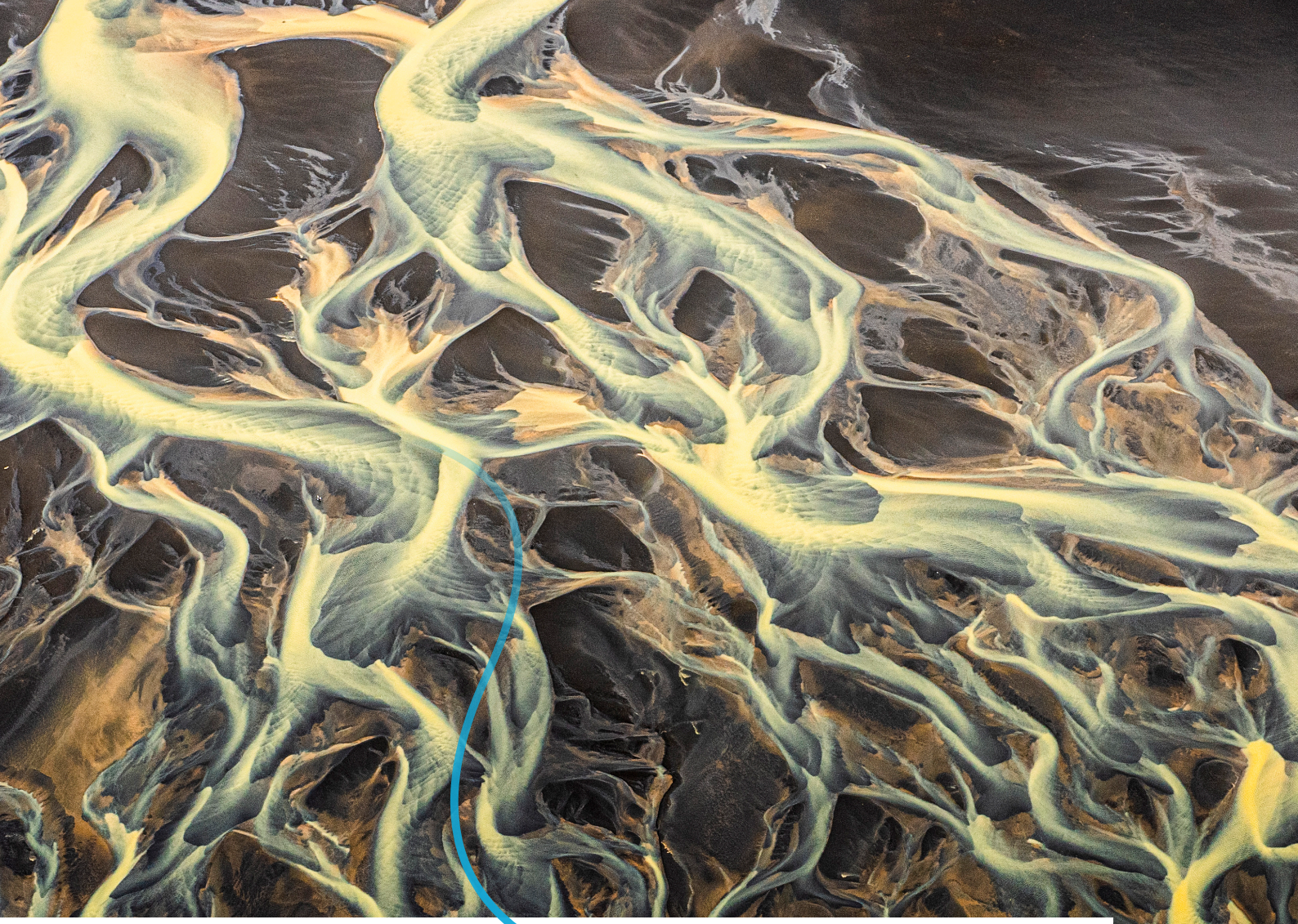


5G connectivity

Transforming critical national infrastructure

Capgemini

Developing intelligent industry for critical national infrastructure over the decade

Connectivity is the backbone of critical national infrastructure (CNI) that ensures resilient, secure, and seamless operations of all the essential services across transportation, energy and utilities, healthcare, defense, and public safety.

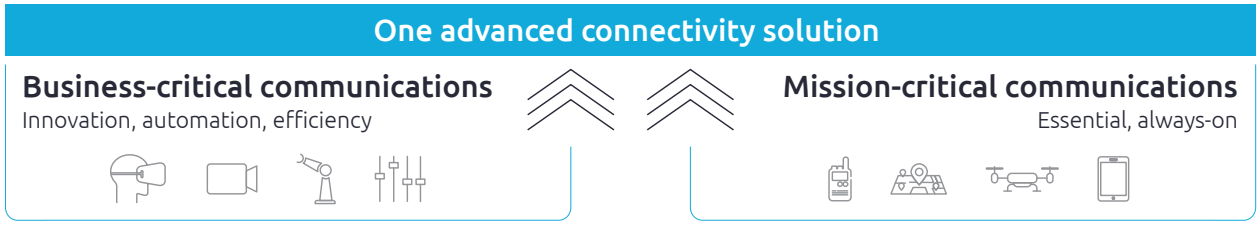
Threats such as those targeting the 2024 Summer Olympic Games highlight the vulnerability of infrastructure in a complex and interconnected world. As CNI operators accelerate the adoption of digital technologies to enhance resilience, reliability, scalability, and collaboration, the load on underlying networks and their functional requirements are intensifying.

> The need for best-in-class, reliable connectivity is more relevant than ever.

Connectivity for CNI today encompasses a plethora of many different solutions:

- Fiber for business-critical and static applications
- PMR/Tetra for mission-critical applications
- LoRaWAN® and Nb-IoT to monitor and track assets
- Satellite for marine communications and less accessible areas
- Wi-Fi for collaboration and coordination.

5G connectivity represents a significant leap forward, offering guaranteed quality of service, flexibility, multi-device support, massive IoT connectivity, and extensive geographic coverage. Amongst all CNI organizations, the global public safety community has been a rapid and one of the earliest adopters of LTE/5G technologies, notably for mission-critical communications (MCx).[1] This adoption underscores the value of a ubiquitous, secure, and compliant mobile network capable of unlocking new advanced multimedia services and providing a panorama of new use cases, while rationalizing costs. It also sparks a broader discussion about adopting the same paradigm and transitioning to IP-based communications across a wider range of CNI organizations, sharing similar requirements for both mission and business-critical communications.



[1] *Capgemini, "Transitioning public safety critical communications to LTE/5G MCX"*

The time has come to shift the perception of connectivity from a commodity to a crucial accelerator of large-scale digital transformation. Embracing this perspective will drive the adoption of a unified, advanced connectivity platform, instrumental for materializing Intelligent Industry. This can empower CNI operators to:

1. **Enhance their service offering:** Evolve into service providers and offer new experiences through app subscriptions, advertising, and AI/data analytics.
2. **Improve operational efficiencies:** Automate maintenance of assets and reduce breakdowns, cost, and environmental impact.
3. **Strengthen and simplify surveillance and security monitoring:** Mitigate this permanent challenge with advanced technologies such as IoT, multimedia communication platforms, and drones or robots.
4. **Prepare for adoption of AI at scale:** Develop specific networking products that cater for the high cybersecurity, reliability, and traffic demands of the sector as part of a broader infrastructure modernization effort for massive adoption of AI.

Based on the advances made in public safety with the adoption of LTE/5G, other CNI sectors could also realize significant gains, but they lack a unified voice for a single best-practice connectivity recommendation. Where public safety is fundamentally mobile-centric, making LTE/5G a prime candidate to enable multimedia services across a wide area, for other CNI sectors, mobility is only a partial requirement, with many operations requiring diverse connectivity solutions.

This complicates the pursuit of the ideal connectivity standard: should it be a multi-system landscape with various single-purpose solutions or a rationalized system with a unifying solution?

There are multiple considerations when seeking an optimal solution:

- **Business:** Prioritizing investments as part of a broader digital transformation roadmap while ensuring satisfactory and immediate return- on- investment.
- **Organizational:** The implementation and use of new technologies requires new skills, resources, training, and effective change management. A user-centric process requires understanding and prioritizing of the needs of users.
- **Operational challenges:** Ensuring the continuity of always-on service in accordance with security, compliance, and regulation standards.
- **Technology:**
  - Interoperability: Ensuring seamless integration with legacy IT systems and devices, while maintaining a flexible system that is future-proof and forward compatible with technological advancements.
  - Cybersecurity: Ensuring the highest standards of protection while adopting innovative solutions and reducing over-engineering.
- **Ecosystem:** Due to regulatory constraints, complex and specialized infrastructure, and collaboration with state authorities, an elaborate and specialized ecosystem is in place to cover telecom needs for CNI. To accelerate any technology modernization, a collaborative framework with product suppliers, telecom service providers, and engineering companies needs to be in place. 5G goes beyond connectivity. It is the fabric of digital transformation across multiple sectors, bringing together IT, OT, and NT for smart connected services.

A closer look at 5G in CNI sectors

Transportation

The transportation sector, with large operational areas, inherent mobility, and complex logistics, embarked on experimentation with 5G in the early days of its availability. This phase coincided with the COVID-19 pandemic, which posed significant challenges to the sector and influenced the adoption of many digital technologies to develop efficient and future-proof organizations. Given the diversity of transportation subsectors, each comes with a different adoption curve of 5G.

Use cases for transportation powered or enchanced by 5G

Indicative, not-exhaustive list

Private / Public / NaaS* 5G	MCx	Edge Computing
Open road autonomous mobility and C-V2X		Automation streaming repetitive tasks to increase efficiencies
Real time monitoring of assets and people: particulary in sensitive sites and smart quality control / visual inspection		Real-time information services for flight / train services & availability of infrastructure
Connected worker with digital tools (wearables, AR/VR, smart devices) for collaboration, operations, safety		Connectivity services to tenants, passengers, patients, employees
Remote assistance: providing support to technicians and operators in their daily activities		Predictive maintenance: utilizing sensors to continuously monitor noise, vibrations, temperature, and other parameters
Enhance security and situational awareness: ensuring continuous real-time monitoring and rapid response to potential threats and Smart Surveillance and inspection of vast estates with HD cameras and drones		

**Network as a Service*

Air and sea

5G proofs-of-concept for ports have been the most prominent examples of early adoption. Trials demonstrated how advanced wireless technology can streamline complex operations through automation and digital workforce augmentation. They also showcased how the cost of surveilling vast estates with connected cameras and drones could be reduced while supporting many new digital experiences and transforming ports into smart environments and social hubs.

Similarly, airports have approached the technology with curiosity and evaluated its potential for addressing their operational needs and new monetization routes.

The COVID-19 pandemic separated the evaluation from the implementation period. Since 2024 there has been significant acceleration of adoption with deployments focusing on:

- Enhancing coverage for a superior passenger experience.
- Transitioning from legacy PMR/Tetra technologies to mission critical communications (MCx) over 5G for critical coordination of field workers.
- Increasing coverage in large airside and landside areas for automation, digital collaboration, and security monitoring.

Road

Adoption of 5G for vehicles on open roads has been slower and constrained. The lack of a common global system and stringent local regulations are challenging the transition from successful trials and pilots to more widespread adoption.

The 5G Open Road program[2] is a French initiative with government support and 17 academic, public, and private actors. It fostered a pilot zone to test technical and commercial viability of connected and automated mobility services and proved successfully the potential of the 5G-powered C-V2X standard.[3] Similarly, with a focus on telco network interoperability, an MEC[4] live trial was conducted with global players representing car manufacturers, telcos, standards organizations, and technology providers. The conclusion of the trial[5] highlighted the critical role of edge computing as part of the C-V2X stack. Live initiatives like these play a crucial role in energizing the adoption of 5G and edge at scale, drive collaboration across a diverse ecosystem, and effectively mature the international mobility ecosystem.

Rail

Lastly, in transportation, rail could be the pinnacle of potential for 5G. Trials for applications are continuing, and there is a clear line of sight to commercialized and industrialized deployments with multiple opportune areas, especially in rail safety.

Replacement of Tetra and transition to 5G-based FRMCS,[6] planned for 2032, will enable scenarios such as:

- Management of rail yard traffic by control centers through verbal communication with drivers and conductors, which currently relies on radio communication for location and direction
- Onboard cameras that can transmit video to control rooms, significantly enhancing safety and efficiency
- Real-time data exchange delivering greater precision in train traffic coordination, which will be crucial if demand for train travel increases, resulting in more trains on the tracks, shorter distances between them, and tighter safety margins.

5G can accommodate the expanding number of mobile-connected sensors over larger areas while increasing operational efficiency. This enables better monitoring of passenger journeys, dynamic scheduling, and insights from richer data analysis using machine learning and AI. In logistics, goods transport becomes more detailed and accurate, with sensors attached to individual items instead of entire shipping containers.

Beyond these critical functions, rail shares use cases with other sectors developing intelligent industry systems. At the core of this model is automated data communication, applicable to:

- Train condition monitoring for predictive maintenance
- Railway crossing status updates
- Seamless connectivity at high speeds
- Device automation
- Fire alarms and security systems for intrusion detection
- Passenger comfort through monitoring and setting railcar/wagon temperature

[2] *Cerema, 5G Open Road, the revolution on its way, February 2024*
[3] *5G Automotive Association (5GAA): "Cellular Vehicle-to-Everything, or C-V2X,is a connected mobility platform that allows vehicles to interact with their surroundings, such as other vehicles, cyclists, pedestrians, road infrastructure,or mobile networks."*
[4] *MEC: Multi-access Edge Computing*
[5] *Sabella, Dario, et al. MEC4AUTO trials, Global MEC supporting automotive services: from multi -operator live trials to standardization*
[6] *FRMCS: Future Railway Mobile Communication System*

Energy and utilities

From energy production, to distribution, transmission and consumption, 5G shows potential, but also varying levels of maturity. Trials are at early or interim stages, with their objective usually being to assess 5G's value.

Use cases for electricity powered or enchanced by 5G

Indicative, not-exhaustive list

Within the energy sector, production is the frontrunner for adoption. The localized nature of operations and the need to maintain mission critical communications for operations in hazardous conditions or for response to emergency situations makes 5G a prime candidate with satisfactory ROI. This transition facilitates broader operational efficiencies through automation and remote operation of equipment such as valves or cranes. A collaborative deployment with Schneider Electric, Qualcomm and Capgemini, demonstrated this potential.[7] 5G powered the integrated automated control system (IACS), which led to a 200% productivity improvement and a 40% reduction in maintenance. Applications like this can be combined with remote site inspections with 4K secure video streaming to protect workers, reduce downtime and further increase overall productivity.

Beyond energy production, the transformation of energy grids towards more adaptive systems calls for an update of connectivity. Dynamic energy demand, the "prosumer" commercial model, and energy flexibility in home usage require existing networks to offer scalability, flexibility and real-time intelligence.

[7] *Capgemini, Schneider Electric and Capgemini collaborate to accelerate 5G industrial automation, February 27, 2023*

How 5G can bring transformation to energy grids:

- Private networks for substations: Even though the amount of information exchanged between smart meters and the grid is small, an independent and fully dedicated network can facilitate transparency and control between the two allowing for a bidirectional communication that is fundamental for dynamic response.

- Edge computing for substations: A key component in grid modernization is substation transformation into intelligent nodes that can accommodate multi-purpose functions and mixed criticality workloads. A fundamental step in this transformation is the replacement of purpose-built hardware and the adoption of software-defined architectures. Multi-access edge computing can facilitate that while allowing for real-time communications that are essential for closed-loop systems.

- 5G RedCap: The rationalization of IoT connectivity across smart meters, distributed energy resources (e.g., turbines or solar panels), grid sensors, and monitoring systems.

- 5G interoperability with non-terrestrial networks: While the remote locations of grid components and assets leave them fully unconnected today, advances in the 5G standards are defining seamless handover between terrestrial networks and satellite resources, allowing for continuous coverage in these remote locations.

Given the scale and geographic reach of electricity infrastructure, adopting a new connectivity paradigm requires a concrete business case and investment availability. The adoption and standardization of edge computing will enable a smoother transition to connectivity as a platform, rather than as a hardware commodity.

Healthcare

Many experts in the field consider healthcare to be one of the most promising sectors for 5G. The COVID-19 pandemic accelerated its adoption, and many successful initiatives took place globally. Notably, Vodafone demonstrated in Italy how 5G can transmit superior images and videos and, with the help of edge computing, process it in real-time and on the move, thereby reducing response time and distance between patient and doctor.[8]

5G use cases for health care

Indicative, not-exhaustive list

Distributed care continuum	Connected health enterprise	Life science operations
Private / Public / NaaS 5G MCx Edge Computing	Private / Public Neutral Host 5G MCx	Private 5G MCx Edge Computing
• Telemedicine and remote consultation • Smart ambulance, emergency response and remote expert • Assisted living • Remote patient monitoring • Connected care programs	• Telemedicine and remote consultation • Robotic surgery • Enhanced diagnostics with AI and high resolution imaging • Asset tracking & monitoring • Digital and immersive training and guidance • Augmented doctor and connected worker with digital tools for collaboration, operations, safety • Real-time information services and availability of infrastructure (beds, care personnel)	• Real-time monitoring and control • Advanced robotics and automation • Connected worker • Immersive training and remote expert • Enhanced quality control and compliance

Ubiquitous broadband connectivity is a valuable tool for a global healthcare system struggling to cope, as it enables immersive and data-intensive applications to be implemented with confidence. Across the home, primary, secondary, or specialized care, wearables, remote diagnostics, video, and AI with machine learning can contribute to the development of a care continuum by balancing patient load and, therefore, better proactive and reactive health management. Connectivity and digital technologies can decentralize care from overwhelmed A&E departments and enable cutting-edge diagnostics, placing humans at the center of a modernized, digitized, and efficient system.

[8] *Vodafone, 5G connects ambulances to hospitals for more accurate diagnosis and critical treatment*

Capgemini 5G labs and 5G-in-a-box

Capgemini has developed a global network of 5G labs to incubate advanced connectivity solutions, including use cases for CNI organizations and MCx.

As part of this initiative, the 5G-in-box solution enables a smooth transition between mobile network standards and an impactful experimentation period. It facilitates secure and reliable group communication and implementation of advanced 5G use cases, e.g., drone supervision and smart surveillance. It is future-proof, aiming to achieve interoperable connectivity with satellite networks for collaboration with external user groups.

The box can also be used in scenarios with limited or no connectivity. For example, rail workers repairing tracks in the countryside, or in a tunnel, and teams constructing major structures (stadiums, motorways, bridges) where they require efficient, sophisticated communication systems using data and video.

Capgemini advanced connectivity assets and capabilities for CNI

Capgemini, as a leader in Intelligent Industry with a track record in transforming public safety networks, aims to de-risk and accelerate advanced connectivity adoption as a means to a digital and efficient organization. With deep understanding of CNI needs and challenges, Capgemini's multidisciplinary teams of advisors, engineers, and experts on connectivity, cybersecurity and Industry 4.0 bring a tested approach to building complex and critical networks for the decade ahead.

2,100+ 5G projects delivered since 2019, relying on **20,000 telco experts** worldwide

E2E Vision & Strategy methodology with focus on **Digital Transformation**

50+ 5G/IoT use Cases supporting the key industries with **microservices approach**

Communication Service Providers (CSPs), Network Equipment Providers (NEPs), Devices, Hyperscalers, Semiconductors

Transportation, Energy & Utilities, Healthcare expertise and dedicated CoEs

125+ inhouse licensable Software Frameworks / accelerators MEC platform (IEAP), AI: Netanticipate, Drones Networks

Cybersecurity CoE with 6000+ security experts, and CIS team supporting key offers: Define, Protect, Audit, Monitor, Comply

Forums and Standards: GSMA, TIP, O-RAN Alliance, LF Edge, TCCA, TM Forum, 3GPP

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Capgemini is a global business and technology transformation partner, helping organizations to accelerate their dual transition to a digital and sustainable world, while creating tangible impact for enterprises and society. It is a responsible and diverse group of 340,000 team members in more than 50 countries. With its strong over 55-year heritage, Capgemini is trusted by its clients to unlock the value of technology to address the entire breadth of their business needs. It delivers end-to-end services and solutions leveraging strengths from strategy and design to engineering, all fueled by its market leading capabilities in AI, cloud and data, combined with its deep industry expertise and partner ecosystem. The Group reported 2023 global revenues of €22.5 billion.

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