Trends and recommendations for 6G across key verticals sectors: Opportunities and paths ahead

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1. Background

The mobile telecommunications sector is a crucial driver of Europe's economic growth. In 2022, the Mobile Economy, encompassing both the mobile industry and its impact on other sectors, contributed 910 Billion euros to Europe's GDP, accounting for 4.3% of the total. By 2030, as 6G emerges and 5G matures, the Mobile Economy in Europe is projected to approach 1 Trillion Euros, with 5G alone generating 153 Billion euros through productivity gains in various vertical sectors.[1]

Building on 5GPPP's foundation, the Smart Networks and Services Joint Undertaking (SNS JU) Programme aims to promote vertical engagement activities fostering the role of 5G and 6G technologies among key industrial stakeholders. Such an attempt stems from a comprehensive look into larger economic trends, technological innovations and requirements, potential market uptake and adopters, and last but not least, use cases' specific needs. The final goal is to favour policymaking actions capable of grasping and encapsulating these key requirements, implementing practical actions and setting a future-proofed pro-investment environment.

The lessons learned from the 5G-PPP trials and pilots highlight three critical areas of development: service creation and deployment, network management and performance, and the innovative use of network slicing and function virtualisation. These areas encompass a range of capabilities, from supporting advanced services with diverse network requirements and orchestrating services across distributed cloud infrastructures to ensuring seamless cross-border connectivity and deploying secure, portable networks for emergency services. Moreover, the trials have underscored the potential of network slicing to provide tailored services and resources, enhancing the efficiency and flexibility of 5G infrastructures.

As the SNS JU programme enters its second year, Phase 1 projects have already developed use case applications spread across different vertical sectors, capitalising on the functionalities developed by 5G to produce innovations headed towards 6G. In order to lay the foundations for such an attempt, it is necessary to carry out a comprehensive analysis of these key vertical sectors, understanding their main trends and future challenges. This document summarises key findings of the SNS ICE consortium emerging from the analysis carried out in deliverables D3,2, "Initial Trends Analysis in Vertical Sectors – Rel. 1" and the co-creation event "5G for Verticals: From Large Scale Trials to Adoption, Driving Economic Value in Europe" convened as part of 5G Techritory, in Riga on October 19, 2023. These are complemented by a selection of key sources featured in the document's footnotes.

1 See SNS ICE deliverable "D3.2 Initial Trends Analysis in Vertical Sectors – Rel.1", January 2024. Available at https://smart-networks.europa.eu/wp-content/uploads/2024/02/d3.2-initial-trends-analysis-in-vertical-sectors_v1.0.pdf.

2. Key trends in vertical sectors

The integration of advanced digital technologies across various sectors is reshaping societal norms and driving significant economic growth and technological innovation. Each sector, from **public safety** to **healthcare** and **urban mobility** to **smart manufacturing**, **agriculture**, **media**, and **transportation**, is witnessing a paradigm shift towards more interconnected, intelligent systems. This transformation is largely fuelled by adopting technologies such as LTE, 5G, and the anticipated 6G, which promise to enhance operational capabilities, improve efficiency, and offer unprecedented connectivity and data analysis capabilities. An analysis of key technological, economic, and social trends is necessary to understand emerging challenges and orient effective policy agendas.

2.1 Technological trends and challenges

Vertical sectors face common, cross-sectoral technological challenges and trends that underscore the interconnected nature of modern industries. From manufacturing to healthcare, transportation to agriculture, and the integration of advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), and robotics are driving significant transformations. These changes promise enhanced efficiency, personalised experiences, and innovative solutions to longstanding problems. However, alongside these opportunities, industries are grappling with challenges, including interoperability, cybersecurity, and the need for skilled workforce adaptation. A non-exhaustive list of such challenges include:

- **Integration of AI, IoT, and Robotics**: The adoption of these technologies is becoming increasingly prevalent, offering the potential for automation and data-driven decision-making. However, this integration poses challenges in ensuring interoperability and seamless system integration across diverse technological platforms.
- **Cybersecurity and Data Privacy**: As sectors become more interconnected and reliant on digital technologies, the importance of securing networks and protecting sensitive data against cyber threats becomes paramount.
- **Skilled Workforce and Automation Balance**: The digital transformation demands a workforce skilled in new technologies while also necessitating strategies to balance automation with human labour, ensuring job creation and workforce upskilling.
- **Customisation and Customer Involvement**: A growing trend towards involving customers directly in the design and manufacturing processes, leading to more personalised products and services. This shift requires flexible and adaptable production systems and poses challenges in managing real-time data for supply chain and production optimisation.
- **Infrastructure and Network Requirements**: The deployment of IoT devices and the execution of AI algorithms require robust and reliable network infrastructure capable of handling large volumes of data with minimal latency.
- **Regulatory and Standardisation Issues**: Navigating the complex landscape of regulations and standards that vary by region and sector is a challenge for organisations aiming to deploy new technologies on a global scale.

2.2 Economic trends and challenges

In the face of rapid technological advancements, vertical sectors are also encountering a range of economic challenges that are as diverse as they are complex. These challenges not only affect the immediate financial health of organisations but also have long-term implications for global economic stability and growth. The economic landscape is being reshaped by factors such as investment requirements, market competition, and the evolving nature of consumer demand. These economic challenges underscore the need for industries to adopt flexible and resilient financial strategies, innovate their business models, and seek out new market opportunities to ensure sustainable growth in the digital era.

- **High Investment Costs**: The initial outlay for integrating advanced technologies such as AI, IoT, and 5G/6G networks into existing systems is substantial, posing a significant barrier to entry for many organisations.
- **ROI Uncertainty**: With the rapid pace of technological change, there is high uncertainty regarding the return on investment (ROI) for new tech implementations, making it difficult for businesses to justify the upfront costs.
- **Market Competition and Disruption**: Digital transformation is levelling the playing field, allowing start-ups and tech-savvy companies to disrupt established markets and challenge traditional industry leaders.
- **Consumer Demand Shifts**: As digital technologies evolve, so do consumer expectations and behaviours, requiring businesses to continuously adapt their offerings and business models to meet changing demands.
- **Supply Chain Volatility**: Global supply chains are facing increased volatility due to geopolitical tensions, trade disputes, and the impacts of climate change, affecting the cost and availability of materials and components.
- **Regulatory and Compliance Costs**: Navigating the complex web of regulations across different markets adds costs and complexities to business, especially for international companies.
- **Workforce Transition Costs**: The shift towards automation and digital technologies requires significant investment in workforce retraining, upskilling, and potential restructuring costs.

Policymakers should address 6G economic sustainability, encompassing pro-investment policies fostering application deployment and adoption by citizens and businesses.

2.3 Societal & environmental trends and challenges

As emerging technological applications reshape different vertical sectors, they are increasingly confronted with cross-sectoral societal and environmental challenges, reflecting the broader implications of technological advancements on society and the planet. These challenges underscore the importance of sustainable practices, ethical considerations, and the need for industries to contribute positively to societal well-being and environmental preservation. Addressing these societal and environmental challenges requires a concerted effort from all sectors to prioritise ethical considerations, invest in sustainable technologies, and engage in practices that promote social equity and environmental stewardship. By doing so, industries can ensure that digital transformation leads to positive outcomes for society and the planet, fostering a future where technological progress and sustainability go hand in hand.

- **Digital Divide and Inequality**: The uneven access to digital technologies exacerbates existing inequalities, leaving certain populations behind in the benefits of digital transformation.
- **Privacy and Data Security Concerns**: As data becomes a crucial asset, protecting individual privacy and ensuring data security have emerged as paramount societal concerns, requiring robust safeguards.
- **Impact on Employment**: Automation and AI are transforming the job market, displacing jobs, and creating the need for significant workforce transitions and reskilling efforts.
- **Ethical Use of Technology**: The ethical implications of technologies such as AI and biotech raise concerns about bias, autonomy, and the potential for misuse, necessitating ethical frameworks for development and use.
- **Environmental Degradation**: The environmental impact of digital infrastructure, from energy consumption of data centres to e-waste, poses significant challenges for sustainability.
- **Resource Depletion**: The demand for rare earth metals and other resources for technology manufacturing highlights the need for sustainable resource management and circular economy practices.
- **Climate Change**: The tech industry's carbon footprint and its role in climate change demand urgent action to reduce emissions and integrate climate resilience into planning and operations.

3. Policy recommendations

Based on the challenges described above and on the insights gathered in SNS ICE D3.2, the following sector-specific recommendations have emerged.

3.1 Public Safety

Invest in Advanced Network Infrastructure: Public safety policymaking actions should prioritise investments in advanced network infrastructure that can handle high traffic volumes and extreme conditions. This includes developing robust routing protocols and leveraging emerging technologies like edge computing and AI to enhance network efficiency and responsiveness. Improving network resilience and reliability can ensure seamless communication during critical situations such as natural disasters or high-demand scenarios.

Promote Interoperability Solutions: Collaboration between public safety agencies, technology providers, and network operators is essential to seamlessly integrate new communication standards with existing systems. Emphasising the development of interoperable solutions will facilitate smooth transitions and uninterrupted service delivery. This involves standardising protocols and fostering innovation to bridge the gap between legacy systems and emerging technologies, ultimately enhancing communication capabilities for first responders.

Enhance Real-Time Emergency Response Coordination: Investing in smart network integration can significantly improve real-time coordination and situational awareness during emergency responses. By leveraging video-based applications and systems, agencies can enhance decision-making processes and improve outcomes in critical situations. Emphasising the development of intuitive user interfaces and leveraging advancements in location-tracking technologies will further enhance the effectiveness of emergency response efforts.[2]

3.2 Healthcare

Regulatory Frameworks and Standards: Governments should establish clear regulatory frameworks and standards for the deployment and use of 5G and 6G technologies in healthcare. This includes ensuring compliance with data privacy regulations such as GDPR, implementing cybersecurity measures to safeguard sensitive medical data, ethical and transparent use of AI/ML algorithms in decision making and promoting interoperability among different healthcare systems and devices. By providing clear guidelines and standards, a conducive environment for the adoption of digital health technologies can be induced, and potential risks and challenges associated with their implementation can be mitigated.

Addressing Healthcare Disparities: Governments should prioritise addressing healthcare disparities and ensure equitable access to digital health technologies, especially for underserved and marginalised communities. This includes expanding network coverage to rural and remote areas, providing training and support for healthcare professionals in utilising advanced technologies, and implementing initiatives to bridge the digital divide among patient populations.

International Collaboration and Harmonization: Given the global nature of healthcare challenges and technological advancements, governments should prioritise international collaboration and harmonisation efforts in developing and deploying 5G and 6G technologies in healthcare. This includes collaborating with international partners to establish common standards and protocols, sharing best practices and lessons learned, and promoting cross-border data exchange and interoperability. Working together on common goals allows governments to maximise the benefits of digital health technologies and address shared healthcare challenges more effectively.[3]

2 For further information see Deloitte Whitepaper, Next Generation Mission Critical Networks, Global Telecom Engineering Excellence (gTEE), 2023. Available at https://www2.deloitte.com/content/dam/Deloitte/pt/Documents/technologymedia-telecommunications/TEE/gTEE-Whitepaper-Next-Generation-Mission-Critical-Networks.pdf.

3 See also 5GHealth Whitepaper, The Need for 5G Technologies in the Healthcare Domain, 2020. Available at https://5g-health.org/wp-content/uploads/2020/11/5G-Health-Whitepaper-V1.pdf; European Council, European Health Data Space: Council agrees its position, 2023. Available at https://www.consilium.europa.eu/en/press/press-releases/2023/12/06/european-health-data-spacecouncil-agrees-its-position/.

3.3 Automotive

Spectrum Allocation for Connected Vehicle Communications: To support advanced automotive V2N (Vehicle-to-Network) and V2V/I/P (Vehicle-to-Vehicle/Infrastructure/People) communications, additional spectrum allocation is critical. Collaborative efforts between regulatory bodies and mobile operators are necessary to secure at least 50 MHz of low-band and 500 MHz of mid-band spectrum. This allocation is vital for ensuring the affordability and scalability of connected vehicle services, especially in rural and urban environments where high-capacity, citywide services are required.

Development of Ubiquitous Connected and Automated Mobility Systems: Future connected and automated mobility systems should prioritise features like extreme network availability and reliability, predictable performance, harmonised Quality of Service (QoS), and enhanced privacy and security. To achieve this, industry stakeholders should collaborate on developing standardised frameworks and policies that ensure seamless interoperability and consistent performance across diverse environments. Additionally, technological enablers such as integrated sensing and communication, distributed onboard communication systems, and novel privacy mechanisms should be further researched and implemented to support the evolving needs of connected vehicles.

Facilitate Cross-Regional Collaboration and Standardisation: Given the global nature of the automotive industry, it's crucial to foster collaboration and standardisation efforts across regions. Organisations like the 5GAA play a pivotal role in facilitating dialogue and knowledge exchange between stakeholders from different parts of the world. By aligning spectrum regulations, policies, and standards, the industry can streamline the deployment of connected vehicle technologies and accelerate the realisation of cooperative connected and automated mobility (CCAM) on a global scale.[4]

3.4 Smart manufacturing

Investment in Skills Development: Addressing the shortage of skilled workers in advanced manufacturing technologies is crucial. Policymakers should collaborate with industry stakeholders to develop comprehensive training programs tailored to the needs of smart manufacturing. This could include initiatives such as vocational training, apprenticeships, and retraining programs for existing workers. Additionally, incentivising educational institutions to incorporate courses on emerging technologies like AI, IoT, 5G/6G and robotics into their curricula can help bridge the skills gap and ensure a steady supply of qualified professionals for the industry.

Facilitating Technology Adoption: To overcome interoperability and system integration challenges, industry standards and guidelines for adopting disruptive technologies in manufacturing processes should be established. This could involve creating regulatory frameworks that encourage collaboration among technology providers and manufacturers to develop interoperable solutions. Moreover, offering financial incentives such as tax breaks or grants for companies investing in innovative technologies and infrastructure upgrades can accelerate the adoption of Industry 4.0 practices and mitigate the risks associated with commercialisation delays of essential network components.

Promoting Research and Development (R&D) Collaboration: Encouraging collaboration between government-funded research institutions, academia, and private industry can drive innovation in smart manufacturing. Funding for collaborative R&D projects focused on addressing key challenges such as data management, cybersecurity, and technology standardisation should be allocated. Fostering knowledge, resources, and expertise among stakeholders can accelerate the development and deployment of cutting-edge technologies in manufacturing. Additionally, establishing innovation hubs or technology clusters dedicated to smart manufacturing can facilitate networking and knowledge exchange, fostering a culture of innovation and entrepreneurship in the sector.[5]

4 For more information see 5GAA, C-V2X Use Cases and Service Level Requirements Volume III, Whitepaper, 2023. Available at https://5gaa.org/content/uploads/2023/01/5gaa-tr-c-v2x-use-cases-and-service-level-requirements-voliii.pdf.

5 For further information see GSMA, Industry 4.0 Brownfield Evolution Framework, 2023. Available at https://www.gsma.com/iot/resources/industry-4-0-brownfield-evolution-framework-2023/; Isabel Castelo-Branco, Maria Amaro-Henriques, Frederico Cruz-Jesus, Tiago Oliveira, "Assessing the Industry 4.0 European divide through the country/industry dichotomy," Computers & Industrial Engineering, Volume 176, 2023, 108925. https://doi.org/10.1016/j.cie.2022.108925.

3.5 Agriculture

Investment in Rural Connectivity Infrastructure: To fully leverage the potential of smart agriculture enabled by 6G technology, investment in rural connectivity infrastructure should be prioritised. This includes ensuring reliable and high-speed internet connectivity and robust communication networks capable of withstanding adverse weather conditions. This would, in turn, facilitate the adoption of digital farming technologies, improving productivity and sustainability in the agricultural sector.

Standardisation and Interoperability of IoT Devices: Given the diverse range of IoT devices used in smart farming, there is a need for standardised protocols and interoperability standards to ensure seamless communication and data exchange between different devices and systems. Collaborations among governments and industry stakeholders should be enacted to develop and implement these standards, facilitating the adoption of digital farming technologies and driving innovation in the agricultural sector.

Research and Development for Future 6G Networks: To meet the evolving needs of digital farming, governments should invest in research and development for future 6G networks tailored to the agricultural sector. This includes developing ultra-low-power communication technologies for autonomous sensors, ensuring ubiquitous connectivity in remote areas, and enhancing data transfer capabilities to support advanced services such as artificial intelligence and machine learning. This allows the seamless integration of 6G technology into the agricultural ecosystem, enabling sustainable and efficient farming practices.[6]

3.6 Media

Investment in Rural Infrastructure: To ensure equitable access to enhanced media connectivity, governments should prioritise investment in network infrastructure in rural and remote areas. This includes funding for installing 6G hardware and upgrading existing systems to provide high-quality network coverage. Bridging the digital divide between urban and rural areas provides all citizens with equal access to the benefits of 6G technology, including real-time content delivery and immersive media experiences.

Data Privacy Regulation and Transparency Standards: Given the increasing reliance on AI for content personalisation in the media sector, robust data privacy regulations and transparency standards should be enacted in order to promote trust and accountability. These regulations should address concerns about media companies' collection, storage, and use of personal data, ensuring user privacy. Additionally, transparency standards should be established to clarify how AI algorithms influence content recommendations and decision-making processes.

Support for Small and Medium-sized Enterprises (SMEs): Recognising the challenges smaller media companies face in acquiring the technological expertise and resources needed for immersive content creation, competitiveness-support programs tailored to SMEs' needs should be provided. These may include grants, subsidies, or tax incentives for investing in advanced software development, content creation tools, and specialised skill development.

6 For further information see European Commission, Agriculture and Rural Development, 2024. Available at https://agriculture.ec.europa.eu/data-and-analysis/markets/outlook/medium-term_en?prefLang=it; European Commission, The Digitalisation of the European Agricultural Sector. Available at https://digitalstrategy.ec.europa.eu/en/policies/digitalisation-agriculture.

3.7 Transportation (Railways)

Investment in Rail Infrastructure and Technology: Governments should prioritise investment in rail infrastructure and technology to support the transition to more sustainable and efficient rail transport systems. This includes funding for developing and implementing high-speed rail networks, modernising existing rail infrastructure, and deploying advanced communication and signalling systems.

Alignment with Sustainability Goals: Governments should align rail transport policies with sustainability goals, such as those outlined in the Paris Agreement and the European Green Deal. This includes setting targets for reducing emissions from the transportation sector, increasing the share of rail transport in the overall transportation modal split, and promoting the adoption of clean energy sources for rail operations. Overall, by prioritising sustainability, the environmental impact of transportation can be mitigated, contributing to global efforts to combat climate change.

Promotion of Digitalization and Automation: Governments should promote the digitalisation and automation of rail operations to improve safety, efficiency, and passenger experience. This includes investing in digital signalling systems, onboard communication networks, and automation technologies for train control and operation. Embracing digitalisation and automation allows the enhancement of the reliability and resilience of rail transport systems, reduces operating costs, and improves the overall quality of service for passengers and freight operators.[7]

7 For further information see European Commission, Sustainable and Smart Mobility Strategy – putting European transport on track for the future, 2020. Available at https://eur-lex.europa.eu/legalcontent/EN/TXT/?uri=CELEX%3A52020DC0789; Subtil, J., Cohesion Policy Rail Investments, European Commission, Directorate-General for Regional and Urban Policy, Smart and Sustainable Growth Unit, 2021. Available at https://cohesiondata.ec.europa.eu/stories/s/In-profile-Cohesion-policy-rail-investments-2014-2/ruwbxkpv/.

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