WHITE PAPER

Private cellular networks (4G, 5G) – challenges for wider commercial deployments

From limited roll-out to full-scale deployment seen from a Danish perspective

By:

1. Christian Kloch, Ph.D. Technology Lead and head of Danish 5G Innovation Hub & Testbed
   ckl@forcetechnology.com

2. Radheshyam Singh, Ph.D. Expert in developing M2M/IoT secure and reliable communication, specialist.
   rds@forcetechnology.com

Abstract

The introduction of 5G Standalone (5G SA) marks a significant technological shift for both public and private cellular networks, enabling highly secure, high-performance connectivity. This unlocks new digital use cases and addresses the growing focus on resilience, data sovereignty, and secure critical infrastructure.

Through interviews and dialogue with stakeholders across the value chain (telecom operators, equipment vendors, regulators, system integrators, and end-users), this study maps the ecosystem, identifies key friction points, and analyses why the adoption of 5G SA-enabled services in Denmark has not progressed more rapidly. The findings suggest that several of the Danish challenges reflect broader international trends.

By clarifying the regulatory environment, highlighting commercial opportunities (supported by global data), and providing concrete recommendations for cross-sector collaboration and ecosystem strengthening, this white paper aims to support more informed decision-making and accelerate the deployment of 5G SA-enabled services. Ultimately, unlocking the full potential of 5G SA will require both technological readiness and a coordinated effort to address regulatory, commercial, and organisational barriers.

Contents

5G SA in a global perspective

The introduction of 5G Standalone (5G SA) marks a significant technological shift for both public and private cellular networks. 5G SA enables highly secure, high-performance connectivity with features such as ultra-low latency, high device density and advanced network slicing capabilities that unlock new digital use cases across e.g. logistics, public safety, healthcare, manufacturing, energy and media. The capabilities in 5G will increase with the release of new standards beyond 3GPP Release 16, and as operators implement these features, the commercial and operational potential of 5G will expand further.

Metric / indicator	Value / estimate / forecast	Notes / source
Total number of private LTE/5G network deployments worldwide (excluding PoC) by end of 2024	~ 4,700 networks	Global private-network report (Berg Insight / ResearchAndMarkets) [1]
Global spending on private LTE and 5G in 2025	USD 4 billion	SNS Telecom 2025 [2]
Forecasted private LTE/5G market value by 2029	USD 8.9 billion	Reported 2024 “Private LTE/5G Network Market” forecast. [1]
Number of customer organisations deploying private mobile networks (≥ €100,000) worldwide by Q2 2025	1,846 customers	Latest update from Global mobile Suppliers Association (GSA) as of 2Q25 [3]
Share of customers using 5G (vs. LTE), indicating migration towards 5G	Of the documented private-network customers, 876 (~47%) deploying 5G	Per 2Q25 GSA reporting. [3]

Table 1. Key figures for the 5G market. GlobeNewswire forecasts that the overall market for 5G Private Networks (hardware, software and services) will increase to USD 102.5 billion by 2034.

Globally, the commercial 5G footprint is growing rapidly. By Q1-2025, approximately 2.4 billion people worldwide were connected to 5G with a 23 % GAGR until 2030, making 5G the dominant mobile connectivity technology [4]. As of September 2025, 78 CSPs have launched 5G SA, and 96 operators have expressed interest in launching [5]. **33 CSPs** of those now offer “differentiated connectivity” (e.g. via network slicing), totalling 65 distinct offerings, many targeting enterprise and vertical-market use cases [6]. For the enterprise and private-network segment, the global private mobile network market counts **1,846 customers** deploying private LTE or 5G networks in Q2-2025, and a growing share is transitioning to 5G [3].

Private Networks are no longer fringe experiments: They are gaining traction worldwide and forming part of mainstream vendor and operator roadmaps. In that light, failing to pursue 5G Private Networks could mean losing out on a substantial market wave in industries transforming through automation, IoT and secure connectivity. Furthermore, introducing 5G improves both data sovereignty and security. The study [7] describes the 5G radio and core technology and investigates how many 5G SA-based services were launched by the end of 2024.

However, commercial adoption of many 5G SA-enabled services remains limited relative to the theoretical potential. For services to be commercially applicable, it is also important that the business models are well understood and that the regulation for e.g. autonomous units in the public and drones flying Beyond Visual Line of Sight is in place, in order not to hinder the evolution of new advanced digital-based use cases.

The regulatory environment for private spectrum licensing, local 5G networks and testing of autonomous units (e.g. drones, robots) is evolving. By July 2026, the spectrum 3.8-4.2 GHz is most likely available for 5G Private Networks in Denmark.

5G Private Networks can be one of the enablers to meet the growing focus on resilience, data sovereignty and secure, critical national infrastructure. Whether deployed by enterprises, municipalities or public-private consortia, 5G Private Networks offer a means to address these requirements by enabling more direct control over data flows, local hosting and isolated network slices for sensitive operations.

The supply ecosystem and deployment numbers are rising, but many deployments are still in early phases, underlining that the “enterprise 5G revolution” is far from complete.

The challenges in the 5G ecosystem

The Danish 5G Innovation Hub & Testbed was launched by the end of 2023 as a result of the slow uptake of 5G Stand Alone (SA)-enabled commercial services. The standards for 5G SA (3GPP Release 16) were frozen in 2020 [8], but 5G SA networks were first launched in Denmark in 2025. Even though the 5G SA technology has been available for several years, the use cases have mainly been proof of concepts.

In this white paper, the ecosystem has identified key commercialisation challenges that explain why the uptake of 5G SA-enabled services is slower than expected. Initially, the focus has been on regulation and the ability to describe the business value of the use cases and slow deployment. However, the study also highlights other interesting aspects, some of which are specific to Denmark while others apply globally.

The focus of the white paper is the private cellular networks. A private cellular network can be:

1. A fully Private Network
   The organisation owns the network, leases the spectrum and operates the network

2. A physically hybrid network
   The organisation owns the network and the spectrum, but it can interact with Public Networks

3. A virtual hybrid network
   The organisation can access a share of the network resources under defined conditions – also defined as “Network Slicing”.

By using the broader term *private cellular networks*, this white paper seeks to encompass all relevant architectures, regardless of generation (4G, 5G), thereby providing a more inclusive and practical foundation for understanding current challenges and opportunities in the Danish context.

The 5G SA-enabled services

With the launch of 5G SA capabilities in both Private and Public Networks, a number of commercial services are already available in the global markets, as described in the study “5G mobile networks - Review of the technological capabilities and the commercialisation challenges” [6].

The advantage of 5G SA in a production environment is its ability to support multiple use cases with a single technology. In the case of a production facility, this spans intrusion detection as part of the perimeter surveillance, asset tracking, asset maintenance, product quality inspection, digital twin and cloud data collection, warehouse automation, and connecting workers through cyber-secure wireless connectivity. Furthermore, selecting a European vendor can help ensure a high level of data sovereignty.

When considering the harbour and the increasing demand for dual use cases (both commercial and defence-related), 5G enables full isolation due to its network slicing capabilities. With 5G SA, the same network technology supports asset management, industrial wireless for (semi-) automated operations, drone inspection, voice communication, remote monitoring of refrigerated ship containers, video analytics, enhanced AI security, regulation of traffic flow and intelligent maintenance plans, the latter being important for minimising downtime for the machinery/OT.

With the general roll-out of 5G SA in the Public Network, many of the above services can be replicated in larger areas. In addition, it is worth mentioning that the general availability of 5G SA enables wider appearance of AI-enabled services, e.g. in Non-Destructive Testing (NDT) or more generic services such as robots for cleaning/logistics purposes and drones for general surveillance or supporting emergency services.

The ecosystem

Understanding the challenges related to creating commercially viable 5G SA-based use cases requires an understanding of the ecosystem, the players within it and their relations with each other. Figure 1 shows the most important players in the ecosystem, their roles and the awareness points identified in the interviews.

As seen in the model in Figure 1, there are a range of challenges across the ecosystem (marked with a red lighting icon). The white paper will now uncover these.

Already now, it is worth highlighting some of the identified challenges:

1. Regulators’ policies govern not only the deployment framework for private cellular networks but also the legal boundaries of permissible use cases**.**

2. Telecom operators provide network solutions using their public infrastructure, as well as offering network consultancy services to enterprises.

3. Academic and research institutions contribute by developing standards, informing public policy and enhancing the credibility of emerging use cases through experimental deployments and applied research.

4. The Innovation hub & Testbed plays a critical role in awareness-building and de-risking early implementations.

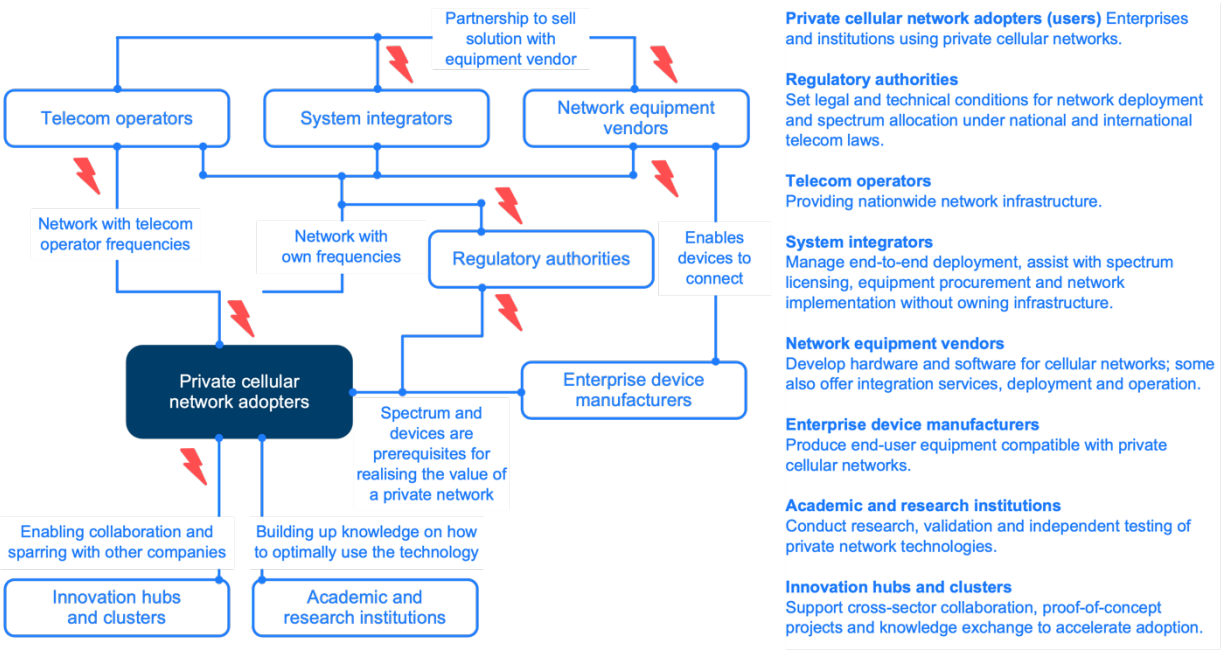

Figure 1. The players in the ecosystem, their roles, and where challenges have been identified.

On top of the identities shown in Figure 1, the service integrator also plays a crucial role in commercialising 5G SA-based services. The service integrator is responsible for creating the service by integrating the data from the different digital parts into various business support systems that can be used to realise the value of the data collected, e.g. for smart manufacturing, smart city, public safety and other use cases. Figure 2 highlights the coordination points (dashed arrows) where closer collaboration is needed to turn pilots into repeatable commercial deployments.

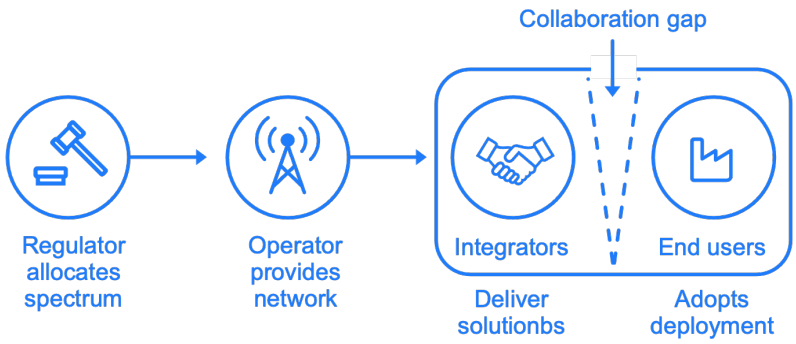

Figure 2. The Danish 5G ecosystem relies on coordinated action across regulators, operators, vendors, integrators, academia and innovation hubs. Collaboration gaps shown by dashed arrows must be bridged to unlock commercial value.

The barriers to viable commercial services on 5G

Despite growing interest in private 5G, several structural and operational barriers continue to slow down commercially viable deployments in Denmark. Insights gathered from ecosystem stakeholders reveal challenges that span technology readiness, organisational alignment, market awareness and regulatory clarity. Figure 3 provides an overview of the key barriers identified, which are further explained in the subsections below.

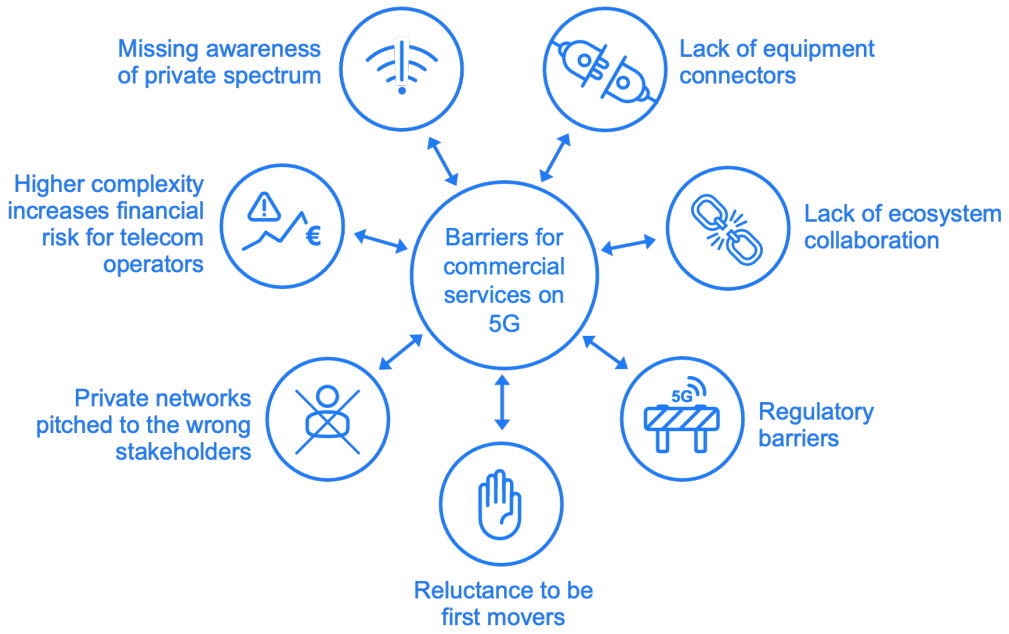

Figure 3. Barriers to commercial services on 5G.

1. Missing awareness of & consulting on private spectrum

Most stakeholders interviewed saw low awareness of private spectrum as the main barrier to private cellular deployment. Many companies do not know that private frequencies can be licensed directly through the Danish Agency for Digital Government, independent of telecom operators. They also assume licensing is expensive, influenced by media coverage of costly national spectrum auctions. In reality, spectrum for Private Networks is far cheaper and may even be granted on a trial basis. With the availability of the frequencies 3.8 - 4.2 GHz from July 2026, a dedicated spectrum will be available for 5G Private Networks similar to what Germany did in 2019 with the frequency band 3.7 - 3.8 GHz.

Finland shows much higher 5G private-network adoption, largely due to neutral third-party system integrators such as Vaiscom and Digita. These firms help enterprises license spectrum, source equipment from multiple vendors, and deploy networks without owning infrastructure. Denmark lacks such players, leaving companies to manage the process on their own and slowing adoption. Semco Maritime is a partial exception in the offshore sector, but no comparable integrator currently supports onshore industries.

2. Higher complexity results in financial risk for telecom operators

Most stakeholders do not see telecom operators as the primary providers of fully private cellular networks using their own spectrum. Instead, operators are viewed as potential integrators or service partners for networks running on enterprise-licensed local frequencies. Operators can also offer hybrid Private Networks via their nationwide infrastructure, which is useful for mobile use cases such as logistics fleets, drones or autonomous machines that need connectivity beyond a single site.

However, operators face structural and commercial barriers. Industrial 5G requires varied virtual network setups that add complexity and financial risk. These services must scale across many customers to be profitable, making operators hesitant to invest in specialised hybrid-network capabilities. Hybrid networks also create a prioritisation dilemma: Giving enterprise traffic precedence can degrade nearby consumer performance. Without clear regulation or compensation models, operators remain cautious about enabling such mechanisms.

3. Pitching private cellular networks to the wrong people (IT vs business)

One of the main consensuses among the stakeholders was that private cellular networks are often pitched to the wrong people. Many vendors and integrators instinctively approach IT departments, expecting them to lead the implementation. However, IT personnel are typically sceptical. One source of hesitation is that private cellular networks are configured differently from traditional enterprise setups, often requiring what is referred to as Layer 3 knowledge rather than the more familiar Layer 2 configurations. Although the complexity is largely front-loaded and manageable, especially for smaller, localised networks like warehouses or ports, IT teams tend to overestimate the difficulty and deprioritise the project. Experts familiar with 5G emphasise that integrating it into existing IT systems is entirely feasible, if IT teams are open to learning and adapting to the new architecture.

Meanwhile, the real decision-makers - those with the problem that cellular connectivity can solve - are often in charge of operations, logistics, security or production. Business stakeholders care less about protocol layers and more about uptime, mobility, coverage and resilience. These are the people who understand the value of fewer cables, seamless roaming and secure infrastructure, and who have incentives to improve efficiency or reduce risk. Several stakeholders emphasised that when Private Networks are framed as a strategic enabler rather than a technical upgrade, interest grows.

To accelerate adoption, the conversation needs to shift. Instead of trying to overcome IT resistance, vendors should target the parts of the business that feel the pain and are motivated to act.

4. Lack of equipment connectors

A critical component of any private cellular network is ensuring that equipment can connect reliably and efficiently. Several stakeholders noted that the integration of industrial and media equipment with cellular infrastructure remains under development. Optimal connectivity solutions are still being explored, and some current implementations rely on using prototype modules that are expected to become commercially available soon.

Stakeholders consistently emphasised the importance of using modular add-ons rather than embedding connectivity directly into high-value equipment. This approach provides greater flexibility and helps avoid costly hardware replacements as network standards evolve. While the limited availability of such modules has posed a barrier to adoption, there are encouraging signs that the device ecosystem is beginning to mature, with connectivity solutions now entering the market.

5. Lack of collaboration within ecosystems

Despite the presence of a 5G Innovation Hub, stakeholders report a lack of hands-on collaboration. There is a shared sentiment that there is too much talk and not enough action and real collaboration. More structured initiatives, such as joint pilot projects, shared testbeds or cross-sector demonstrations, are needed to transform the hub from a dialogue platform into an action platform. For example, some participants suggested joint site visits to operational Private Networks abroad to accelerate mutual understanding and inspiration.

6. Regulatory uncertainty and emerging opportunities

While companies in Denmark can already apply for licenses in the 3.8 - 4.2 GHz band, there is still some uncertainty due to a pending EU decision on harmonised technical conditions. The uncertainty lies not in the availability of licenses, but in the fact that the EU decision may change how the spectrum can be used. As a result, any licenses issued now are temporary and will expire at the end of 2025. Once the EU framework is finalised, companies will be able to apply for longer-term licenses, enabling more stable and strategic planning for Private Network deployments.

Regulatory frameworks also affect several promising use cases, particularly those involving autonomous devices in public spaces, which are currently constrained due to safety concerns. Stakeholders point out that as wireless technologies mature, private cellular networks could play a key role in improving the safety, traceability and reliability of autonomous operations. This may help lower regulatory barriers by offering higher levels of assurance.

A notable example is EU Regulation 2023/1230 [9], which mandates that, by January 2027, e.g. AGVs support wireless safety communication. This means that they must have implemented a remote emergency stop. This requirement creates a clear incentive for deploying wireless technologies such as Wi-Fi or cellular networks, and illustrates how regulation can also drive adoption.

7. Reluctance to be first movers

A recurring theme across stakeholder interviews is the hesitation among companies to act as early adopters of private cellular networks (mostly regarding 5G). While organisations express interest in the technology and acknowledge its potential benefits, they are unwilling to proceed until a proven, real-world example has been demonstrated within their own sector or for a similar use case.

This hesitation is often linked to a desire to limit uncertainty. Companies are concerned about integration risks, unforeseen costs and the internal effort required to adopt new technologies. Even when technical feasibility is not in doubt, the lack of visible, sector-specific case studies makes it difficult for organisations to justify early investment. Several stakeholders highlighted that firms are looking for reassurance - proof that technology works not just in theory or pilots, but in operational environments that resemble their own.

Larger players are seen as capable of absorbing the potential costs of experimentation and failure. Once these front runners validate the value of private cellular networks, smaller and more risk-averse organisations may be more likely to follow.

As a result, promising use cases risk stalling, not because of technical limitations, but due to a collective wait-and-see approach. Stakeholders emphasised that more visible, well-documented deployments could help break this deadlock and drive broader market adoption.

Furthermore, the heavy focus on 5G reinforces the association with public mobile broadband – the technology most people are familiar with from smartphones – rather than drawing attention to the distinct value private cellular networks can provide in industrial, operational and infrastructure-specific contexts.

Method for gathering insights from the ecosystem

To gain insights, the project engaged with a variety of stakeholders currently active in the private cellular ecosystem, particularly those working to advance cellular connectivity in the Danish industry. Interviews with 7 companies in the ecosystem were conducted. Key findings from these interviews were then used to facilitate discussions in different forums. This included a meeting in the Danish 5G Innovation Hub & Testbed [10] and a panel discussion during a webinar hosted by FORCE Technology's "IoT & Wireless Klubben" [11].

Figure 4 illustrates the research method: structured interviews with some of the companies, follow-up open panel discussions at the 5G Innovation Hub & Testbed, and triangulation against public global-market sources to validate and contextualise findings.

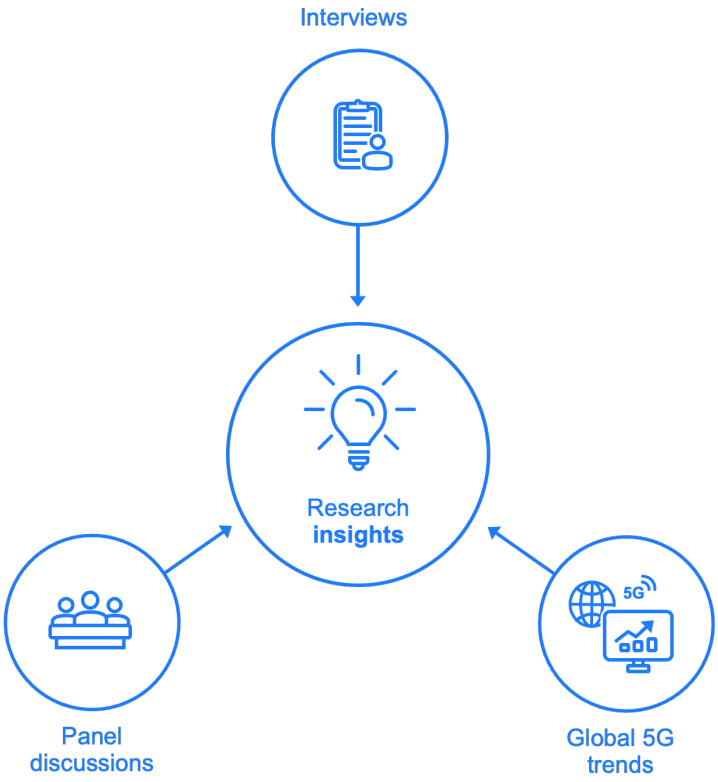

Figure 4. Insights were gathered through structured interviews with key stakeholders, panel discussions at Denmark's 5G Innovation Hub, and triangulation with global 5G trends.

Primary contact form	Company	Ecosystem role	Position of representative
Interview	3 Denmark	Telecom operator	Business Development Manager
Interview	TDC	Telecom operator	5G B2B Teamlead
Interview	Cumucore	Core network vendor; provides 4G/5G core software and deployment support	Senior Business Development Manager
Interview	Pedab	Technology distributor; positions itself as an ecosystem enabler and intermediary	Business Development Manager
Interview	TV2	User; private 5G networks for media production and live broadcasting	Head of Production and News Technology
Interview	Semco Maritime	Solution provider; implements 5G infrastructure, especially in offshore energy sectors	Senior Sales Manager
Interview	Digitaliserings-styrelsen	Regulator; responsible for spectrum licensing and national digital infrastructure policy	Special Advisor
Open Discussion	Maersk	User; exploring Private Networks for logistics and port infrastructure	Lead Infrastructure Engineer
Open Discussion	Verizon	Global telecom operator	Senior Solutions Partner
Open Discussion	Alcatel-Lucent Enterprise	Vendor; promotes network infrastructure and enterprise connectivity in Europe	Market Development Director, NE Europe
Open Discussion	Telcon A/S	Consultant/integrator; supports telecom and 5G deployment strategies	CEO
Open Discussion	Aalborg University	Provides academic insights into wireless communication and Private Network validation	Professor
Open Discussion	Mediathand	Technology innovator; focuses on IP-based media infrastructure relevant to private 5G in broadcasting	CEO

Table 2. The interviewed stakeholders, their company and how the insights have been gathered. "Open Discussion" refers to the panel debates in the Danish 5G Innovation Hub & Testbed.

Conclusion

This white paper presents a stakeholder-driven view of the main barriers preventing wider adoption of private cellular networks in Denmark. Through ecosystem mapping and interviews across the value chain, it highlights both structural challenges, such as regulatory uncertainty, limited awareness of spectrum options and commercial hesitancy, and strategic issues, including misaligned sales approaches and insufficient integration support.

Overall, the technology itself is largely ready. What remains underdeveloped are the surrounding conditions: awareness, incentives, ecosystem maturity and clear strategic framing.

To address these issues, the white paper identifies several areas where targeted initiatives could accelerate adoption: strengthening neutral integration capacity, promoting concrete use cases, supporting first movers and increasing cross-industry knowledge exchange. Together, these steps can create a foundation for coordinated national action.

The Danish 5G Innovation Hub & Testbed plays a central role in enabling this collaboration. The opening of the 5G testbed facility at Odense Havn expands opportunities for near-shore and on-shore experimentation with Private Networks. Aalborg University's Smart Factory Lab supports testing of production-related use cases, while TV2 offers a media-focused testbed for exploring next-generation broadcast and production workflows.

On spectrum, the Digitaliseringsstyrelsen has announced that frequencies in the 3.8-4.2 GHz range will be available for Private Networks from July 2026 [12]. This is an important development for planning and investment cycles.

Recommendations linked to key findings

1. **Reduce complexity and financial risk**
   - Recommendation: Develop clear, evidence-based requirements for typical use cases.
   - Rationale: Early findings indicate that technical needs - particularly for drones and robots - may be lower than originally assumed. Reducing perceived complexity helps operators size solutions more realistically and lowers barriers for enterprises.

2. **Engage the right decision-makers**
   - Recommendation: Maintain consistent, vertical-specific outreach.
   - Action: Four industry-focused events are planned for 2026 to demonstrate how 5G can address concrete, well-defined industry challenges. Targeting business decision-makers, not only IT departments, will be essential.

3. **Strengthen equipment connectivity options**
   - Recommendation: Increase visibility of available "equipment connectors" and build proof-of-concepts.
   - Action: Promote existing solutions from suppliers such as HMS, More Electronics and Siemens. Launch a technology-scouting effort to identify and validate additional connectors.
   - Outcome: Demonstrating that connectors already exist will build confidence among equipment vendors and integrators.

4. **Enhance collaboration across the ecosystem**
   - Recommendation: Expand opportunities for shared experimentation and bilateral knowledge exchange.
   - Action: Ongoing initiatives include establishing a 5G Private Network at Odense Havn, study visits to Siemens' lab in Aachen, demos at TV2 in Tivoli, and AAU's Smart Production Lab. Involvement from international leaders such as Nokia and Verizon can help illustrate the real-world value of mature 5G installations.
   - Challenge: Motivating solution developers to build directly on 5G remains difficult, and continued facilitation is required.

5. **Reduce regulatory uncertainty**
   - Recommendation: Maintain a structured dialogue with regulators and communicate updates clearly to the industry.

   - Action: Engagement with Digitaliseringsstyrelsen on spectrum availability continues. However, regulatory uncertainty also affects BVLOS drone operations and the use of autonomous robots in public spaces - areas that will increasingly require 5G standalone capabilities.

   - Need: A coordinated regulatory roadmap.

6. **Support and attract first movers**
   - Recommendation: Use international cases to demonstrate maturity and business value.

   - Action: Share insights and lessons learned from early deployments abroad to help Danish enterprises make informed investment decisions and reduce perceived risk.

Authors / contact

Christian Kloch, Ph.D. Technology Lead and head of Danish 5G Innovation Hub & Testbed
ckl@forcetechnology.com

Elias Kristian Hersted, Specialised in innovative development to address complex challenges, M.Sc. stud. Elias Kristian Hersted | LinkedIn (linkedin.com/in/eliashersted/)

Radheshyam Singh, Ph.D. Expert in developing M2M/IoT secure and reliable communication, specialist.
rds@forcetechnology.com

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