FNS & digital autonomy

How FNS contributes in semicon components, software, and interoperability

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Summary

Europe relies on global partners for its digital infrastructure. As mobile networks evolve toward 6G, the increasing role of cloud computing and software virtualisation poses additional challenges for European hardware manufacturers and additional risks to Europe's digital sovereignty. These dependencies raise concerns not only about economic competitiveness but also national security, as disruptions could impact essential services.

One of FNS's three goals is on digital autonomy. This paper looks at how the FNS work fits the three main policy pathways available to governments looking to push forward the digital autonomy agenda in a practical way. These pathways are:

1. **Supporting Industry Leaders** – through funding, public procurement, and tax incentives.
2. **Encouraging Contestable Markets** – via open standards and interoperability to avoid vendor lock-in.
3. **Setting Government Mandates** – not directly applicable to FNS but relevant in broader policy discussions.

While innovation programmes like FNS cannot offset all risky dependencies, they help European companies to research, build, and test locally developed solutions within the telecommunications sector, setting them on the path as industry leaders. This includes support in areas around specialised hardware that are key in 6G, such as antenna arrays, which are required for mobile networks to function as well as software solutions that rely on local and edge computing rather than via centralised cloud solutions. At the same time, the testing and using open-source solutions—that help keep markets contestable—can help to ensure that European companies always have viable alternatives and are not locked into specific solutions.

Challenges & Recommendations

While FNS already provides support to digital autonomy along two of the three main policy pathways to digital autonomy, should it wish to more concretely address the topic, the following recommendations could be considered:

- Digital autonomy is an **outcome**, but not necessarily a **design criterion** in FNS projects. This is not a critique of how FNS addresses digital autonomy in its outputs, but a more robust foundation could be considered as the programme moves forward. Some of the outputs from FNS could focus more clearly on resiliency and dependencies within the stack, which would lead to projects more in line with the principles of digital autonomy (a recommendation that is already under consideration for phase 2).
- Future phases could **explicitly explore autonomy trade-offs**, assessing options that lead to options for European hardware—such as around specialised energy-efficient chips for edge AI—and software in the RAN and core parts of the network, so that government policies can be aligned towards this goal, underpinned by technical and commercial options.
- While testing how open-source components such as CAMARA and Sylva may help facilitate use cases, FNS could consider contributing more to these projects. This can mean **contributing enhancements to open-source projects** based on unmet requirements from the use cases.

1. The changing nature of risky dependencies in mobile networks

Currently, more than 80 percent of Europe's digital infrastructure is sourced from global partners.[1] While these global collaborations have served Europe well in enhancing connectivity and innovation, they have also created *risky strategic dependencies* as the economy (and broader society) relies heavily on this digital infrastructure. This has created vulnerabilities.[2]

Traditionally, these vulnerabilities have revolved around the 'winner take all' dynamic and network effects created by digitalisation, in particular the increasing importance of cloud computing and platforms that extend to many parts of the economy. This includes mobile network infrastructure, especially as we approach 6G, a new generation of mobile technology where software and virtualisation are part of its key advancements. This enhanced role of cloud computing is particularly challenging for the competitive advantage of European equipment manufacturers that excel in specialised hardware. Although companies such as Ericsson and Nokia continue to be market leaders[3] , concerns about the competitive position of European companies facing unfair competition in digitalised market has encouraged new regulation. This includes the possibility of an upcoming Digital Networks Act, which looks to set up dispute resolution mechanisms between large traffic generators, like streaming services, and telecom operators.[4]

Recently, the focus on digital autonomy has expanded beyond these economic concerns, to fears about national security and continuity of basic services. A major disruption within mobile telecommunication networks would mean, for instance, that digital payments could fail and government services that rely on mobile-based two-factor authentication would cease functioning. A disruption of even a few days would hold severe consequences and bring real risks to the financial backbone of the national economy, among many other negative consequences. European governments have become more aware of the risk of relying on non-European state and corporate actors, particularly given increasing geo-political tensions. Guiding research and innovation towards local cloud services for sensitive government data and critical physical infrastructure governed by the Netherlands has been one option discussed by stakeholders.[5]

Within this context, programmes such as Future Network Services (FNS)[6] that serve an economic function by contributing to innovation become increasingly relevant as a vehicle to develop more autonomous digital infrastructure. While these innovation programmes cannot offset all risky dependencies, they help European companies to research, build, and test locally developed solutions within the telecommunications sector. This includes specialised hardware, such as antenna arrays, which

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1 Bria, F., Timmers, P., & Gernone, F. (2025). *EuroStack – A European Alternative for Digital Sovereignty*. 127 p. https://doi.org/10.11586/2025006

2 Rijksoverheid. (2023, October 17). *Agenda Digitale Open Strategische Autonomie*. Ministerie van Economische Zaken en Klimaat. https://www.rijksoverheid.nl/documenten/rapporten/2023/10/17/bijlage-agenda-dosa-tgpdfa

3 McMorrow, R., & Smith, K. (2025, October 2). China curbs use of Nokia and Ericsson in telecoms networks. *Financial Times*. https://www.ft.com/content/7d08731c-189e-4835-8cfa-048fe68611bd

4 de Luca, S. (2025). *Digital networks act* [Briefing]. European Parliamentary Research Service.

5 NBIP. (2025, May 27). Strategische digitale autonomie en het Rijksbreed cloudbeleid. Nationale beheersorganisatie internet providers. https://www.nbip.nl/en/actueel/coalition-of-companies-and-organisations-presents-approach-for-digital-autonomy-in-government/

6 "Future Network Services: 6G for and by the Netherlands." *Future Network Services*, https://futurenetworkservices.nl/en/. Accessed 1 Oct. 2025.

are required for mobile networks to function as well as software solutions that rely on local and edge computing rather than via centralised cloud solutions. This support becomes particularly important when European and Dutch companies face intense competition from Chinese and American vendors backed by government support, both in terms of financing and, in some cases, protected markets.

1.1. The purpose of this paper

This paper intends to explore how FNS fits within the context of these wider concerns of digital autonomy. It begins with a short exploration of the different policy pathways to achieve digital autonomy—not as a way to review government policy, but rather to provide context to the actions and activities within FNS. Then, it proceeds to summarise the activities that fit the described pathways. Finally, the paper ends with a series of recommendations around further stages of the FNS programme should it wish to engage more systematically with topics around digital autonomy.

2. Policy pathways to digital autonomy and how they frame FNS activities

Before addressing directly the FNS programme, it can be useful to put its activities within a broader context of the policy pathways available to governments looking to push forward the digital autonomy agenda in a practical way. This can assist in understanding where FNS supports digital autonomy and in what way.

There are three main policy roadmaps to reducing economic and societal risks: **supporting industry leaders**, **encouraging contestable markets** and **setting government mandates**. The following chapter briefly summarises the FNS lines of activity and fits those programme lines into the three policy pathways—the details of which are addressed further in the next chapter.

2.1. The FNS programme lines

FNS activities are broken down into four main programme lines (PLs). Three of the four programme lines within the FNS programme focus on various software and hardware components of the 6G stack. Of those three programme lines, two are focused on the infrastructure itself, while the third, PL3, focuses more on leading applications, use cases and extracting added value from the new mobile networks and services standard. Programme line 1 focuses on innovation in silicon hardware components, while programme line 2 largely focuses on software and virtualisation. The three programme lines are briefly summarised in the table below.

PL1. Intelligent components	Highly efficient transmitters Joint communication and sensing Over-the-air testing Optical-enabled wireless
PL2. Intelligent networks	Architecture design 6G DevOps & digital twins AI network automation
PL3. Leading applications	Transport hubs Remote surgery Smart grids Wireless detection Wireless factor E-commerce platform Digital sports

Underlying these three programme lines is a fourth, supporting pillar that looks to strengthen the (European) ecosystem. Part of this is in direct support of the three programme lines through a national testbed environment, giving participants space to test prototypes. The testbed is helpful not just for users or application developers, but also those that are developing the network, providing a place to test new hardware components. It also provides technical and in-kind financial support to spin-offs, start-ups, and other small companies that may bring the next big innovation. At the same time, programme line 4 works on standards development as well as regulatory policy analysis of the network and communications technology sector, such as on the supply and management of cloud infrastructure stack.

A summary of the organisations working on the various programme lines is shown in the diagram below.

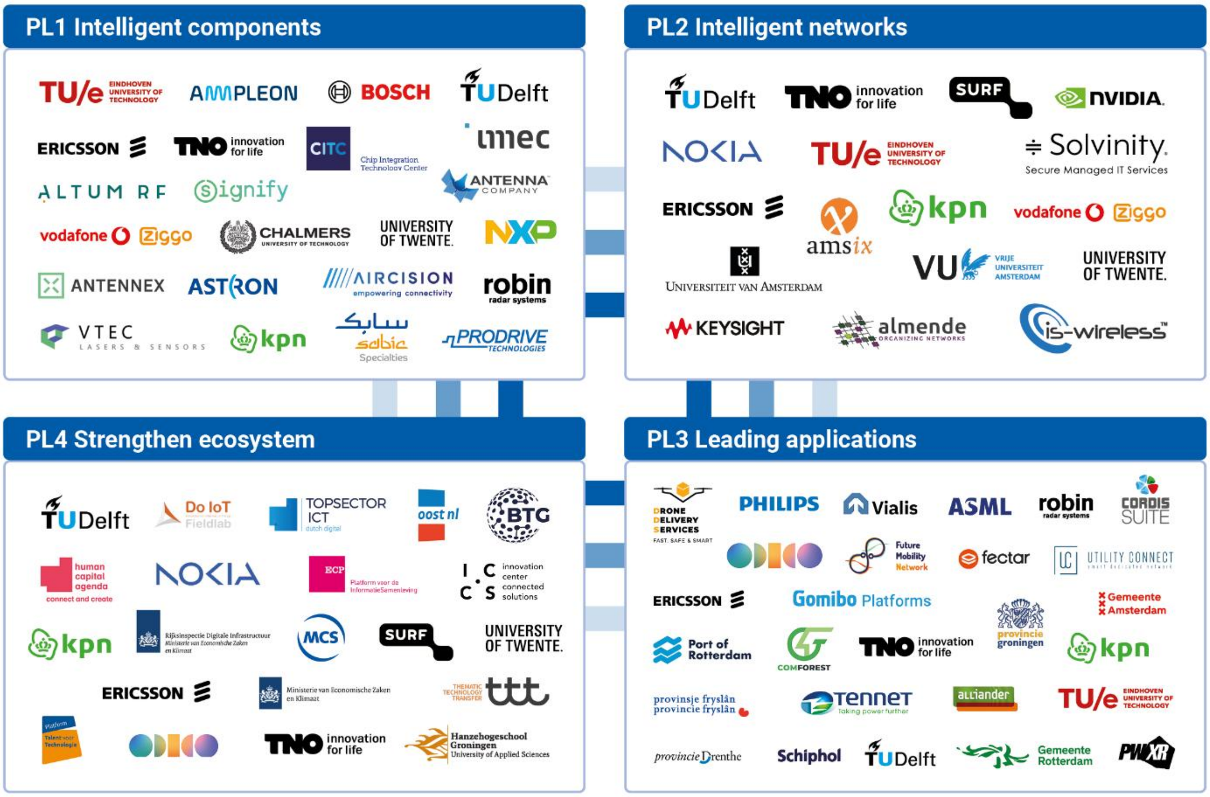

Figure 1. The partners and programme lines in FNS

From a digital autonomy perspective, programme lines 1, 2, and 4 relate most to the mobile network infrastructure itself, which is the focus of this paper. Programme line 3, depending on the use case, could also touch upon question of digital autonomy, but this would be in relation to other sectors of the wider economy, and remains outside of the scope of discussion.

2.2. Policy pathways to digital autonomy

Before addressing the details of the relevant programme lines in more detail, the following section provides some policy context in terms of how governments can achieve digital autonomy. It groups the policy options into three main pathways, which are summarised below.

2.2.1. Policy 1: Supporting industry leaders

The first pathway is for governments to support companies to become **industry leaders**, leading the design and supply of hardware and software. In doing so, industry leaders shape global supply and value chains while also developing the way by which the digital world is organised and run. This support can be direct or indirect.

Industrial policy can lead to co-financing and developing of large-scale R&D infrastructure projects, such as the French government's 2021 initiative for a *cloud de confiance*, where Capgemini, Orange, and Thales worked directly with the French government to deliver sovereign cloud services.[7] More common are sources of research and innovation funding, such as those provided by the National Growth Fund *(Nationaal Groeifonds)* in the Netherlands, which is the funding mechanism by which FNS is operated.

Governments help local industry grow not only through funding, but also when they become clients of the very innovations that their companies create. Strategic public procurement helps companies gain the scale, credibility, and capability they need to expand into developing markets. The public sector—as a large purchaser of both goods and services—can provide an important market for rising players.

Trade and tax policy can also support companies in the same way that investment and innovation policy can. Current Dutch policy offers tax credits and deductions on research and development, with a reduced corporate income tax on profits from innovative activities, to encourage innovation.[8] The Netherlands does not stand alone in this policy as Belgium offers a 40% deduction for SMEs (30% for large enterprises) for green tech assets, and France enacting its Green Industry Law (2024), which provides new battery manufacturing investments a 20% investment tax credit.

Attracting foreign companies that can strengthen local supply and value chains can also support industry leaders. Creating an investment friendly environment with foreign companies in the Netherlands can boost growth and innovation, potentially raising the performance of local businesses that operate as suppliers. Companies operating in a particular jurisdiction can also end up transferring important intellectual property and technologies to their suppliers to ensure that they service them better. This targeted investment strategy creates a roadmap to later become a leader in the industry, as exemplified by the EU's Battery Booster components of the Industrial Action Plan, where joint venture requirements and IP licensing is being explored to build resilient, value-driven supply chains.[9]

By supporting local industry leaders, R&D&I programmes such as FNS help companies to maintain their lead and potentially support start-ups and scale-ups that can also become industry leaders. Programme Line 1 in FNS largely falls under this pathway, in part supported by the testbed element of PL4 (which will be addressed further in the next chapter).

2.2.2. Policy 2: Encouraging contestable markets

Another method to achieve digital autonomy is for governments to work towards **contestable markets**—markets that are easily accessible to new competitors. Governments make it harder for any single company to dominate, which limits control over the stack, helping reduce the risk of vendor lock-in from any single company. If a provider is deemed to be risky, it should be easier to switch to an alternative, hence reducing (though not eliminating) risky dependencies. For example, EU legislation such as the Data Act looks to impose interoperability requirements on companies to ensure that, at minimum,

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[7] Qui sommes-nous ? (n.d.). *Bleu*. Retrieved October 6, 2025, from https://www.bleucloud.fr/qui-sommes-nous/

[8] RVO, Netherlands Enterprise Agency. "Innovation Box." Business.Gov.Nl, https://business.gov.nl/subsidy/innovation-box/. Accessed 1 Oct. 2025.

[9] European Commission. (2025). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Industrial Action Plan for the European automotive sector*. https://transport.ec.europa.eu/document/download/89b3143e-09b6-4ae6-a826-932b90ed0816_en?utm_source=chatgpt.com

organisations have at least the technical ability to move their data between different providers. This also, potentially, opens the space for smaller European providers to enter a market and grow economically.[10]

The European Union uses antitrust law, merger control, and other competition policy mechanisms to keep markets open and diverse, reducing risky dependencies on single suppliers. The European Commission has been using the Digital Markets Act to enforce rules around self-preferencing as well as interoperability requirements. As an example, the European Union has been breaking open various digital markets, with proceedings against Alphabet because of concerns that it is preferencing its own vertical search services and various concerns within the Apple ecosystem, notably around application distribution.[11] These both led to rulings around non-compliance.[12] In short, regulating powerful platforms can be viewed as an attempt by the EU to create space for European alternatives.

In the mobile networks sector, given the prevalence of cloud (and the role that hyperscalers may play in it), both open standards and government regulation can help keep mobile network markets contestable, though only to an extent. Despite the move towards Open RAN, many providers still choose to work with companies that work as integrators of various components, which leaves open the theoretical possibility to mix-and-match equipment, but simply remains too complex for companies to engage with in practice, leaving the large manufacturers in a dominant position. In terms of the cloud, however, the Data Act could be used to reduce lock-in of cloud providers that charge high fees to retrieve data, raising barriers to change providers. Article 23 of the Data Act specifically obliges cloud providers to remove commercial, organisational, and contractual barriers to switching.[13]

PL2 largely falls under this pathway, in part supported by the standards work in PL4 (which will be addressed further in the next chapter).

2.2.3. Policy 3: Setting government mandates

The third pathway is for governments to use regulation to **mandate** the use of their national or regional companies to deliver essential services or to regulate markets to ensure that oligopolies or monopolies cannot form, focusing on identified ‘control points’.[14] Of the three policy paths, this one poses the greatest economic risk, as it can lead to protectionism, potentially leading to long-term economic stagnation. Nonetheless, there have been historical and modern examples where time-limited protectionism has helped protect a local industry until it could become globally competitive. China is the most current example, with a combination of controlled market access, tariffs, and technology transfer rules helping to grow local industry and reduce foreign dependencies. Most recently, it banned the import of Nvidia AI

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[10] Of course, making a market more contestable does not guarantee against lock-in, as the cost of switching also involves organisational changes as processes inevitably need to change.

[11] *Commission opens non-compliance investigations against Alphabet, Apple and Meta under the Digital Markets Act—Digital Markets Act (DMA)*. (March 2024). Retrieved October 6, 2025, from https://digital-markets-act.ec.europa.eu/commission-opens-non-compliance-investigations-against-alphabet-apple-and-meta-under-digital-markets-2024-03-25_en

[12] Kirkwood, M. (2025, April 23). *Understanding the Apple and Meta Non-Compliance Decisions Under the Digital Markets Act | TechPolicy.Press*. Tech Policy Press. https://techpolicy.press/understanding-the-apple-and-meta-noncompliance-decisions-under-the-digital-markets-act

[13] *Data Act: Part 4 – The Data Act regulates cloud switching and influences the contractual relationship between customers and cloud service providers*. (July 2025). Retrieved August 20, 2025, from https://www.osborneclarke.com/insights/data-act-part-4-data-act-regulates-cloud-switching-and-influences-contractual-relationship

[14] Pisa, Daan, et al. *Grip Op Control Points*. no. R11817, 18 Nov. 2024, p. https://vector.tno.nl/en/articles/grip-control-points-effectively-innovate/ .

chips in an effort to force companies to buy locally produced chips from manufacturers such as Huawei and Cambricon.[15]

This pathway is not covered by FNS. Setting mandates is policy instrument that is outside the scope of an R&D&I project like FNS.

2.3. Digital autonomy issues in the 6G stack

The oft-quoted paper, *EuroStack – A European Alternative for Digital*, attempts to break down the critical elements of the stack for the digital economy. This digital stack comprises seven components, one of which is labelled as 'Euroconnect', a reliable pan-European connectivity that promotes the development of standalone 5G networks and anticipates 6G. The networks component of the stack, as illustrated below, is represented by a number of key companies, alliance, and networks in Europe. This list includes companies that are a part of FNS, and FNS-supported companies are also important suppliers for many of the key companies listed.

Key companies

- Nokia (Finland)
- Ericsson (Sweden)
- Alcatel Submarine Networks (France)
- Orange (France)
- Airbus Defence and Space (Germany/France)

Alliance & networks

- 5G Infrastructure Public Private Partnership (5G PPP)
- Smart Networks and Services Joint Undertaking for 5G and 6G

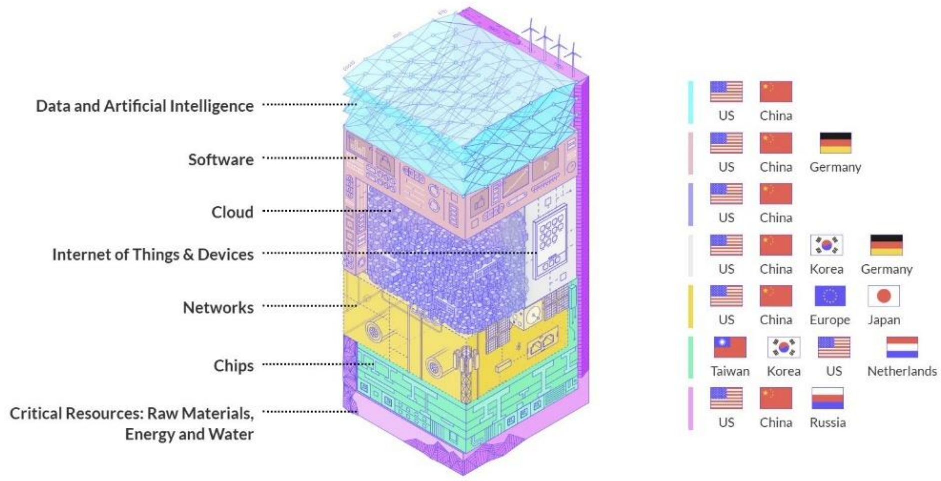

Figure 2. Exploring the technical stack by Eurostack.[1]

While the digital stack contains 'networks' as a key element, the stack includes a number of key intersecting layers. As already mentioned earlier in this report, cloud and software services are becoming more important in the delivery of mobile network services, as is data and artificial intelligence, which are

[15] Bradshaw, T., Wu, Z., & Leng, C. (2025, September 17). China bans tech companies from buying Nvidia's AI chips. *Financial Times*. https://www.ft.com/content/12adf92d-3e34-428a-8d61-c9169511915c

used to make mobile networks more effective and efficient. The following section outlines in further detail, based on interviews with members of FNS, some of the issues specific to 6G that are relevant from a digital autonomy perspective.

2.3.1. The large role of the cloud in mobile networks

In 4G, network functions were typically deployed on dedicated, vendor-specific hardware components. The network was vertically integrated, with software tightly coupled to the hardware. With 5G, various network components can be decoupled into software-based network functions that run in a cloud environment—usually packaged into containers like Docker or Kubernetes.[16] This virtual environment can be run on standard off-the-shelf CPUs and network interface cards, running on top of any properly configured open-source Linux distribution. And while 5G introduced this concept of a Service-Based Architecture (SBA) and began embracing cloud-native principles, 6G will fully integrate cloud compute, changing the link between networks and cloud layers in the stack (as captured by the 3C network concept).[17] 6G will extend the network functions running on generic platforms in the cloud, which includes elements in the packet core, the radio access network (including the Central Unit and Distributed Unit), and in service orchestration.[18]

This decoupling of hardware and software presents a competitive challenge for European manufacturers, though the problem is not one of product innovation. While companies like Ericsson and Nokia may not be cloud-first organisations, they can provide cloud-based solutions to various hardware components. Ericsson, for example, foresees that "6G architecture will build on the ongoing trend of network horizontalization, enabling the 6G radio-access network (RAN) and core network (CN) functions to benefit from the fast evolution of cloudification".[19] While some European manufacturing sectors have struggled with digitalization, mobile networks do not appear to be an area where European companies are being left behind by innovation.

Rather, the challenge that European companies face is a competitive one (which can also become a risky dependency). Companies like Amazon already provide cloud services for customer billing and customer relation management, which network operators already rely on for their day-to-day activities. Should these hyperscalers invest heavily in cloud services, they could have the ability to bundle 6G services with existing services, giving advantage over existing players that would lack this vertical integration of cloud services. Companies like O2 Telefónica are already virtualising some elements of their 5G core with AWS

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[16] Tufeanu, L., Martian, A., Vochin, M., Paraschiv, C.-L., & Li, F. (2022). *Building an Open Source Containerized 5G SA Network through Docker and Kubernetes*. https://doi.org/10.1109/WPMC55625.2022.10014753

[17] Consequences of this are further addressed in a white paper from the European Commission, which addresses the Connected Collaborative Computer network concept (3C): *White Paper - How to master Europe's digital infrastructure needs? | Shaping Europe's digital future*. (n.d.). Retrieved November 3, 2025, from https://digital-strategy.ec.europa.eu/en/library/white-paper-how-master-europes-digital-infrastructure-needs

[18] Boopathy, E. V., Vijayalakshmi, V. J., Gajendiran, K. S., Ramana, S., Ramachandran, G. M., Ragunesh, M., Rahman, N. P., & Pyntamilselvan, N. (2025). A Review of Softwarization and Virtualization in 6G Mobile Networks: Current Trends and Future Challenges. In V. S. Reddy, J. Wang, P. Chetti, & K. T. V. Reddy (Eds.), *Soft Computing and Signal Processing* (pp. 615–626). Springer Nature. https://doi.org/10.1007/978-981-96-0924-6_48

[19] *6G network architecture – a proposal for early alignment*. (2023). Ericsson.Com. Retrieved August 19, 2025, from https://www.ericsson.com/en/reports-and-papers/ericsson-technology-review/articles/6g-network-architecture

cloud.[20] It is true that some hyperscalers, such as Microsoft, have announced that they will not compete in this space, but that does not mean that they competitive threat does not continue to exist.[21]

2.3.2. The enhanced role of artificial intelligence

While softwarisation of the stack has given attention to the role that cloud providers and commodity chipmakers have, artificial intelligence (AI) also plays a role in managing the network. This would include, for example, self-optimizing networks (SONs), where AI algorithms continuously monitor traffic, interference, and latency conditions, adapting network architectures, resource allocation and even software functions in real time. [22] Unlike 5G, which uses rule-based SONs, 6G envisions reinforcement learning-driven policies that adjust dynamically to new contexts.

Not only can artificial intelligence dynamically adjust the network according to prevailing conditions, but the technology can also run workloads *on top* of the RAN, using RAN infrastructure to host or enable applications. The AI-RAN alliance has an AI-on-RAN working group that looks to benchmark the performance of applications on the network itself.[23]

Currently, policymakers have shown some concern around the dominance of players like Nvidia, who produce the chips required to develop the large language models (LLMs) that underlie applications that are currently being pushed by big tech players, like Open AI and Microsoft. FNS, discussed in more detail in the next chapter, also works with other types of AI, which is not limited to LLMs. At the same time, industry is finding that small language models (SLMs) are more effective and cheaper to build in specialised contexts.[24] A paper published by Nvidia argues that "small language models (SLMs) are *sufficiently powerful, inherently more suitable, and necessarily more economical for many invocations in agentic systems, and are therefore the future of agentic AI*."[25]

With AI increasingly being integrated into 6G networks, particularly at the edge, the question arises: what kind of hardware will support these compute-intensive tasks? Already, RAN and base stations rely on specialized processing units to handle workloads that generic processors cannot manage, even without AI. While Nvidia now has a monopoly on centralised cloud-based solutions, these new processing needs with AI creates room for new vendors to possibly step in. Companies like NXP, known for their embedded systems, are exploring how their chips could support edge AI workloads, especially for SLMs.[26] Though still in early stages, this research signals potential for European players, and possibly smaller companies,

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[20] *First 5G core network in the cloud for an existing operator: O2 Telefónica sets new impulses in the core network together with Nokia and AWS. (n.d.). Retrieved September 12, 2025, from https://www.telefonica.de/news/press-releases-telefonica-germany/2024/05/first-5g-core-network-in-the-cloud-for-an-existing-operator-o2-telefonica-sets-new-impulses-in-the-core-network-together-with-nokia-and-aws.html*

[21] karthikananth. (n.d.). *What is Azure Private 5G Core?* Retrieved November 3, 2025, from https://learn.microsoft.com/en-us/previous-versions/azure/private-5g-core/private-5g-core-overview

[22] Ford, T. (2025, July 10). AI-native networks and the Implications for 6G. *Wireless Infrastructure Association*. https://wia.org/ai-native-networks-and-the-implications-for-6g/

[23] Carvalho, J. (n.d.). Working Groups. *AI-RAN Alliance*. Retrieved October 7, 2025, from https://ai-ran.org/working-groups/

[24] Faith in God-like large language models is waning. (n.d.). *The Economist*. Retrieved September 9, 2025, from https://www.economist.com/business/2025/09/08/faith-in-god-like-large-language-models-is-waning

[25] Belcak, P., Heinrich, G., Diao, S., Fu, Y., Dong, X., Muralidharan, S., Lin, Y. C., & Molchanov, P. (2025). *Small Language Models are the Future of Agentic AI* (No. arXiv:2506.02153). arXiv. https://doi.org/10.48550/arXiv.2506.02153

[26] *AI and Machine Learning*. (n.d.). Retrieved October 21, 2025, from https://www.nxp.com/applications/technologies/ai-and-machine-learning:MACHINE-LEARNING

to challenge the dominance of centralized, cloud-based solutions and offer viable alternatives for edge AI deployment.

This reflects a broader move away from reliance on large-scale, centralized infrastructures and toward a more distributed, software-driven architecture. This not only challenges the dominant party NVIDIA, but also answers the demands for European AI, and more flexible and secure processing.

3. Digital autonomy within FNS

FNS uses its role as a research and innovation consortium to pave a leading international position for the Netherlands in 6G. It facilitates innovation both for the hardware and software needs of 6G networks, in collaboration with industry and government partners. FNS combines funding from the Dutch National Growth Fund with investments by its partners. Its primary goal is to contribute to "sustainable earning capacity" for the Netherlands, connected by principles of reliable connectivity, digital autonomy and environmental sustainability. As an upcoming international leader in intellectual property and production of intelligent 6G technology and semiconductor components, FNS is enabling the Netherlands to position itself in the competitive 6G global market.

Currently the Netherlands is establishing a key role in select components of the stack: antennas, software and specialised chips. The direct economic benefits to the Netherlands of these activities feed into the overall Dutch economy, with high-tech manufacturing *across all industries* providing 6% of GDP.[27] Taking a broader perspective, while 6G is a potential enabler of new economic activities—and the many use cases that have been hypothesized—it can be argued that those benefits could accrue in a *structural* way to the earning power of the Dutch economy whether Dutch companies make contributions to the digital infrastructure or not.

However, from a digital autonomy perspective, being a critical component as a part of the digital stack provides not only economic benefits, but also geopolitical clout. The importance of ASML for the manufacture of microchips, for example, has led to constant diplomatic discussions between the American and Dutch governments around ASML's exports to China. While the Netherlands may be the smaller player in that negotiation, the fact remains that the Netherlands remains a player with whom negotiations need to take place, giving Dutch stakeholders a relevant seat at the table. And in this sense, it could be argued that it remains critical to be an important player within specific, well-chosen areas of the digital stack for telecommunications rather than a broad footprint across a number of areas in the stack.

3.1. European and Dutch companies in the 6G stack

Understanding where the Netherlands holds a degree of autonomy within 6G first requires a short break-down of the hardware and software stack of 6G as we currently understand it (given that it is a developing technology). The diagram below focusses on those elements of the stack where European and Dutch companies provide hardware or software solutions in 5G, and where one would expect them to continue to provide solutions within the 6G stack.

Traditionally, European and Dutch companies have excelled on the hardware side of mobile infrastructure. Nokia and Ericsson have long been at the forefront of mobile technology. For Dutch companies, global competitiveness largely falls on components around the antenna array, as shown in the diagram below, with kit that includes antennas, amplifiers, and the other components that are used to transmit and receive signals from base stations.

[27] https://www.pwc.nl/nl/actueel-publicaties/assets/pdfs/made-in-nl.pdf

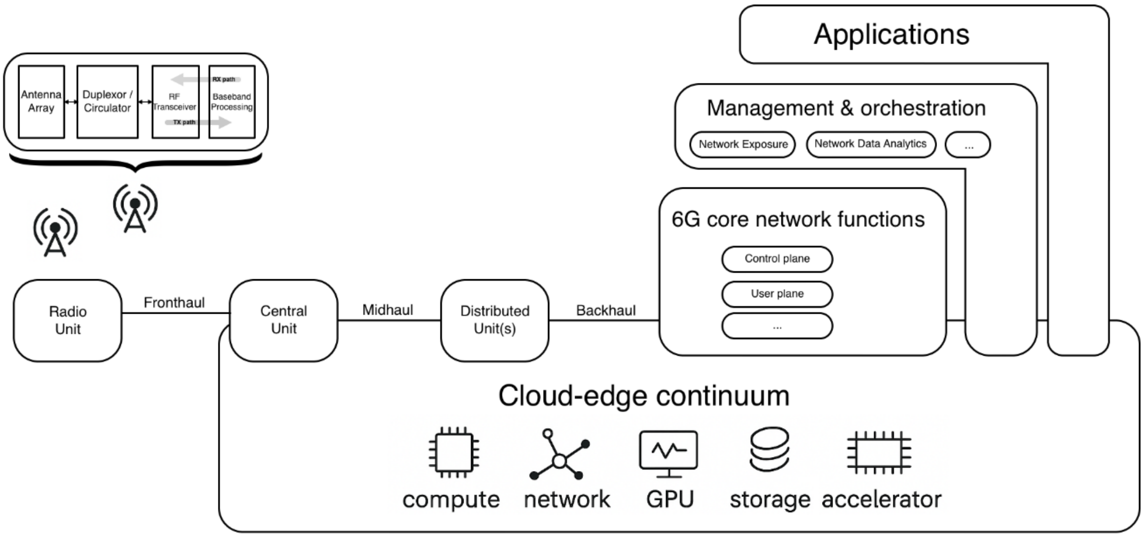

Figure 3. Diagram of the 6G network

Within FNS there is increasing attention surrounding the shift of hardware sourced from Europe as opposed to China and Vietnam. The Netherlands holds an important position in RF power transistors and antennas. NXP and Ampleon, for example, are global leaders in high-frequency RF power transistors (LDMOS and GaN) used in base station power amplifiers. The European market is also scaling up, with NXP joining other European companies to scale up semiconductor manufacturing and develop new chip technologies. The RF includes specialised antenna arrays that need to provide massive multiple-input and multiple-output (MIMO), highly specialised equipment that has been a requirement for telecommunication since 4G. As such, while some companies in the mobile infrastructure face serious disruption to their business models, those working on antenna arrays retain an advantage.

A recent paper commissioned by Bertelsmann Stiftung—a German private, not-for-profit organisation—makes this toehold in the digital stack for European companies clear.[28] For components that are critical for 6G, European and Dutch companies occupy a relatively narrow band of the stack around networks and, to some extent, chips. Increasing competition from non-European firms is evident on the core side of the network—made up of the control and user planes—where user management, geographical mobility, session control, authentication, policy enforcement, and connections with other networks can all be virtualised. In earlier iterations of the telecommunications network was generally handled by specialised equipment with embedded software, but now the softwarisation and virtualisation of components has meant that components within the RAN and core perform on commoditised hardware, elements of the digital stack where European companies have less clear strength.

[28] Bria, F., Timmers, P., & Gernone, F. (2025). *EuroStack – A European Alternative for Digital Sovereignty*. 127 p. https://doi.org/10.11586/2025006

3.2. Support for digital autonomy in programme line 1: innovation in components

Much of the innovation research being conducted under PL1 looks to either further the advantage that companies like NXP and Ampleon and SMEs like AltumRF and The Antenna Company have in antenna arrays, such as the work being done with transmitters, or to leverage new capacities of 6G networks that rely on hardware. One such component of 6G networks is joint communication and sensing (JCAS), an area in which Ericsson and NXP have been co-operating in the past to understand its potential.[29] This relates to the work within FNS on drone and traffic intersections as a part of not just PL1, but PL3.

6G networks are expected to enable a new class of applications that depend on real-time awareness of their physical environment, such as autonomous mobility, drone coordination, industrial automation, smart healthcare, and immersive XR (some of which align with PL3 use cases). Achieving this level of contextual intelligence requires networks that not only exchange data but also perceive their surroundings.

To support these and similar 6G functionalities, the development of specialised hardware components will be essential, including:

- **Wideband multi-functional antennas:** Antenna arrays that support both data modulation and echo reception.
- **Reconfigurable RF front-end modules:** Current RF chains are optimised for either communication or sensing. JCAS needs adaptable architectures that switch between transmit and receive modes with microsecond precision.
- **Full-duplex transceivers:** In-band simultaneous transmit-and-receive that require cancellation of self-interference at power levels significantly higher than in conventional systems.
- **Mixed-signal processing units:** Joint processing of communication and sensing demands new baseband architectures that combine standard modulation/demodulation with real-time radar signal processing.

Together, these elements illustrate the broader technological shift toward **sensing-aware communication infrastructures**, of which JCAS is a central—but not exclusive—realisation.

PL1 is also exploring includes optical-enabled wireless communication, which addresses several key limitations of traditional RF-based systems. Rapidly growing demand for ultra-high data rates, spectrum availability, energy efficiency, and secure connectivity means that alternative to congested RF spectrum, particularly below 40GHz, can be useful. Optical wireless technologies—including visible light, infrared, and ultra-violet—enable high-speed data transmission, low latency, and high quality of service.[30] These technological demands require the development of new hardware, which the FNS programme supports.

One further area of development is for energy-efficient semiconductor amplifiers for software antennas, focused on significantly improving existing semiconductor technologies and circuit concepts. A number of successful prototypes of chips and other hardware components have now been realised, and a number

[29] *Nine takeaways from early 6G research*. (n.d.). Ericsson.Com. Retrieved October 7, 2025, from https://www.ericsson.com/en/blog/2023/2/6g-early-research-global-takeaways

[30] Nguyen, H., Al-Imran, & Jang, Y. M. (2025). Survey of next-generation optical wireless communication technologies for 6G and Beyond 6G. *ICT Express*, *11*(3), 576–589. https://doi.org/10.1016/j.icte.2025.04.006

are in production. An example of this is a power amplifier that operates in the new FR3 band (15 GHz) and has high energy efficiency.

3.3. Support for digital autonomy in programme line 2: innovation in software

In terms of software development around mobile network infrastructure, the Netherlands is not home to any large players. Nonetheless, Dutch companies have a good reputation in software development, especially in innovative spaces like AI—a position that is driven by tightly integrated academic, industrial, and governmental collaboration. Much of the ways in which PL2 supports digital autonomy lies in supporting open-source and locally run tools that help circumvent vendor lock-in and the need to rely on hyperscalers. It leads to a two-pronged approach:

1. Develop software modules to commercialise
2. Aim for interoperability through open source and standards to prevent lock-ins, hence creating room for software modules from new players like those that could come from FNS

As an example, interviews with FNS researchers highlighted that with regards to AI, projects tend to prioritise the use of LLMs that can be run in-house, offering more control over the data sharing and performance of the model. This acute awareness among the FNS researchers can be seen when selecting the appropriate LLMs and looking at trade-offs in finding the best to use; however, digital autonomy is not always considered as their key priority. In addition, FNS is open about its dependency on NVIDIA for the most powerful AI chips in the 6G network—and future phases of the project will seek to replace NVIDIA by European alternatives. While this dependence is not unique to FNS, with many other hyperscale's being similarly locked into their technology, the reliance on the US tech giant is on the FNS radar.

One of the challenges in this programme line, which was also highlighted in the interviews conducted is that while open-source components provide a viable alternative and allow for mobile providers to build most of their network in-house, it also ignores the fact that many providers simply do not have the capacity or in-house knowledge to successfully work with a combination of independent components. Smaller providers, for example, outsource much of their operations, such as billing and configuration services.[31] PL2 looks to develop interoperability and mix-and-match options by developing DevOps platforms and orchestration mechanisms that combine software from different sources, including open source. The challenge is to make this practical and feasible so that operators and system integrators can use this option in a way that is competitive with larger integrated solutions.

3.4. Support for digital autonomy in programme line 4: strengthening the ecosystem

While the FNS programme fits the model of helping Dutch companies to be globally competitive and thus ensuring long-term economic and geopolitical relevance, it still engages in activities that support a different pathway to digital autonomy—namely in pushing open standards and interoperability. FNS

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[31] *How Telcos Can Find the Right Balance in the Cloud*. (2024, February 26). BCG Global. https://www.bcg.com/publications/2024/how-to-find-the-right-balance-in-the-telco-cloud

explicitly focuses on open architectures and interoperability. This includes support for Open RAN technologies, replacing proprietary base station equipment with interoperable modules using open interfaces. It also includes investments in a complete sovereign cloud stack with container-based standard interfaces for core network functions. These activities align with PL2, which also looks to push open-source standards and smaller scale testing of ‘independent’ solutions.

As an example, within FNS, there has been work conducted to develop own-cloud platforms, using European equipment providers, including for the radio network. Using European equipment, it should be noted, was not an FNS requirement, but because the testbed is aimed at European companies, it seems to naturally favour European software and a sovereign cloud in its activities (even if some hardware components, such as CPUs from AMD and Intel, remain non-European). Of course, not all components are European, with collaborations happening with Japan and Taiwan to get access to particular chips, but the components that can be European, are.

In addition to helping companies to innovate and test products and services, the programme also supports the next generation of engineers that would be essential to maintain the health of the ecosystem. FNS supports more than 50 doctoral students and includes a large effort with HBO/MBO around the testbed to understand the technical and ecosystem aspects of 6G.

4. Observations and suggestions

The following outlines discussion points and preliminary recommendations around how digital autonomy might be more directly addressed within FNS. We note that while interviews were conducted, this paper is not a full evaluation of the FNS programme, and as such, can only make general suggestions.

4.1. Digital autonomy by design rather than by outcome

FNS has interconnected goals to promote the earning power of the Netherlands and enhance its digital autonomy. When FNS outputs lead to more productive and competitive industrial leaders, these goals can re-enforce each other, as addressed earlier in this paper. However, ask programme managers whether digital autonomy is a primary driver and selection criterion for projects covered under FNS, and the answer is not a straightforward yes. Within these two goals, earning power (and innovation) seems to be the more pressing driver for participants and programme managers, likely because this is the main goal of the growth fund as a whole. Achieving the outcome of greater digital autonomy relies on projects successfully enhancing the competitiveness of local companies. FNS achieves its goals around digital autonomy as an outcome of its activities, but it could more strongly embed digital autonomy as a selection criteria and requirement for projects that it runs.

This point is further exemplified in a brief analysis of the projects running under the Test Bed in WP4. One project runs a fully independent cloud, using wherever possible European equipment, such as for the radio network. But, when asked whether the use of European equipment was a requirement, the answer came back that because the programme is aimed at European companies, it naturally leads to the use of European equipment. This shows that the programme supports autonomy well in a practical way, but more as an outcome than by design.

This is not a critique of how FNS addresses the subject of digital autonomy in its outputs, but it does lead to questions about whether a more robust foundation could be considered as the programme moves forward. Innovation funding tends to prioritise optimisation and novelty, and for innovation funding focussed on higher TRLs, this can mean development of new products for a global market. But digital autonomy, by its nature, can involve understanding suboptimal solutions with fewer risky dependencies. These are not necessarily going to be technologies and solutions that will dominate global markets, but are suboptimal solutions that may have lower performance and higher costs (though, of course, there remains the possibility that digital autonomy policies could drive market demand in the future). The FNS programme has not been designed to examine these kinds of trade-offs.

As such, some of the outputs from FNS could focus more clearly on resiliency and dependencies within the stack, which would lead to projects more in line with the principles of digital autonomy. This could be run under a programme exploring, for example, disaster management and cybersecurity,[32] testing what would happen with 6G networks where key components would no longer be available and what alternatives would be available: some of these elements are already being planned for phase two of FNS. While risk assessments would be useful, given the character of the FNS programme, this research could be focused on understanding the technical options available to operators and understanding better the necessary trade-offs.

[32] The point here is that research under a framework of diaster management and cybersecuirty—topics for which there is a lot of attention—are more tangible than those captured by a more general label of 'digital autonomy'.

4.2. Consider reassessing the current portfolio

Following from the previous point, FNS currently conducts research & development work that both supports open standards and helps companies to develop new technologies that can be used in both local and global markets. There is a good argument for a mix to ensure that leading companies can maintain their position, while opening possibilities for start-ups and scale-ups to grab new opportunities to grow. This is, arguably, a strength of the programme that allows it to explore and test options that fit both views of how to support digital autonomy. At the same time, if FNS chose to more concretely orient itself towards the question of digital autonomy, it might wish to assess activities not just from an earning power perspective, which leads it indirectly to digital autonomy, but also more to digital autonomy options that lead to options for European hardware—such as around specialised energy-efficient chips for edge AI—and software in the RAN and core parts of the network, so that government policies can be aligned towards this goal, underpinned by technical and commercial options.

4.3. Strengthen contributions to open source

FNS actively contributes to developing 6G standards within 3GPP, offering concrete use cases and technical specifications that are ready for implementation as standardization progresses. FNS also contributes to several open-source initiatives. Still, this effort could be strengthened. An example is the FNS work on the open-source APIs—such as those from the CAMARA Project under the Linux Foundation. These are crucial to ensuring application-level interoperability and avoiding infrastructure lock-in.

While testing how open-source components such as CAMARA and Sylva may help facilitate use cases, FNS does not seem to contribute to these projects. In future iterations of this project, it may wish to dedicate resource to contributing enhancements based on unmet requirements from the use cases in the seven priority areas, such as data chains for drone detection and XR experiences. This can help to ensure that 6G will support the use cases where the Netherlands may have some competitive advantage.

Additionally, open-source orchestration solutions for 6G networks and embedded AI applications present a strategic opportunity to harness autonomy and operational efficiency. Projects like Sylva, also under the Linux Foundation, aim to facilitate interoperability between container layers and telco infrastructure. Testing Sylva within the PL4 testbed is advised to assess its suitability, with contributions encouraged if current specifications fall short.

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