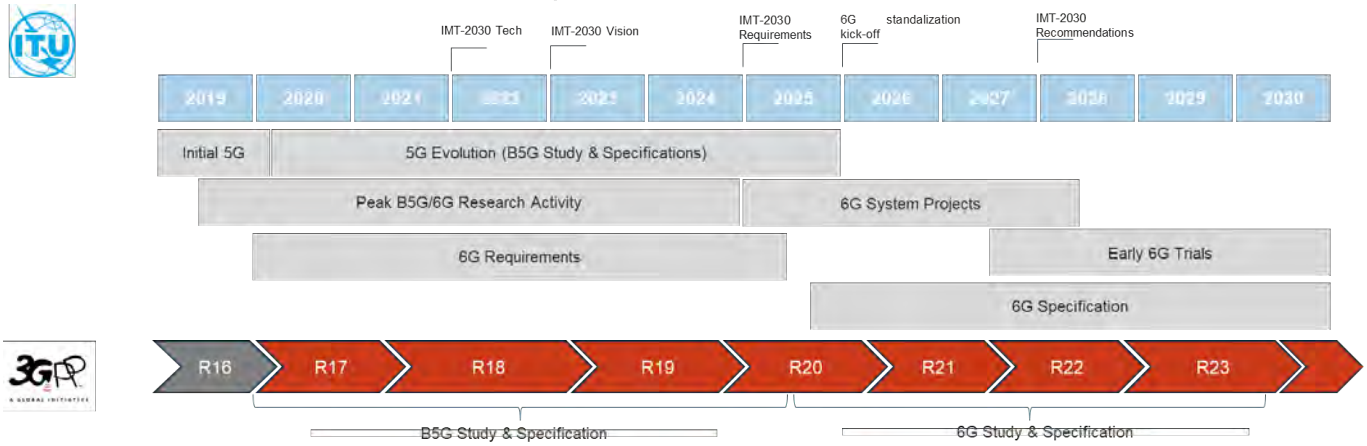
3.1. Evolution towards 6G

Mobile network technology has evolved from 1G to 5G over the past forty years, with 5G still being deployed and 3GPP beginning the standardization work for 6G in 2025. The specifications for 5G-Advanced, which will include improved MIMO, AI/ML-enabled air interface, extended reality (XR), and enhanced mobility support, are set to be released in 3GPP Release 18, with early commercial deployment expected in 2024/25.

6G is the next-generation mobile network technology that builds upon the foundation of 5G. It operates on a wide spectrum range, including low, mid, mmWave, and sub-THz bands. Equipped with integrated artificial intelligence and sensing capabilities, 6G is expected to provide improved connectivity performance and support new use cases and services.

Moreover, 6G networks will be designed to support distributed and decentralized architecture of intelligence, enabling the linking of physical, digital, and intelligent worlds. It aims to establish a truly trustworthy infrastructure while ensuring sustainability by reducing energy consumption, resource usage, and carbon emissions.

Evolution path towards 6G[22]



3.2. 6G drivers

Driver 1: Sustainable development of our society

Economies and sustainable development have become a core priority for many countries and industries worldwide. In 2015, the United Nations established 17 Sustainable Development Goals (SDGs) to be achieved by 2030. The SDGs address a broad range of sustainability issues, including poverty, gender inequality, health, and climate protection.

UN SDG goals and selected targets on emission reduction[23]

[22] 2023 EuCNC & 6G Summit

[23] IDATE, From 5G to 6G : How can Europe front run in 6G race?

Source: IDATE, *From 5G to 6G: How can Europe stay ahead in the 6G race?*

Mobile technologies have played a significant role in driving economic and sustainable development by providing access to internet, services, and resources that promote economic growth, social inclusion, and environmental sustainability. As mentioned above, 5G technology is expected to contribute an estimated total economic value of USD 1 trillion to the global economy in 2030.

Furthermore, 5G connectivity could save over 250 million tons in CO2 emissions globally by 2030 through accelerating the move to wind and solar energy. Other research has calculated that 5G-enabled use cases can reduce carbon emissions in the energy industry by almost 1% between2020-2030[24].

6G has the potential to reduce inequalities and drive economic growth through its unique connectivity capabilities and providing full coverage of space, aerial and terrestrial. The ubiquitous and high-speed 6G mobile connectivity is expected to facilitate the access to digital services, improving digital inclusion and unlocking economic opportunities for rural and remote areas.

Moreover, The upcoming 6G network will be designed more energy-efficient and environmentally friendly by integrating AI, using renewable energy, energy harvesting technology and the reduction of environmental footprint of devices.

Driver 2 : Enhanced digital experience and new uses cases

Each mobile technology advancement transformed not only our personal lives but also the business world in countless ways. 4G brought broadband wireless connectivity to mobile device, such as video streaming. 5G, on the other hand, promises to change the business industry by enabling new use cases that require high-speed, low-latency, and reliable connectivity. These use cases include things like autonomous vehicles, remote surgery, smart cities, and more. 6G has the potential to enable even more collaboration between the digital and physical worlds, bringing new users experience and transform industries by enabling new uses cases.

[24] Mobile UK, Connectivity and Climate Change: How 5G will help lay the path to net zero

- **Pervasive communication:** 6G enable to interconnect devices and sensors to create a seamless and ubiquitous communication environment, enabling new applications and services in various industries, such as healthcare, transportation, and entertainment.
- **Metaverse**: 6G enables immersive communication that allows users to share shared experiences with a virtual world that seamlessly integrates digital objects and experiences into our everyday lives, enabling new use cases such as gaming, socializing, shopping, education, and work, through virtual or augmented reality interfaces.
- **Digital Twins**: 6G enables digital twins by providing real-time monitoring and control of physical objects and environments through high-speed and low-latency connectivity, allowing for more efficient and effective management of physical assets.
- **Ubiquitous connectivity**: 6G integrate different communication technologies, including terrestrial and non-terrestrial systems, to ensure reliable and high-speed communication services ubiquitous, even in remote and less populated areas. This can create new business models and economic opportunities on a global scale.
- **Hologram telepresence:** 6G can enable advanced holographic technology to create immersive virtual environments that can be accessed from anywhere in the world, allowing for remote collaboration, communication, and entertainment experiences that feel like being physically present in a different location.
- **Collaborative robots and Autonomous system:** 6G networks enable real-time and intelligent collaboration between humans and robots or autonomous systems by levering its extreme connectivity. This can enable various applications such as smart factories, autonomous vehicles, and robotic surgeries, where robots and autonomous systems work alongside humans to enhance productivity, efficiency, and safety.
- **Sensors and sensing fusion**: 6G networks not only integrate data from a variety of third party sensing sources, such as cameras, lidar, radar, and other sensors, but also support wireless sensing via the infrastructures and potentially the devices to have real time perception of the environment, enabling advanced applications such as autonomous vehicles, collaborative robots, smart cities, digital health, and smooth interaction in virtual and augmented reality.
- **Smart verticals**: 6G benefit various industry vertical sectors, enabling them to operate more efficiently, sustainably, and profitably by leveraging the high speed, low latency, and massive connectivity. Vertical industries can harness the potential of advanced technologies like AI, IoT, and AR/VR, made possible by 6G, to create new business models and revenue streams, optimize their operations, and achieve improved sustainability by reducing waste and optimizing resource usage.
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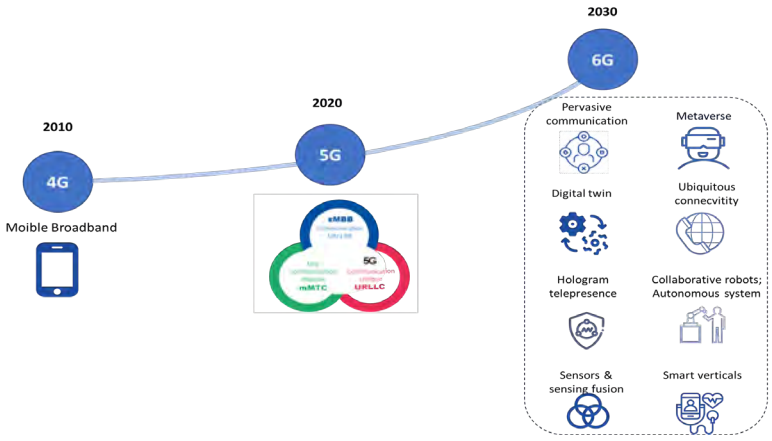
Main mobile technologies use cases from 4G to 6G

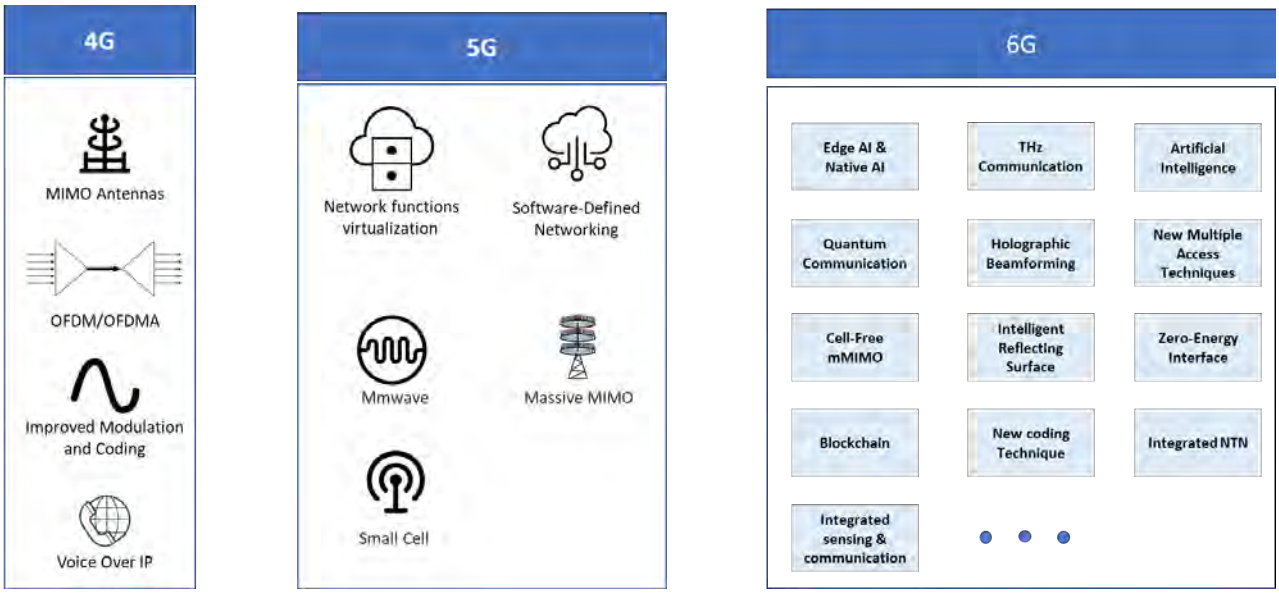


Source: IDATE, *From 5G to 6G: How can Europe stay ahead in the 6G race?*

Driver 3 : technological advancement in wireless technology

The development of 6G technology is likely to involve a combination of both evolutionary and revolutionary advancements in various technology areas, and it will require the use of new materials, new technologies, and new spectrums to enable new capabilities and performance. The standardization process by 3GPP will ensure that the ecosystem is aligned with interest areas, and R&D efforts will be collaborative to create a platform suited to the next decade's needs. The evolution of mobile networks towards 6G will be driven by advancements in the core and radio access network, air interface, and terminal sides, which will be specified by 3GPP.

Main Technologies Enablers From 4G to 6G



Source: IDATE, *From 5G to 6G: How can Europe stay ahead in the 6G race?*

Core network: edge computing, AI, and other innovative technologies will be applied to the core network. Emerging technologies like blockchain and digital twin will enhance the performance of 6G core networks with new dimensions. AI and Machine Learning technologies are studied as part of 6G research to further improve network automation and optimization. Edge computing enables 6G by utilizing decentralized and distributed architecture to provide higher bandwidth and lower latency, facilitating support for cloud-based applications and handling more complex services.

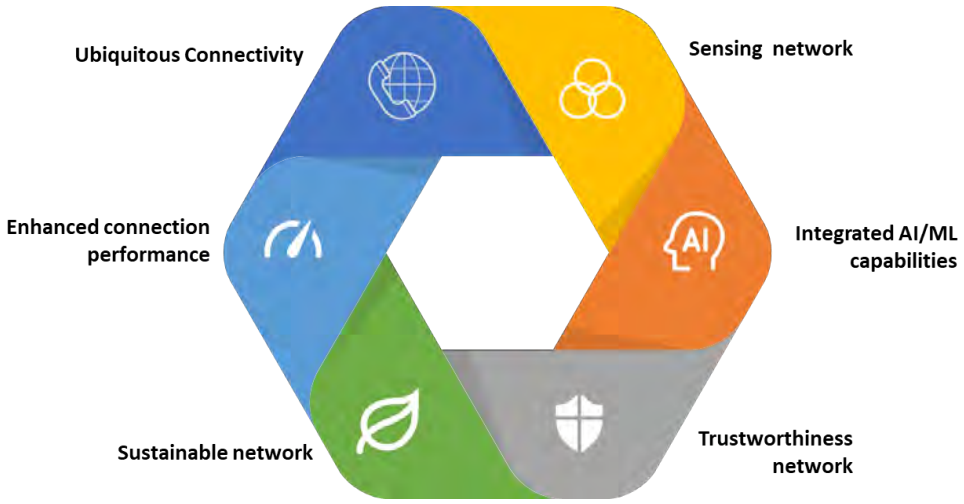
Radio access network: 6G technology is set to push forward the telecommunications industry by utilizing new frequencies, new materials, new technologies, and new architectures. Additional sub-terahertz frequencies open new opportunities for ultra-fast connections and ultra-precise sensing at the same time. To support such high bands, new radio and antenna technologies will be developed and the use of new materials and advancements in semiconductor technology are also essential for enabling THz communication. AI-enabled and sensing-assisted air interfaces, on the other hand, will bring agility and flexibility to the network, improving spectrum and energy efficiency, security, and adaptability to diverse use cases. In addition, seamless integration of terrestrial and non-terrestrial networks in a single network is under study for ubiquitous connectivity.

Terminals: The advent of 6G technology is expected to transform the capabilities and performance of mobile devices. The evolution of 6G devices is likely to be driven by a combination of advanced hardware capabilities, novel sensors and interfaces, and powerful AI and machine learning algorithms. With higher capacity and speed, 6G technology will enable new applications and services that are currently beyond the realm of possibility on current networks. These advancements will include a range of new capabilities such as advanced sensors, holographic displays, multimodal human-machine interaction, energy harvesting, and artificial intelligence, ushering in a new era of enhanced experiences and new scenarios.

4. 6G technology central capabilities

6G technology promises to be an evolutionary leap beyond 5G, with capabilities that will transform industries and change the way we interact with technology. 6G is envisioned with the following capabilities to achieve sustainable development goals.

6G technology key capabilities



Source: IDATE, *From 5G to 6G: How can Europe stay ahead in the 6G race?*

4.1. Sustainable network

As we move towards 6G technology, network sustainability has become a top priority. To achieve this, 6G networks must deliver higher network capacities while reducing energy consumption and minimizing environmental impact.

To improve the energy efficiency of 6G networks, a holistic design approach is being taken that encompasses various aspects of the network, including the air-interface design, network architecture, internet protocol, and other elements. According to a study, 6G will require a network energy efficiency improvement of ten-fold over 5G and a hundred-fold increase over 4G.[25] For example, the air interface of 6G network is expected to use advanced antenna technologies, such as large-scale MIMO (Multiple-Input Multiple-Output) and beamforming, and centralized RAN architecture to reduce energy consumption and improve resource efficiency. 6G networks could optimize energy consumption of IoT and M2M by utilizing scheduling and resource allocation algorithms and energy-efficient protocols.

Additionally, 6G networks are expected to minimize their environmental impact through a variety of strategies, including the use of renewable energy, energy harvesting technology and the reduction of environmental footprint of billions of devices. The use of renewable energy sources, such as wind, solar, and hydropower, will reduce the reliance on non-renewable energy sources, which have a significant environmental impact. In addition,

[25] Vision and research directions of 6G technologies and applications

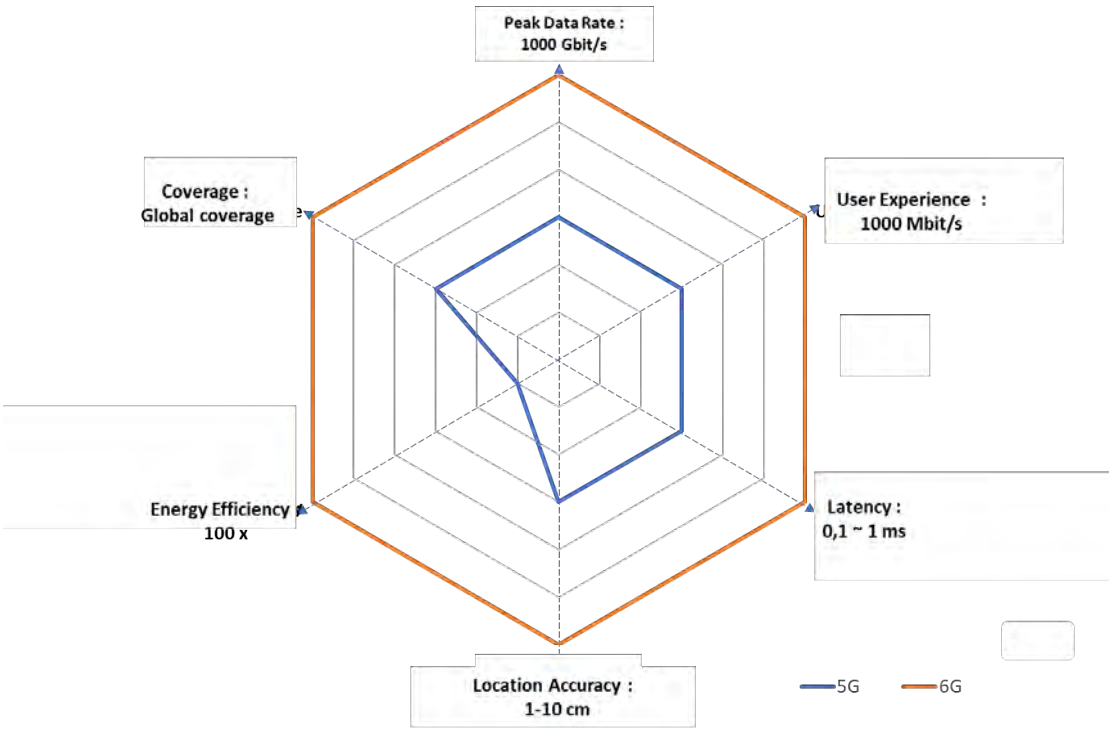
harvesting technology is a promising new technology that could be incorporated into 6G networks, which could capture energy from the environment and convert it into usable energy for IoT devices and sensors, thereby reducing the need for frequent battery replacements and reducing waste. Moreover, other approaches such as infrastructure sharing, extending equipment life through modularity and upgradability, and improving material use and recycling efficiency will help to reduce the waste and promote a more circular economy.

4.2. Enhanced connection performance

6G is expected to delivery faster data rates, lower latency, greater reliability and expand the scope of capabilities to support new and innovative applications across sectors, making it a key driver of innovation and economic growth. Telecom equipment manufacturers widely believe that 6G will achieve terabits peak rate, sub-millisecond level latency, a tenfold increase in the density of 5G connections, centimeter-level localization, millimeter-level imaging. Unlike its predecessor, 5G, 6G is expected to push the boundaries of performance even further. It will deliver faster data rates, lower latency, and greater reliability to extend the capabilities of 5G applications.

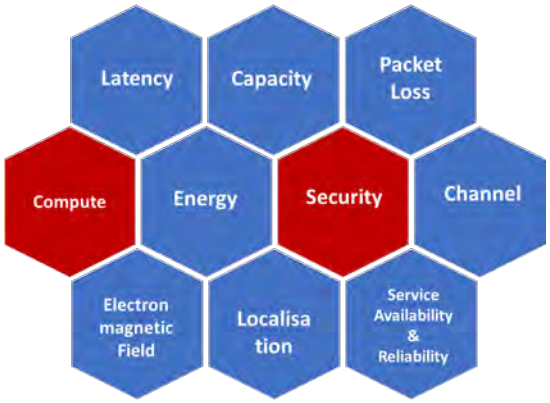
6G will also enable immersive communication experiences through location and context-aware digital services and sensory experiences. The introduction of new network capabilities, such as 3D localization, sensing, and AI/compute, will also introduce new indicators to evaluate, such as localization and sensing accuracy, as well as computing and security related metrics. Notably, vertical coverage range indicators could be added to further improve network capabilities. Furthermore, 6G is designed to be a more sustainable network, with energy efficiency and other sustainable performance indicators being key metrics.

Comparison of key performance aspects between 5G and 6G



In June 2022, the 5G PPP published the "Beyond 5G/6G KPIs and Target Values" white paper, which presented 10 clusters of KPIs provided by the ICT-52 projects and outlined the European Union's vision for 6G wireless communication systems. The white paper included newly added KPI clusters for security and compute, which are expected to be critical in the early stages of 6G development based on anticipated features and use cases.

6G 10 KPI clusters



Source: IDATE organized based on “Beyond 5G/6G KPIs and Target Values”

4.3. Ubiquitous connectivity

6G technology is poised to transform communication, enabling a wide range of communication types, including device-to-device, machine-to-machine, and human-to-human communication, and seamlessly integrating different forms of communication into a unified system. This interconnected and intelligent world will allow users to communicate and share information more efficiently, facilitating collaboration. 6G will connect trillions of electronic and mobile devices, such as sensors, actuators, smart phones, and RFIDs, providing full wireless coverage and integrating all functionality required for IoT connectivity and service delivery, such as sensing, transmission, computation, cognition, and automated control. Furthermore, users can benefit from IoT data acquired from ubiquitous mobile devices to interact with their environment and objects in a more immersive and natural way.

Moreover, 6G's advanced 3D communication infrastructure integrates all types of terrestrial networks and NTNs, including satellites, drones, UAVs, and HAPS, providing global coverage across space, ground, air, and sea. This integration will provide users with the ultimate experience by allowing them to select the optimal access point at any given time, while also enabling unified billing. The technology's super-flexible network, with configurable radios and support for almost deterministic services, makes it ideal for cost-effective deployment in rural areas or disaster situations. This ensures that users receive seamless and reliable services quickly, even in challenging environments.

4.4. Sensing network

Integrating sensor capabilities into 6G network infrastructure can enhance communication through features such as high-accuracy localization, imaging, and environment reconstruction. It can also enable a deeper understanding of the physical world through capabilities such as simultaneous imaging, mapping, and high-accuracy localization, as well as gesture and motion recognition.

The integration of sensing capabilities into 6G has several benefits. Compared to dedicated sensing and communication systems, 6G sensing will significantly reduce costs by

eliminating the need for additional standalone equipment and associated infrastructure, while more efficiently using spectrum and energy to improve sensing. Leveraging the extensive network of base stations and user devices, 6G sensing will also be able to enhance sensing accuracy and quality, facilitating faster and more precise decision-making during data analysis. Moreover, 6G sensing unlocks new applications and services, such as highly accurate positioning, localization and tracking, biomedical and security imaging, as well as gesture and activity recognition.

The use of THz frequencies is one of the main features of 6G sensing, offering a broader range of applications across various sectors. 6G sensing utilizes THz frequencies to enable high-accuracy localization and positioning capabilities compared to 5G, which has limited location and positioning capabilities. THz frequencies also provide higher-resolution imaging capabilities than microwave and millimeter-wave frequencies because of their shorter wavelengths, which enable capturing finer details and deeper penetration into certain materials. These capabilities make THz frequencies ideal for biomedical imaging applications, as they can penetrate through certain biological tissues to create high-resolution images. Moreover, THz waves can penetrate non-conducting materials like plastic, clothing, and paper without causing any damage, making them suitable for detecting hidden defects or damages in structures and for detecting hidden objects in security screening applications. In summary, THz frequencies in 6G sensing offer a range of benefits for various applications.

By combining 6G sensing with AI/ML, the 6G network can become more agile and intelligent, providing new insights from the physical world. This powerful combination has the potential to revolutionize various industries, increasing productivity and efficiency. In the transportation sector, the 6G sensing network can accurately detect road conditions and traffic patterns, providing real-time data to create a 3D road pattern. This data can be used by self-driving vehicles to make real-time decisions, leading to smoother traffic flow, fewer accidents, and reduced travel time. Additionally, the healthcare sector can benefit from the combination of 6G sensing and AI. The technology enables remote medicine to the next level by allowing healthcare providers to perform real-time remote scanning. With 6G sensing, medical images can be captured and transmitted for AI analysis, providing automated diagnoses, and identifying treatment options based on a patient's medical history and other relevant factors.

4.5. Integrated AI/MI capabilities

In the 6G network, artificial intelligence will be an integral part of the communication systems. AI/ML will be the foundational technologies in 6G, creating an AI-native, comprehensive, and end-to-end network that enables intelligent decision-making at every level, supports various advanced applications such as autonomous systems and smart city infrastructure, and improves overall performance and user experience with greater adaptability, resilience, and security.

As 6G networks become more capable and support increasingly diverse services, the network's complexity will inevitably increase, making manual or human-operated management impossible. As a result, Incorporating AI/ML technologies in 6G air interface and network designs is expected be required to manage communication systems with zero-touch. This will involve using machine learning algorithms and other AI techniques for network planning, automating network and resources management, analysis, detecting anomalies and security threats, and optimizing network resource allocation.

On the other hand, all components of 6G networks are expected to incorporate AI capabilities to facilitate AI applications and enable the delivery of cloud-based AI services, including machine learning, natural language processing, computer vision, and predictive

analytics. The integration of AI will play a crucial role in supporting emerging applications such as autonomous vehicles, smart cities, and augmented/virtual reality that require highly reliable network connectivity and advanced AI capabilities to handle the large volumes of data and complex calculations.

4.6. Trustworthiness network

As telecommunications infrastructure increasingly underpins modern society, it is essential to ensure that it is secure, private, resilient, safe, reliable, and accessible. 6G will incorporate native trustworthiness as a foundational aspect of its architecture. Security, privacy, and resilience are the major objectives of 6G network design. The widespread use of AI is essential to achieving these objectives by developing and deploying multiple solutions. In addition, other enabling technologies such as physical layer security, blockchain technology, quantum key distribution, and more also play a critical role in ensuring the trustworthiness of 6G networks and applications. These technologies provide secure and transparent data management, protect against potential threats, and promote privacy and transparency.

Advanced security measures are critical in protecting the confidentiality, integrity, and availability of 6G networks from cyber threats. These measures encompass advanced authentication and authorization protocols, like blockchain-based identity management solutions, and advanced encryption algorithms and protocols. Additionally, AI-based threat detection and response solutions will be used to identify and mitigate potential security breaches, and AI-based security solutions will provide an extra layer of protection against attacks. By combining these measures, 6G networks will have robust security protocols to safeguard against cyber threats, ensuring a trustworthy and reliable communication network.

Privacy in 6G is essential to safeguarding user data and personal information from unauthorized access and usage. Several advanced technologies could be employed, such as multi-party computation, federated learning, twin synthesis, homomorphic encryption, and edge profiling. Multi-party computation enables secure computation among multiple parties, while federated learning enables data analysis without centralizing the data. Twin synthesis creates synthetic data that can be used for testing and analysis while preserving privacy. Homomorphic encryption allows computation on encrypted data without decrypting it, while edge profiling enables the collection and analysis of data at the edge of the network, reducing the need for data to be transmitted over the network. By leveraging these technologies, 6G networks will have strong privacy protections for users' sensitive information.

Resilience in 6G networks refers to the ability to maintain network availability and service operations in the face of faults and challenges, including natural disasters, cyber-attacks, and other factors. AI can play a crucial role in ensuring 6G network resilience by using AI-based predictive analytics and monitoring tools to detect and address potential network disruptions. Additionally, AI-based dynamic network management can optimize network resource allocation and automatically detect and respond to network disruptions in real-time. By leveraging AI in these ways, 6G networks can achieve greater resilience and ensure reliable communication even in the face of unexpected events.

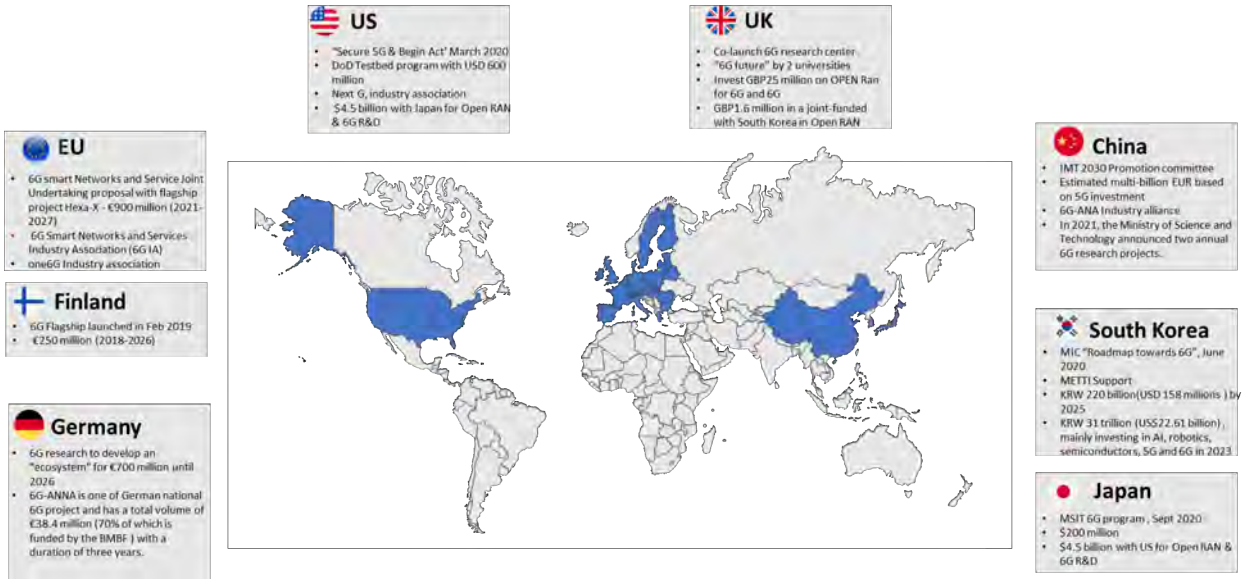
5. How to foster Europe's technological sovereignty in 6G?

5.1. Global initiatives on 6G research

5G is revolving today's vertical industries. It is envisioned that 6G will be the foundation to a new AI based society. Many countries and industries players have already established 6G research programs, looking to build 6G leadership and realize digital sovereignty.

Early 5G frontrunners in Asia, such as South Korea, Japan and China, are intensely developing 6G on the side. In Europe, Germany is one of the countries that has been actively investing in 6G research and development. In fact, the German Federal Ministry of Education and Research (BMBF) has already allocated around 700 million euros for its "6G flagship" research program, which aims to establish Germany's leadership in 6G technology. Moreover, various German companies and organizations such as Bosch, Siemens, and Fraunhofer Institute have also initiated their own 6G research programs to stay ahead in the race towards 6G technology.

Global 6G initiatives[26]



Source: IDATE, *From 5G to 6G: How can Europe stay ahead in the 6G race?*

The European Union provides strong financial support for research and innovation to ensure it maintains/gains its leadership position in 6G

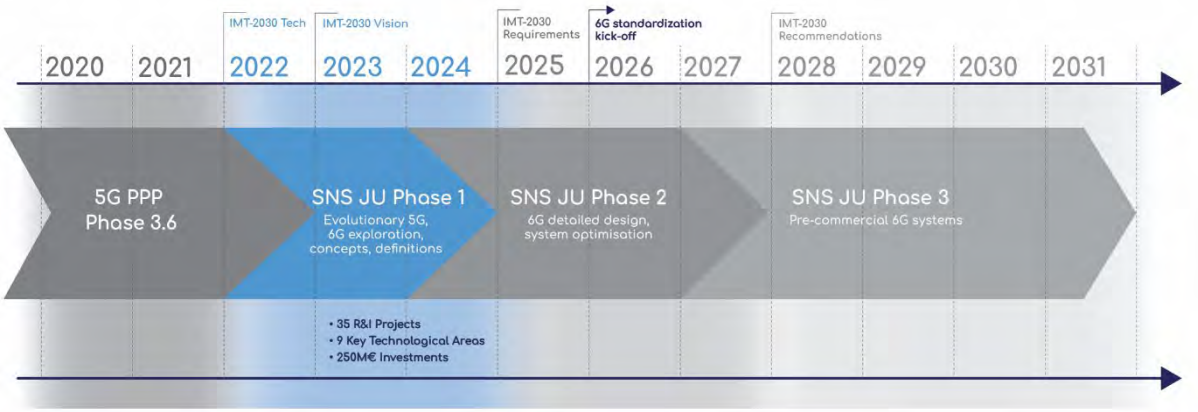
As a part of EU's research and innovation funding program Horizon 2020 (2014-2020), 5G PPP, has been set up and allocated 700 million EUR for mobile technologies research activities. Under 5G PPP initiative, a first set of eight 6G projects worth 60 million EUR have been launched, including Hexa-X and REINDEER projects.

The EU Commission also contribute to Europe Smart Networked and Services Join Undertaking (SNS JU) 900 million EUR to support beyond 5G/ 6G related research and innovation activities through Horizon Europe. In the first phase of the program, the SNS JU has selected its initial portfolio of 35 research, innovation, and trial projects. These projects aim to facilitate the evolution of 5G ecosystems and promote 6G research in

[26] IDATE, From 5G to 6G : How can Europe front run in 6G race?

Europe. The portfolio is supported by approximately 250 million EUR under the Horizon Europe framework.

OVERVIEW OF SNS PHASE 1



Source : 6G SNS , OVERVIEW OF SNS

The NGMN Alliance, founded in 2016, is another essential German-based organization backed by international telecom operators. It has also included 6G as part its latest version. It will support global 6G standards alignment.

Additionally, the EU has considerable influence in setting global mobile standards. ETSI plays a major role in developing a wide range of global applicable standards, notably include fixed, mobile, radio, converged, broadcast, and internet technologies. France-based 3GPP has played a pivotal role to create a global 5G standard.

US tech industry work together to build regional alliance to foster its 6G leadership.

The US based 'Next G Alliance' is one of major North America 6G research group, founded in October 2020 by ATIS, a US based standard development organization for IC. The group is made with a number of telecom operator (ie. AT&T, Bell), leading telecom equipment and device vendors (i.e.. Qualcomm, Ericsson and Samsung), as well as tech giants (ie. Google, Apple). It has presented its 6G vision to build North American 6G leadership over the next decade through private-sector-led effort.

Meanwhile, US and Japan governments have announced to invest a total of 4.5 billon US dollars in research and development of secure networks and 5G Open RAN and 6G networks. The two governments will cooperate in research, development, testing and development of secure networks and advanced information and communications technology.

Chinese government together with its domestic industry players take technological advantage in 5G to move forward on 6G Research.

In June 2019, China Minister of Industry and Information Technology (MIIT) has created a 6G research and development working group -the IMT-2030 (6G) Promotion Group- to promote 6G technology research and build an international view exchange platform. Whitepapers and technical reports on overall 6G vision and technology trends have been published from the group.

China began its 6G research in June 2019 with the establishment of the China IMT-2030 (6G) Promotion Group. This group, led by the Ministry of Industry and Information Technology, marked the official start of China's dedicated efforts in 6G research and development[27] . .

In January 2022, China state -funding Purple Mountain Laboratory has achieved the first time THz wireless transmission a with a speed of 103.125Gbps for a single wavelength and 206.25Gbps for a dual wavelength, increasing 10 times to 20 times compared to 5G.

Compared to the current 5G capacity, 6G will offer greater bandwidth, lower latency, and wider connectivity, enabling support of new application scenarios and transforming the wireless and wired network architecture. In the past few years, European organizations have worked together with various international organizations to establish 3G, 4G, and 5G standards. The development of 6G standard will require closer international cooperation to facilitate the mutual exploration of new fields.

Major nations, like US, China and EU countries, have started their 6G development and are looking to form 6G partnerships with any other country to accelerate the 6G races. For instance, both the US government and ATIS's Next G alliance industry association are actively pursuing 6G partnerships with other leading countries to accelerate as well as coordinate technological developments.

The EU aims to become a technologically advanced and achieve carbon-neutral economy by 2050. EU considers 5G and future 6G to be a key enabler of achieving the Digital Decade goals. Therefore, the EU need to promote the 6G cooperation with international partners to build synergies to European leadership in next-generation telecommunications. In the past, EU has built partnerships with telecom leading countries, such as China, Japan and South Korea on 5G research. It is natural to extent the collaborations on 6G research and development.

In 2015, China and the EU signed a major 5G partnership agreement, which commits to reciprocity and openness in terms of access to 5G networks research funding, market access, and membership in 5G associations. As part of the agreement, the two parties worked together on research initiatives, international standardization, and spectrum requirements, especially in IoT. The cooperation between European and Chinese on 6G research shall continue the momentum of work to accelerate innovation and create economic, social, and environmental gains bilaterally.

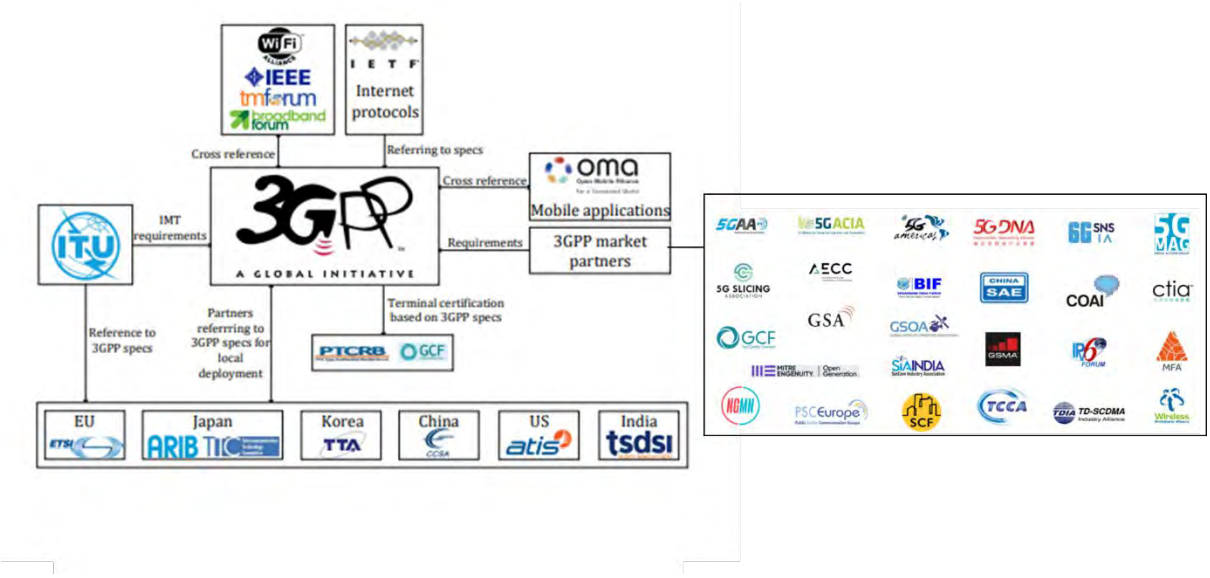
5.2. What are the 6G standardization bodies?

From 5G onwards, the standardization of wireless networks has become a global and collective effort of several standardization bodies, collaboratively and complementary working towards the same target. 5G standardization is led by ITU and 3GPP, with support from the major standardization bodies worldwide. The 6G standardization process will follow the same path[28].

[27] http://www.news.cn/tech/20230330/8542fe65cc5a4b428d6b55c283bd5398/c.html

[28] ITU Journal on Future and Evolving Technologies, Why do we need 6G?

Structure of the standardization effort of 5G[29]



Source: IDATE, From 5G to 6G: How can Europe stay ahead in the 6G race?

International Telecommunication Union (ITU) was founded by the United Nations (UN) in 1865. With the goal of "connecting all the world's people". It is responsible to facilitate internet connectivity, allocate global radio spectrum and satellite orbits, develop the technical standards.

The ITU has currently 193 member states and around 900 business, academic institutions, and international and regional organizations.

ITU work mainly on three areas, including Radiocommunication (ITU-R), standard (ITU-T) and Telecommunication development (ITU-D). ITU-R define the vision and roadmap of each generation mobile technologies development, including 3G, 4G, 5G and future generations of wireless mobile telecommunications technology. "International Mobile Telecommunications" IMT-2030 is a name of 6G systems defined by ITU. Since Mach 2021, The ITU-R's Working Party 5D (WP 5D) commenced its work on the recommendation "IMT Vision for 2030 and beyond" to be available in June 2023.

3GPP

After the ITU define the framework and Vision of future development for IMT 2030+, many standardization bodies, like 3GPP, will then define and develop technical specifications for the next generation of IMT.

3GPP (The 3rd Generation Partnership Project (3GPP) was originally founded in 1998 and involves several telecommunications standard development organization (ARIB, ATIS, CCSI, ETSI, TSDSI, TTA and TTC) from Asia, Europe and North America. 3GPP has worked on a set of standards, covering all GSM, W-CDMA, LTE and 5G specifications. It has become the primary standardization body that define the development of 5G specifications at global since 2016.

It is expected that 3GPP's 6G standardization work will likely start from 2025, and the first 6G specification in 3GPP published in Release 20 around 2026.

[29] Computing in Communication Networks - From Theory to Practice

5.3. The risk of 6G standard fragmentation

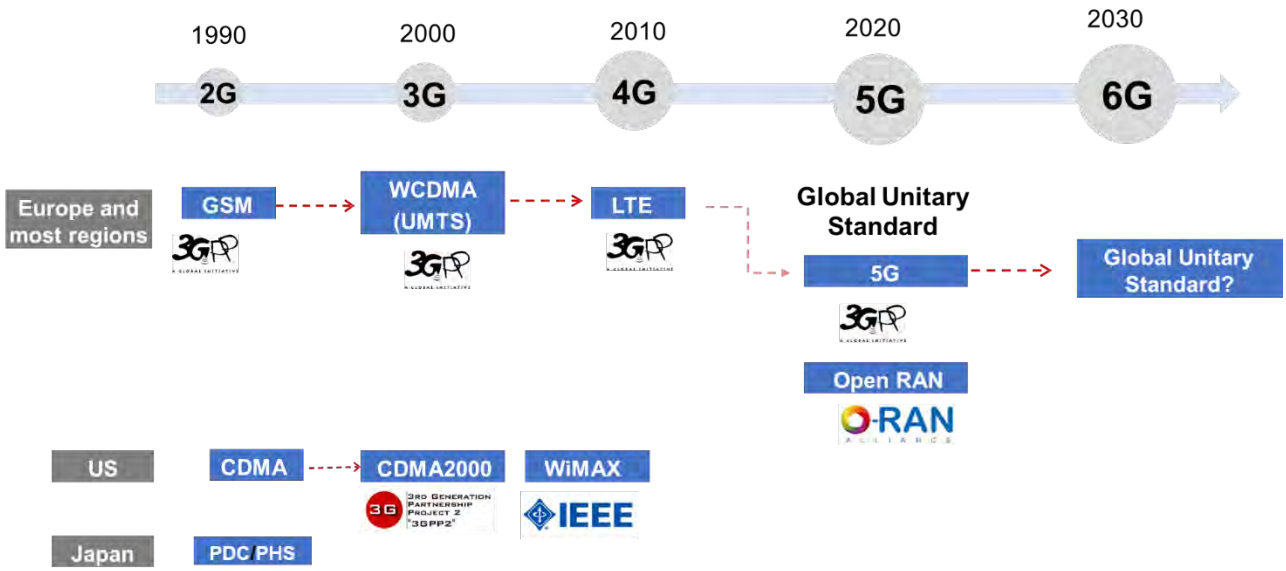
Given the emergence of various world mega region trying to push and develop the new 6G standard.-there is an obvious risk of fragmentation. This fragmentation would lead to several non-compatible 6G standards, a situation that preexist back in the time from 2G to 4G.

Previous generation of mobile technologies were based divergence standards. For instance, 2G standards were fragmented between GSM and CDMA. While GSM was universally adopted in Europe and Asia, while CDMA were the main system in North America. Japan's 2G network was based another technology - Personal Digital Cellular (PDC). In addition, 2G spectrum allocation were inconsistent between US and Europe.

For 3G systems, the technologies were spitted between UMTS, TDS-CDMA and CDMA2000. Among them, 3GPP defined UMTS and TDS-CDMA standards, while CDMA2000 was developed by another organization 3GPP2 (3rd Generation Partnership Project 2.

Regarding 4G technology, there exist also several standards: WiMAX based on IEEE standards and LTE standardized by 3GPP, are two competing technologies. LTE is still the dominant mobile technologies deployed in most of countries worldwide.

Evolution from 2G to 6G



Source : IDATE, From 5G to 6G: How can Europe stay ahead in the 6G race?

Divergent mobile standards increase the complexity of global mobile market. The increasing risk of bifurcation, fragmentation, or decoupling from international standards poses a challenge. Such an outcome would be detrimental to all market participants as it leads to a lack of interoperability, increased system complexity, slower innovation, and higher market barriers. :, thereby diminishing the efficiencies achieved over the past decades.

Lack of interoperability : Fragmentation can lead to a lack of interoperability between different 6G networks. This means that devices, equipment, and services from one network may not be compatible or easily usable in another network. It can result in delays and

increased costs for deployment, repairs, and updates, as well as hinder seamless international roaming for consumers and businesses.

Increased system complexity: Fragmentation can raise the complexity of equipment and devices due to the need to support multiple standards or protocols. Telecom vendors may have to produce different versions of their products for different regions. Additionally, complex designs may be required to support multiple bands and protocols, further increasing costs and complicating device development.

Slower innovation: Fragmentation can divide resources, expertise, and research efforts across different standards, leading to slower innovation and advancements in 6G technology. In addition, fragmentation can result in certain regions or users being excluded from accessing the latest innovations and advancements in 6G technology, , limiting the widespread adoption and potential benefits of 6G.

Market Barriers: Fragmentation can create barriers to entry in the market, as different standards and regulations may make it difficult for new players to compete. It can potentially lead to a dominant vendor or a small group of vendors dominating the market, reducing competition, and limiting consumer choices.Clearly, a unified global wide 6G standard pave the way to enable global truly comprehensive connectivity and benefits through economy scale, while avoid various issues, such as lack of interoperability and limited global roaming. Currently, studies on 6G networks are at the infancy stage. Fragment 6G R&D may leading to the fragmentation of 6G standards and affecting 6G evolution progress.

5.4. Cost of fragmented 6G system in 2030

The development of new 6G technology necessitates standardization across multiple network technologies, operators, sensor providers, and verticals. With the increasing complexity and diversity of these elements, standardization becomes crucial for achieving interoperability and seamless integration.

A highly complex system like 6G cannot be built by one country alone. A fragmented 6G connectivity landscape can pose significant challenges to the commercial deployment speed of new technologies and hinder the widespread adoption of new use cases and customers adoption rate. The costs of associated with fragmentation standardization are significant, mainly from higher system equipment costs, deployment cost and Business value of 6G uses cases :

Products design costs: Fragmentation in 6G standards can increase the costs associated with product design and development. Telecom equipment vendors may need to create different versions or variations of their devices to support multiple standards and protocols. This require additional research, engineering, and testing efforts, leading to higher design costs.

Deployment costs: Fragmentation in 6G standards can impact the deployment costs of networks. Operators may face additional expenses due to the need to customize and adapt their infrastructure to different standards in various regions. Acquiring spectrum licenses, building network infrastructure, and ensuring interoperability across fragmented networks can require more resources and investments compared to deploying a unified 6G standard.

Economic scale of use cases: Fragmented 6G standards can hinder the business value of new use cases. The development and adoption of innovative applications and services may face challenges in terms of compatibility and market reach. Different standards may limit the interoperability and scalability of use cases across different regions, reducing the potential market size and economic scale. This can impact the revenue generation and growth potential for businesses and limit the overall business value that can be derived from 6G technologies.

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5.5. Towards a global united, open and inclusive approach for 6G Research

As commercial 6G deployments is widely expected to take place as early as 2030, the initial standardization of 6G is likely to begin around 2025. Currently, we are still in the very fundamental research stage to develop a unified perspective for 6G, far from beginning to invest in detailed technical and security issues. The 6G supply chain concerns are neither the central topic at this stage.

As mentioned, previous, major leading countries has begun to collaborate on 6G research work. The best window of opportunity for international R&D cooperation, as suggested by the EU SNS, should be between 2023 and 2026, before the initiation of Release 21, in order to jointly develop and explore the next generation of mobile technology.

Compared to 5G, 6G's technological environment is more complex, since it relays on advanced technologies like cloud computing, artificial intelligence, blockchain, and big data. The development of global breakthrough technologies, like 6G, always requires international collaboration to exchange ideas and results in basic research, hardware designs and its environmental impacts. As many countries and global industry leaders have begun to work on 6G research, building an inclusive, open and global research and development environment will leveraging R&D from all world-class players to foster 6G development.

Historically, the European Union strength is its research and innovation capability. EU industry players are well positioned in 5G ecosystem. EU has proven research and innovation experience since 2G. EU suppliers holds around 50% of global market share as well as about 50% of the intellectual property right. In terms of 6G research, Europe has launched the first large-scale 6G Research and Innovation Program in 2021. The EU has published its first 6G call for proposals under the EU Horizon Europe research, science, and innovation instrument 2021-2027.

To reinforce Europe's leadership position, building an inclusive, open and global environments in research and development will boost and unlock 6G innovations, as well as promoting the development of vibrant innovation ecosystems.

- 6G is expected to not only revolutionize vertical industries, but also benefit a much larger population through its ubiquitous wireless connectivity.
  Future 6G architectures will foster digital inclusion and accessibility. Therefore, 6G related research should be based on an **inclusive approach to involve all set of shareholders**. The inclusion of a variety of shareholders is an essential to cope with certain divergence between different markets and different regions. It is crucial that 6G addresses effectively pressing societal needs through important uses cases,
- 6G is driven by a diverse portfolio of applications and technologies which are fundamental for the new generation of mobile technology. Several open research problems have been brought on 6G research agenda from hardware to system design, including effective mobility management for mmWave and THz systems,

optimal deployment and location of large intelligent surfaces and etc. An **open** research approach can facilitate collaborative research on a global scale and accelerate discovery and innovation based on prior knowledge to rapidly bring new technologies to market, while avoid overlap as well as reducing costs and technical barriers.

- A global 6G research approach will bring the global scientists and experts to create a world-class competence pool. Historically, the success development of 5G standard involved the participation of global players from Asia, Europe and North America. Europe plays a pivot role to facilitate the international exchange and collaboration to accelerate 6G research progress.

Moreover, R&D funded projects are not always limited to local players. Various initiatives launched by either US, European or Asian authorities may be open to non-local players. For example, Chinese IMT-30 program is open to international companies. Based on the interview we performed, there is a concern among the private companies concerning a restricted access to these funds. European companies can today beneficiate of Chinese or US funding for their R&D efforts. If some public authorities were about to decide to exclude nonlocal players, one may expect that other world regions would behave in a similar way. In concrete terms, for European players, that would mean a restricted access to public R&D funding and a lower access to innovation process outside of Europe.

Today, 6G related research activities have been started globally by governments and industries leaders. In the early phase of 6G research, global R&D should work together to reach a common consensus on the basic concept of 6G and overcome major technical hurdles.EU has a unique advantage to create a global expert tool under an inclusive, open and global dynamic to reinforce its leadership in R&D capabilities and create a vibrant innovation ecosystem.

6. Conclusion: challenge from 5G to 6G

The ongoing global deployment of 5G has not deterred some markets from beginning research and development efforts for 6G, which is anticipated to be commercially available by 2030. A global unified 6G standard will enable truly global connectivity and generate significant socio-economic benefits. It will also prevent a fragmented 6G hardware ecosystem, which could raise barriers to collaboration among international industry players in innovative 6G use cases.

To ensure a global unified 6G standard, a united, open, and inclusive research and development approach is a prerequisite. Europe, with its powerful institutions and world-class Telecom companies, remains the largest research and development hub for mobile technology innovation. The EU should, therefore, open up its 6G research and development strategy to bring together the best global innovation available and maintain its leadership position in 6G.

The current landscape presents a window of opportunity for the EU to shape 6G technologies and spearhead the establishment of a unified global standard. Collaboration lies at the core of the SNS JU's approach, aiming to involve a broad industry base right from the start. SNS JU is considering International Cooperation projects on 6G Research and Innovation with the USA in 2023, with Japan, and South Korea in 2024.

However, it is important to note that multilateral cooperation has always be a key to innovation is our sector. We have observed the significant efforts made by Chinese players in the international cooperation to develop global 6G standards. Based on our interviews with various European actors of this industry, we have noted that the support of all of telecom leading players is needed to develop new mobile technology standards. When it comes to mobile technology cooperation, there seem to be a contradiction between what the European telecom industry is expecting and the political debate. The key question is how to integrate Chinese companies' contribution and innovation while securing European sovereignty issues and leadership position. In any case, Chinese companies' contributions, and role within the 6G community should not be underestimated or disregarded.

By promoting a collaborative approach to 6G development, the EU can encourage the emergence of a global standard that will foster connectivity, innovation, and socio-economic benefits. The EU can leverage its expertise and leadership to contribute to the development of 6G and ensure that it is an inclusive and collaborative effort that benefits all stakeholders. A global unified 6G standard will be crucial to achieving the full potential of this emerging technology, which will have significant implications for numerous industries and society as a whole.

In addtion, the development of 6G needs to take into consideration the impact of various factors, such as OPEN RAN and the allocation of the 6G spectrum bands.

Open RAN intends to break traditional closed and proprietary RAN architecture by using virtualization and cloudification. The New concept aims to eliminate vendor lock-in, disaggregate hardware and software, and create open interfaces between them.

However, open RAN challenges must be also taken into consideration, since this immature technical concept brings additional complexity, increases attack the interfaces and leaves loopholes in cooperation. Various studies showed the immaturity risk and cybersecurity challenges of Open RAN.

Additionally, multi-vendor integration which requires to ensure that different vendors' software and hardware equipment is compatible with each other, as well as coordinate the

responsibilities of multiple vendors and cooperate on software roadmaps, remains one of the key challenges to overcome to fulfil the expectations of Open RAN technology.

Furthermore, it is still questionable whether interconnecting components from multiple vendors with different designs can lead to better performance, lower power consumption, and lower OPEX compared to traditional RAN architecture., There is no clear evidence that Open RAN can deliver a better energy efficiency. The EU prioritizes 5G as a critical digital infrastructure to support the sustainable development. Is the adoption of Open RAN an effective way to realize EU's sustainable development goals?

Last but not the least, Open RAN does not mean everything Open. In fact, chip supply and cloud adoption are not really based on open models, potentially leading to new dependencies risk. Without EU leading players in Open RAN ecosystem, EU companies' long-term advantage eroded. The EU prioritizes 5G as a critical digital infrastructure to support the sustainable development. Does Open RAN have the chance to overcome these challenges?

The scarcity and value of the spectrum have led mobile and Wi-Fi service providers to seek additional spectrum, particularly the 6 GHz mid-band frequency. This frequency offers significant value to each provider's market and the economy.

For mobile operators, the 6 GHz frequency is crucial in balancing network coverage and capacity, making it ideal for citywide 5G deployment to meet the growing data traffic demand from 2025 to 2030. Licensing 6 GHz for use not only contributes to socio-economic goals but also ensures the effective extension of 5G to 6G. Failure to integrate 6G into IMT could hinder the delivery of the full potential of 5G and affect the development of 6G.

Therefore, the discussion of 6 GHz mid-band spectrum uses at WCR-23 is of utmost importance. It requires international collaboration and support to make informed decisions on the future identification of Upper 6 GHz for IMT. Maximizing the efficient use of the 6 GHz spectrum is critical to meeting the growing demand for mobile and wireless communication services and promoting the development of new technologies as well as related ecosystem.

Annexes

Regulators' documents associated with Open RAN's potential risks

Document	Organization	Published Date	Comments
5G supply market trends	European commission	Aug 2021	"European equipment providers are facing challenges to sustain their viability" "Respondents expect Open RAN not to be mature enough to be deployed widely until 3-4 years from today. And at first, Open RAN deployments will not deliver the same efficiency as traditional solutions in terms of features and power consumption."
"Open RAN Risk Analysis	Germany BSI (the Federal Office for Information Security)	Feb 2022	
An overview of the BEREC work on the Open Radio Access Network	Body of European Regulators for Electronic Communications	Mar 2022	The implementation of Open RAN in its different aspects will take some time due to the lack of maturity;" "The impact that Open RAN will have on CAPEX and OPEX is not yet clear
Report on the cybersecurity of Open RAN	NIC Cooperation Group	May 2022	Overall, the NIS Cooperation Group concludes that Open RAN will have a significant impact on a number of risks that were already identified in the EU Coordinated risk assessment of 5G networks published in October 2019. In addition, it identifies several new risks and vulnerabilities introduced by Open RAN. If not adequately mitigated, those risks could have a particularly strong negative impact on the security of large-scale 5G deployments using Open RAN. the 9 risks already identified in the 2019 EU Coordinated risk assessment, with an estimation of the impact of Open RAN on this risk (amplified, similar, reduced) and its rationale. 7 New risk categories and new risks are indicated in the report
Second report on Member States' Progress in implementing the EU Toolbox on 5G Cybersecurity	NIC Cooperation Group	June 2023	8 key risks that are amplified or brought by Open RAN.

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