Connectivity

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Introduction

In today's rapidly evolving digital world, connectivity serves as the essential foundation for innovation, productivity, and societal progress. As the demand for real-time data, low-latency services, and always-on access continues to rise, the networks that underpin our digital lives are undergoing a profound transformation. Connectivity is no longer just about being online—it is about the quality, intelligence, and sovereignty of the connections that power our homes, cities, businesses, and governments.

This chapter explores three key dimensions of the current transformation in connectivity: Access Networks, Intelligent Networks, and the growing significance of Digital Autonomy in a geopolitically fragmented world.

The journey of connectivity begins at the edge—with Access Networks. These networks form the critical "last mile" between users and the broader internet. Wireless technologies like Wi-Fi, Bluetooth, Zigbee, and cellular networks (4G, 5G) are essential enablers of modern digital environments, from smart campuses to industrial IoT deployments. When paired with global fiber infrastructure, these wireless protocols enable seamless end-to-end data pathways that are foundational for scalable and secure digital ecosystems. Harmonizing these networks on a global scale ensures not only efficiency and interoperability but also opens new possibilities for innovation and inclusivity across regions.

Beyond raw network access, connectivity is being revolutionized by intelligence. Intelligent networks are transforming how operators manage, optimize, and evolve their infrastructures. The shift from manual processes to software-driven orchestration is enabling greater automation, real-time analytics, and responsiveness to dynamic user needs. AI-powered operations (AI/Ops), digital twins for network simulation, and integration with cloud-native environments are now critical to managing the growing complexity of digital services. These intelligent networks also help address ecological challenges by embedding energy efficiency into both hardware and software, enabling sustainable scale.

Finally, the strategic importance of connectivity is rising in the realm of digital autonomy. As global tensions reshape alliances and supply chains, nations are rushing to secure control over their digital infrastructures. Investments in submarine cables, fiber, satellite systems, and alternative data routes reflect a broader desire for continuity and resilience. At the same time, Big Tech's dominance in global data flows raises complex questions around sovereignty and cybersecurity. The future of our digital connectivity landscape will be shaped by the convergence of ubiquitous access, intelligent network management, and strengthened connectivity resilience.

TREND #1

Fixed wireless access

Public Values

Autonomy	Freedom of choice | Independence | Privacy
Justice	Equity | Inclusion| Integrity | Sustainability
Humanity	Well-being

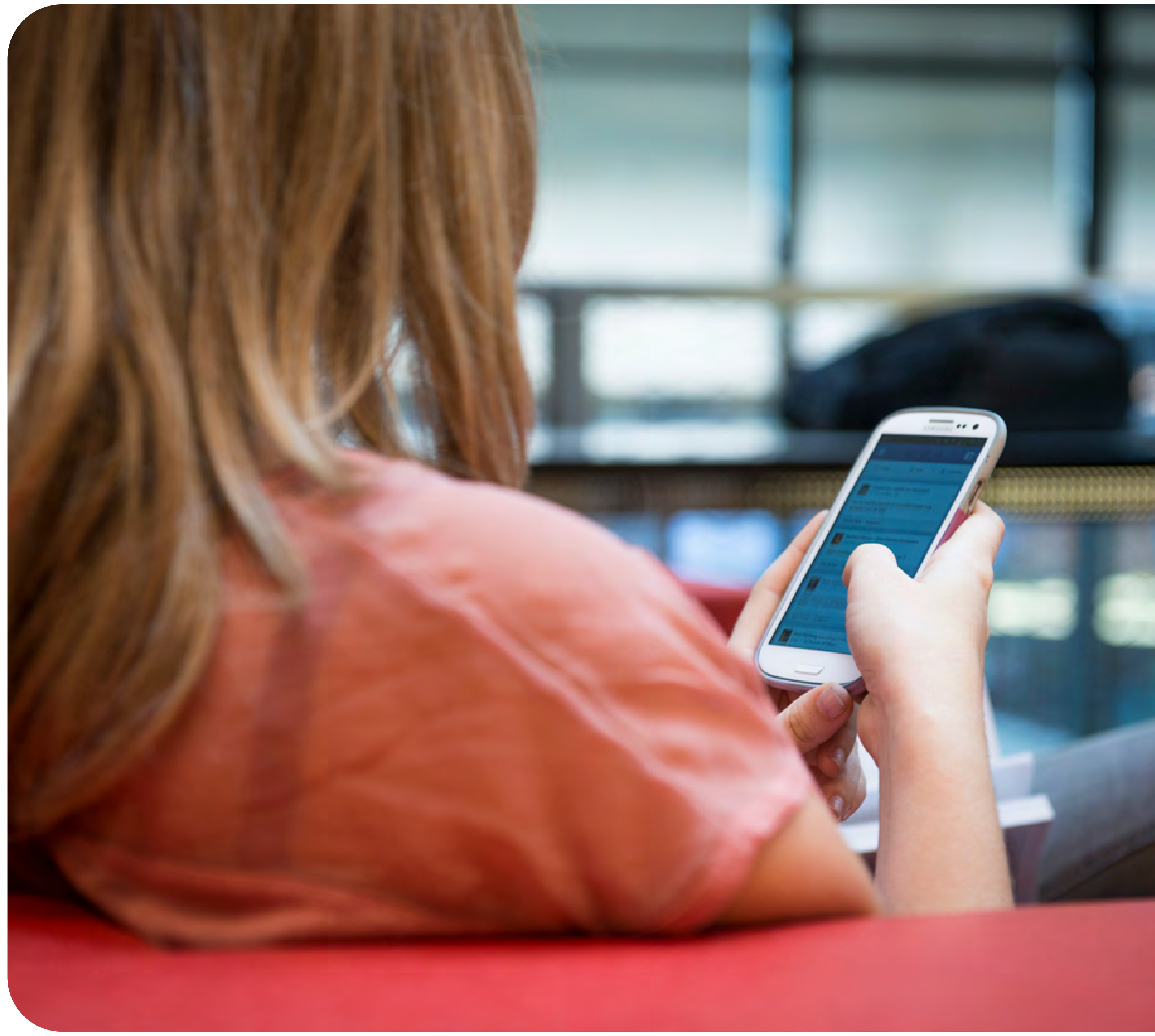
Maturity WATCH PLAN **ACT**

Drivers

Globalisation; Connectivity & interaction; Concentration of wealth & economic inequality

Fixed Wireless Access (FWA) is an alternative to wired access to the internet, particularly in areas where fiber or copper infrastructure is too expensive or logistically difficult to deploy. Modems and routers for FWA are commercially available in the Netherlands and some Dutch mobile operators offer an all-you-can-eat mobile subscription plan that together serves as a connection to the wired infrastructure. In addition, the recent developments in the 5G standards will enable non-terrestrial networks (comprised of various satellites) to integrate with the 5G networks on the earth surface. This will increase the support across mobile handsets and chipsets and improve performance. It may serve as an alternative to the products and services of mobile operators.

The use case for institutes of research and education includes research activities in rural areas and/or internet access for a branch office with no stringent network requirements that is in an area with no fixed network infrastructure.



SIGNALS

Ecosystem collaboration drives innovation (ericsson.com)

5G FWA and its impact on fixed broadband: the trends and strategies driving momentum (gsmaintelligence.com)

TNO - 5G-EMERGE: Satellite-enhanced media delivery at the edge (publications.tno.nl)

"FWA adoption is driven by demand for high-speed alternatives to fixed broadband and national initiatives aimed at reaching underserved areas and supporting smart city ambitions."

- **Ericsson Mobility Report**, June 2025

IMPACT

Education & Research

A 5G router could be considered that supports Wi-Fi with WPA2-enterprise (or solve this through the Wi-Fi deployment in the branch office) such that students, staff and researchers can connect to the network via eduroam as they are used to in other locations.

Operations

In the case an organisation thinks about opening a small remotely located branch office that does not require stringent network requirements (e.g. no exams) it should consider a FWA solution for connecting that office to the internet.

TREND #2

The battle for airwaves

Public Values

Autonomy	Freedom of choice | Independence
Justice	Equity | Inclusion | Sustainability
Humanity	Well-being

Maturity WATCH **PLAN** ACT

Drivers
Connectivity & interaction; Compliancy & regulation; Digital transformation; Globalisation

Frequencies for mobile communications are a limited natural resource. Harmonization of frequencies across the world realizes that network operators, equipment vendors and others leverage global economies of scale such that smartphones and laptops can connect everywhere in the world to the network in the same manner.

In 2021 the EC assigned the lower part of the 6 GHz band to Wi-Fi. As a result, we can use Wi-Fi 6e and Wi-Fi 7 in the Netherlands. The current debate is on the upper part of the 6GHz band. Some regions such as USA, Canada, Brazil, and South-Korea assigned this frequency band to indoor Wi-Fi usage and are considering outdoor usage. Other countries such as China have allocated the complete (or only the upper part of the) 6 GHz band to 5G/6G services.

Wi-Fi requires at least 320 MHz of the upper 6 GHz band for making proper design plans in the near future. The EC is currently engaged in making policy recommendations on how to best organize the future use of this band in Europe. Some countries such as France and Germany opt for assigning the upper 6 GHz band to 5G/6G.

SIGNALS

Public consultation on the draft RSPG report on 6G strategic vision (radio-spectrum-policy-group.ec.europa.eu)

Upper 6 GHz band - Overview of current and potential future use in The Netherlands (repository.tno.nl)

Wi-Fi Alliance - 6 GHz Wi-Fi®: powering sustainable connections (wi-fi.org)

RCR Wireless - Europe's 6 GHz spectrum tug-of-war (analyst angle) (rcrwireless.com)

"The EU's decision on the upper 6 GHz band will directly affect progress on the Digital Decade 2030 goals — bridging the digital divide, enabling smart cities, and ensuring Europe remains competitive in global technology leadership."

- **Adlane Fellah**, RCR Wireless

IMPACT

Education & Research

Benefits of the usage of the 6 GHz band include the enabling of faster, lower latency, and more reliable connections used by students and researchers for e.g. digital classrooms, video conferencing, and online learning.

Operations

Wi-Fi professionals require at least 320 MHz of the upper 6 GHz band to make a proper Wi-Fi design in the 6 GHz band at a medium to large building of an institution. If this capacity is not available, the risks include encountering similar problems as experienced in the past with the 2.4 GHz band, resulting in unstable connections and applications that operate sub optimally. By the end of 2025 the Ministry of Economic affairs ends their plan for and integrated vision for the upper 6 GHz band. Consider persuading them to allocate at least 320 MHz of the upper 6GHz band to Wi-Fi.

TREND #3

AI/Ops, digital twinning and the emergence of the LLM in network operations

Public Values

Autonomy	Privacy | Freedom of choice | Independence
Justice	Accountability | Inclusion | Equity | Transparency | Integrity
Humanity	Safety

Maturity WATCH **PLAN** ACT

Drivers
Automation & AI; Connectivity & interaction

Generative AI (GenAI) has become a transformative tool across many businesses including the networking sector. AI agents such as Retrieval-Augmented Generation (RAG) are being deployed to automate tasks, enhance customer interactions, and enable intuitive data exploration. Vendors are now embedding large language models (LLMs) into Network Management Systems (NMS), allowing users to manage infrastructure through natural language interactions. This has created new business opportunities for vendors, as many customers previously turned to open-source network management tools to avoid vendor lock-in —especially in wide area networks (WANs) managed by Internet Service Providers (ISPs).

Notably, all major networking vendors have introduced AI-enhanced NMS platforms. Meanwhile, the open-source community is working to close the gap, with prototypes emerging from groups like the Network Automation Forum and National Research and Education Networks (NRENs). In the Netherlands, the Future Network Services (FNS) National Growth Fund project is exploring AI/Ops and digital twin technologies to simulate network changes before deployment. However, practical digital twin implementations remain challenging yet due to limitations in replicating hardware behavior and real-world traffic loads.

AI-driven tools can boost operational efficiency, but organisations must weigh the risks of vendor lock-in versus investing in open-source skills and flexible architectures.

SIGNALS

Development of various AI assisted network management systems

Event-driven automation: reliable, simple, adaptable data center network automation (nokia.com)

HPE acquires Juniper: Leading the convergence of AI and networking (mist.com)

Top 10 AI-powered tools every network engineer should know (blog.octanetworks.com)

Digital twins and AI in networking

Intelligently orchestrating programmable 6G networks of the Dutch national growth fund initiative 6G Future Network Services (futurenetworkservices.nl)

What AI means for networking infrastructure in 2024 (forbes.com)

Toward building a digital twin for network operations and management (ieeexplore.ieee.org)

Network orchestration of advanced networks

Shifting from single domain automation to multi-domain orchestration (itential.com)

Decentralized AI-control framework for multi-party multi-network 6G deployments (wimnet.ee.columbia.edu)

“SURF’s ambition is to have an intelligent network capable of correctly assessing incidents and fixing them in real-time by using AIOPs. As a community we should collaborate and develop the algorithms we need to run the network out in the open and make sure they are accessible to all.”

– **Peter Boers**, SURF

IMPACT

Education & Research

Higher-quality network services are crucial for various types of research and education activities that rely on data access and data exchange. For example, this would be critical for online student lessons or high-throughput data exchange to execute scientific experiments or perform scientific analysis.

Operations

- AI-driven tools can improve operational efficiency, but institutions must balance the risks of vendor lock-in with investments in open-source skills and flexible architectures for long-term sustainability.
- High-quality network services require a professional incident management approach to effectively reduce the Mean Time to Acknowledge (MTTA) and the Mean Time to Repair (MTTR) following an incident. Leveraging AI in Network Management Systems (NMS) can significantly reduce MTTA and MTTR.

TREND #4

Power usage and ecological footprint

Public Values

Autonomy	Independence
Justice	Sustainability | Accountability | Transparency | Equity
Humanity	Well-being

Maturity WATCH **PLAN** ACT

Drivers
Energy supply & demand; Connectivity & interaction; Clean water demand; Biodiversity

The energy transition has increased scrutiny on the energy efficiency of digital infrastructures. Rising energy costs and limited power grid capacity have put pressure on data centers and network operators to reduce power and cooling demands. Simultaneously, as Moore's Law slows, chip miniaturization faces physical limits, making efficiency gains from smaller nodes (e.g. 5nm to 3nm) increasingly marginal. With bandwidth demand growing at 25% annually, future performance improvements will depend on higher power input, intensifying thermal management challenges.

To address the need for energy-efficient operations, adaptive energy-saving strategies are being explored. Such strategies include approaches such as router tuning and powering down unused systems supported by standards like Energy-Efficient Ethernet and green computing practices. As traffic patterns are predictable, automated energy optimization could yield major savings.

In the Netherlands and beyond, rising power and cooling costs are prompting institutions to consider energy-efficient hardware for long-term investments. Devices with built-in power-saving capabilities could offer lower total cost of ownership over their 5–10-year lifecycle, aligning performance needs with sustainability goals.

SIGNALS

Energy saving in hardware

Saving energy on Juniper's PTX routers with PFE (packet forwarding engine) power off (community.juniper.net)

Nokia and Orange announce extreme deep-sleep energy-power-saving mode at Mobile World Congress 2024 (telecomtv.com)

Standards & green computing

What is energy efficient internet? (fs.com)

From awareness to action: Evaluating green computing engagement among IT professionals for effective policy design (journalwjarr.com)

"We have long advocated the need for ecosystem cooperation if we are to reduce our industry's environmental footprint and make our networks as energy efficient as possible."

- **Arnaud Vamparys**, CTIO, Orange Europe

IMPACT

Education

- Education programmes should be aware of the sustainability implications of data centres and large-scale data network services regarding power consumption and cooling demands.
- Prepare students for careers in green tech, smart cities, and general awareness of good sustainable computing practices.
- Integrate energy efficiency topics into network engineering, IT management, and sustainability courses.

Research

- Research groups should be aware of the sustainability implications of data centres and large-scale data network services regarding power consumption and cooling demands.
- Sustainability-oriented innovation will drive further research in low-power hardware, software-defined networking (SDN), and AI for energy optimisation.
- Actively seek out funding opportunities for grants that are aligned with climate action and sustainable development goals.

Operations

- Institutions should include sustainability parameters, like power consumption and cooling requirements, in their procurement and operations policies, alongside hardware performance needs and total cost of ownership.
- Consider the significant bandwidth growth that is expected over the next decade when making network design choices regarding service and hardware requirements.

TREND #5

Fibre optic networks: strategic infrastructure for the knowledge economy

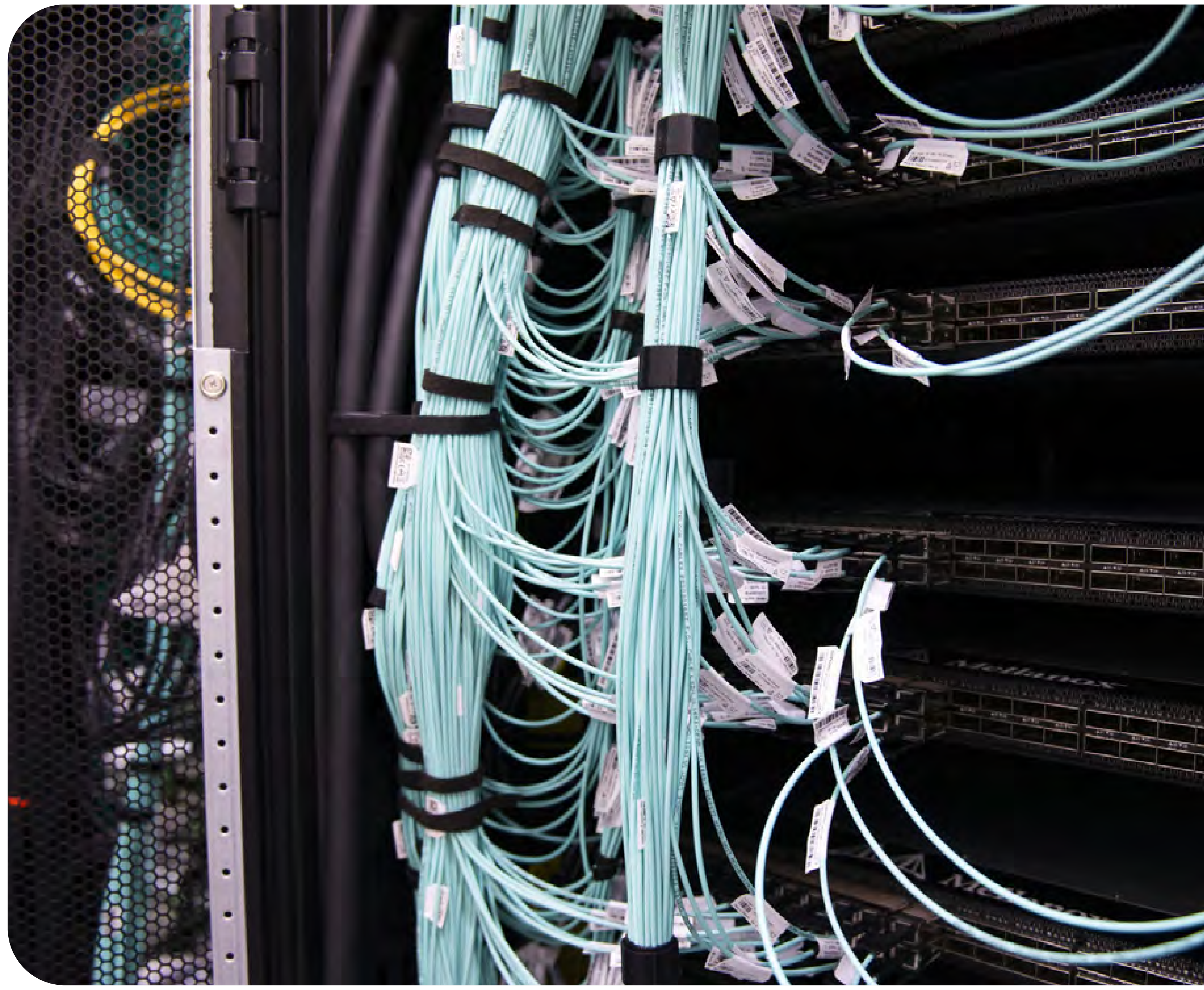
Public Values

Autonomy	Privacy | Independence
Justice	Integrity | Transparency | Accountability | Sustainability
Humanity	Safety | Well-being

Maturity WATCH PLAN **ACT**

Drivers

Globalisation; Connectivity & interaction; Geopolitics & (digital) sovereignty; Critical infrastructure



Intercontinental fiber-optic networks serve as the foundation of today's global digital infrastructure, delivering high-speed, low-latency connectivity vital for economic growth and national security. Countries are rapidly expanding their fiber deployments to improve digital performance and reduce dependence on foreign-controlled infrastructure.

In addition to their traditional role, fiber networks are becoming strategic assets through the advent of fiber sensing technology. This innovation allows fiber-optic cables to detect seismic activity, monitor ocean conditions, and identify physical disturbances—enhancing both infrastructure security and environmental monitoring.

However, this also raises concerns about data privacy and unauthorized access. On a geopolitical level, there is increasing urgency to diversify global data routes, as a large portion of traffic still transits through vulnerable chokepoints like the Suez Canal. In response, nations and corporations are exploring alternative subsea paths, including routes through the arctic, made feasible by melting ice. These routes offer improved redundancy and lower latency between continents but introduce new strategic tensions. As fiber networks evolve into tools of geopolitical leverage, ensuring their resilience, sovereignty, and data protection becomes critical.

SIGNALS

Developments in fibre cable technology

NEC and NTT successfully conduct first-of-its-kind long-distance transmission experiment over 7,000km using 12-core optical fiber (subtelforum.com)

Distributed acoustic sensing in submarine optical fibers (spiedigitallibrary.org)

Nationalisation of commercial fibre infrastructure

'Strategic' submarine telecom cable manufacturer ASN nationalised by France (lemonde.fr)

Arctic fibre infrastructure

Built-in resilience for arctic subsea cables (nordu.net)

Arctic Fibre is a three-phase submarine cable project, planned to connect Asia, Canada and Europe through the arctic ocean (submarinenetworks.com)

Global interest in undersea cables

The geopolitics of undersea cables: underappreciated and under threat (tatic1.squarespace.com)

Whitepaper: The new geopolitics of undersea cables (hinrichfoundation.com)

IMPACT

Education

- Geopolitical tensions surrounding undersea cables could disrupt digital access services, impacting online learning and cloud-based education tools.
- Regions with weak cable infrastructure or limited alternative routes are most affected, widening the digital divide between well-connected and under-connected institutions and learners.

Research

As data flows through politically sensitive regions, there is a heightened risk of surveillance, data interception and sabotage, which can impact how researchers collaborate and share sensitive information internationally.

Operations

- Investment required in redundant connectivity, local cloud services, and stronger cybersecurity to maintain operational continuity amid potential cable disruptions or surveillance risks.
- Transferring sensitive academic and student data through geopolitically sensitive routes raises the need for compliance with data protection laws, increasing legal and technical workloads.
- Current geopolitical dynamics encourage institutions to align with national priorities and enhance digital sovereignty by reducing dependence on foreign infrastructure and supporting local innovation.
- Well-connected institutions provide room for collaboration and access to knowledge, so informed value-based decision-making for investments in critical digital infrastructures remains essential at all levels.

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