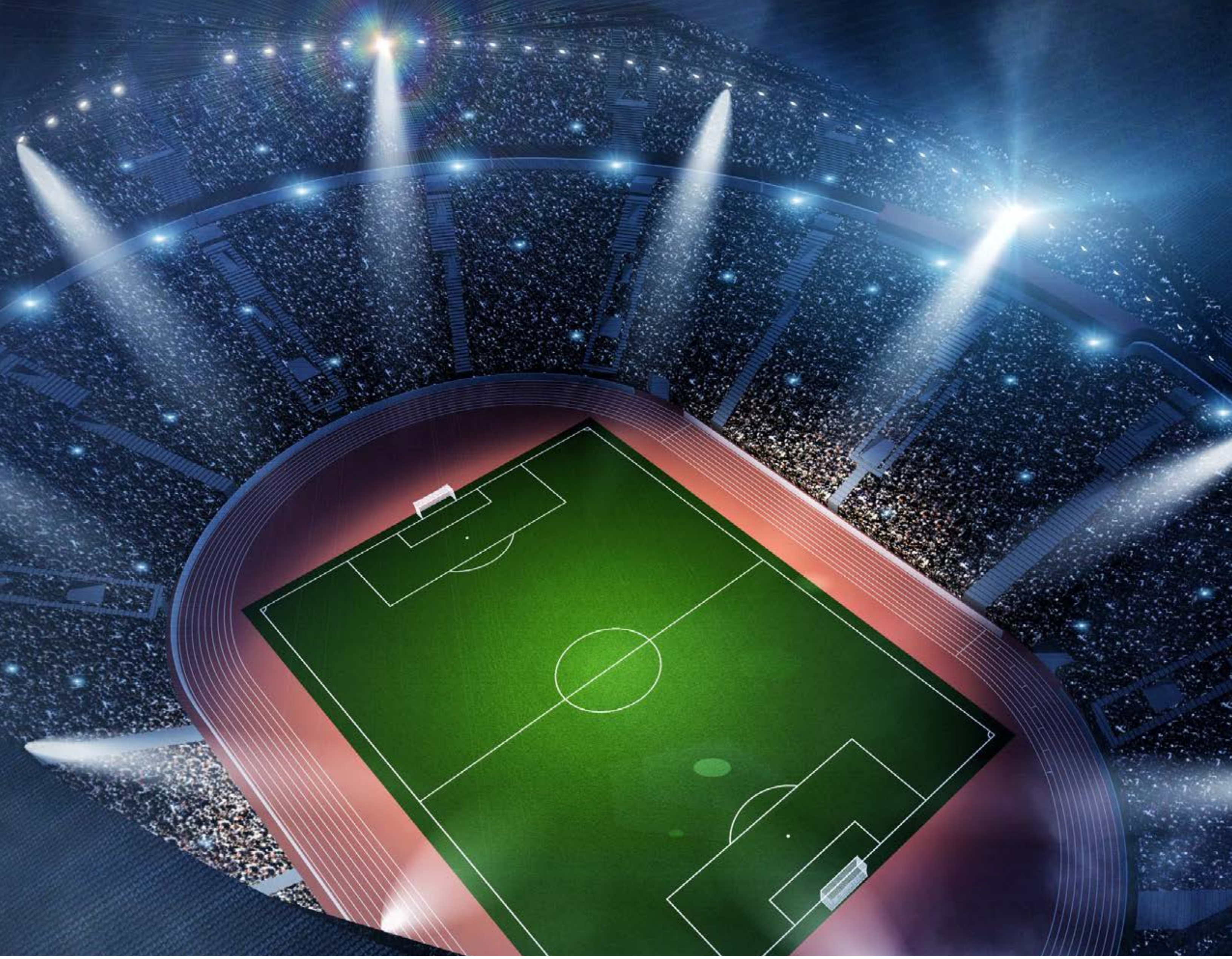


Top Trends for Private Networks in 2023

An overview of the challenges, market drivers, use-cases and trends for private networks.

Disruptive Analysis

iBwave

Table of Contents

Summary

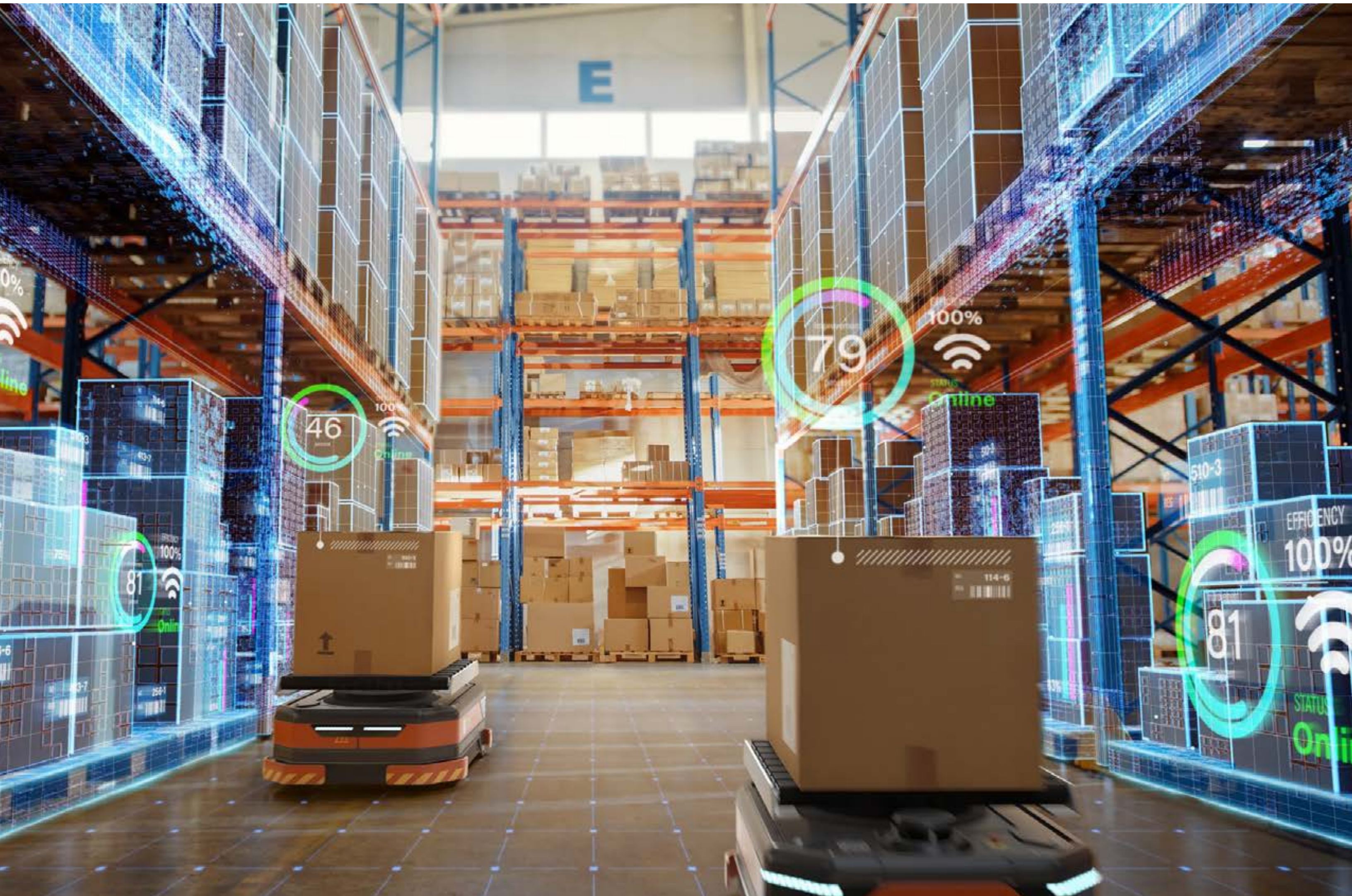
Private or dedicated cellular networks are not new. Various deployments for rail, energy, maritime, and public safety use have existed since the 2G/3G era over 20 years ago. Local spectrum licenses for enterprises or government agencies to deploy private networks have existed for over 15 years in some form.

However, 2022 was a critical turning point for the concept to become mainstream. New networks – 100s[1] , perhaps 1000 or more – were deployed around the world, typically for enterprise campuses, industrial sites, or local fixed-wireless use.

Proper "production" usage has become more common, rather than just trials and proofs-of-concept. Private 5G is moving beyond its roots of critical communications into the most remote and challenging verticals, like oil and mining, and are continuing to grow. New sectors and verticals gained importance, such as ports, logistics/warehouses, construction and defense. The private 4G to 5G transition started to accelerate with the greater availability of 5G radios, standalone cores, and suitable devices like video cameras and handhelds.

While public mobile network operators (MNOs/carriers) hope to see B2B applications of 5G drive revenue growth, many have recognized that dedicated networks need separate units, updated operational models, and sometimes different vendors and infrastructure design. Many new systems integrators have joined the value chain as well, together with specialist service providers.

Meanwhile, more governments and regulatory agencies have followed the trend, issuing spectrum directly to enterprises – with even India and China showing early signs of moving away from the MNO-only model for 5G.



So what trends are expected for private networks in 2023 and beyond?

Industries face a broad set of underlying trends and transformation drivers, shifting towards connectivity and, especially, private wireless networks. Some transformation drivers, such as macroeconomic unpredictability, are external and common across multiple industries. Others such as decarbonization and safety have very specific impacts in heavy industry and energy sectors.

Other drivers behind the market trends include:

- **Improved employee safety and productivity:** Improved connectivity can significantly improve safety through the use of remote control of equipment, proximity awareness, or the use of sensors to spot early signs of danger.
- **Cybersecurity:** Security challenges are becoming multi-layered and highly complex. Private wireless networks may be used as backups in case of failure of fiber or other links, and may also reduce risk associated with older proprietary systems.
- **Data and analytics:** Companies are now rapidly transforming legacy analogue infrastructure and manual processes. Better connected equipment, IoT sensors, and video input can improve asset management, enable fault detection, improve productivity and resource allocation, extend assets' working lives, help diagnostics, and optimize maintenance. The vast amount of data will require much more higher performing and robust networks than in the past.
- **Geopolitics:** Many sectors are having to deal with ongoing shifts in the international political arena. Some countries and sectors have trade restrictions and embargoes. Taxes, tariffs, and import regulations have constant shifts. Governments demand clarity on employment and environmental compliance across entire supply chains. Companies have to deal with more paperwork and maintain better records. This is inherently more data- and network-intensive.
- **Equipment mobility and reusability:** The increased utilization of vehicles, individuals, and assets both between locations and with partners such as rental companies or expanded supply chains necessitates constant and dependable network connectivity for effective monitoring and connectivity.

Private cellular networks are part of the solution to these challenges. They enable enterprise IT and OT teams to control their own connectivity, while maintaining high performance and reliability.

In 2023, a growing awareness of the potential for private 4G/5G (i.e., demand) is mirrored by the improvements in industry supply as more equipment, solution providers, and applications come to market, enabled by greater availability of spectrum and support from governments.

This e-book examines five key trends that are defining the changing marketplace. These should be read together with other iBwave resources which describe the basic underlying "5 Cs" drivers of demand (coverage, control, cloud, costs, and compensation), as well as the specific needs of various industry verticals.

Each of these topics is highlighted in a separate section below:

- Private networks moving from 4G to 5G
- The role of mmWave in private 5G
- Moving from proof-of-concept to large-scale deployment
- Private networks for public venues like stadiums, hotels, and airports
- Combining private 5G with Wi-Fi in enterprises

A final section briefly spotlights a few other trends and discusses international variations.

Private Networks Moving From 4G to 5G

Although many commentators and vendors speak of "private 5G" for enterprise, the market today is made up mostly of private 4G/LTE deployments. Almost all current U.S. CBRS implementations are based on 4G network elements and devices, while many private 5G networks in Europe are still at testing and pilot phases (The installed base in some markets also has a huge tail of legacy private 2G/3G networks, some of which are now 15+ years old).

However, this situation is now changing rapidly. A recent study by the industry vendors' association GSA[2] showed about 41% of publicly referenced private networks featured 5G of some type. While that is likely to be overstated compared to the whole market, given PR preference for publicizing cutting-edge deployments, it is still an important indicator.

There are now 100s of genuine private 5G networks, and in the future that figure will climb to the 1000s and then perhaps far beyond. It is worth noting that this figure refers to *dedicated* private networks, even where they are deployed by carriers/MNOs as business solutions. The future will also likely see more "semi-private" or virtual networks based on extensions or slices of national public 5G infrastructure, although that model has been slow to emerge so far.

There are various factors in play here:

- **Some countries have allocated spectrum for local networks that is *only* suitable for 5G,** especially in the upper midband 4GHz+ and mmWave ranges (see next section). There simply cannot be private 4G in those bands, as it is not supported in devices or network equipment.
- **Many 5G MNOs initially deployed their main networks using "non-standalone" mode.** This requires a 4G network radio and core as an "anchor." This meant that for isolated deployments such as mining, oil, and gas facilities, or even larger ports, they would have needed to install both 4G and 5G coverage.
- **Until 2022, there were few 5G standalone (SA)-capable small cells or core network products on the market.** These have now become more diverse, mature, and tested, although they can still be too costly for bulk IoT applications.
- **The fragmentation of 5G bands has made it difficult for low-volume IoT vendors to justify creating and certifying devices,** until prices of chips or modules fell from initial smartphone-oriented cost points. Some frequencies such as the 3.8-4.2GHz part of Band 77 used in the UK were especially rare until recently.
- **Certain products and applications have only been available in 4G variants.** For sites using private networks for critical voice communications (push-to-talk), the main handhelds used LTE – often as hybrids with PMR systems such as P25 or TETRA.
- In the U.S., **CBRS product guidelines and certifications were heavily 4G-focused until 2022.**
- **Many enterprises have viewed 5G as immature and a "moving target,"** especially as they could see timelines for releases 15, 16, 17, and beyond – with many of the more useful features such as ultra-low latencies only becoming viable later. As a result, some have used 4G either as the basis for proofs-of-concept or for full but "de-risked" deployment in the short term.

This situation is now changing quite rapidly, although private 4G deployments will likely continue for several more years, especially where the performance is adequate for initial applications and the focus is on rollout to multiple sites, rather than more sophisticated applications on a single site.

The key recent developments favoring 5G and those expected in 2023 include:

- **Many regulatory authorities are now focusing their private network allocations in 5G-only bands,** such as 3.8-4.2GHz, 4.9GHz, and higher mmWave ranges. Sometimes this is intended to avoid "set asides" of MNO-oriented pioneer bands, while another reason is policymakers view 5G adoption as a strategic national goal.
- **Multiple vendors now have 5G SA cores available for deployment by enterprises and systems integrators,** both for on-premises and cloud-based delivery. These can also often work in hybrid mode with 4G and/or 5G non-standalone, for greater flexibility and backward compatibility.
- **More MNOs have 5G SA networks, which can potentially support private or semi-private networks,** either through coverage extension or (eventually) some form of network slicing.
- **Some MNOs' regulatory and spectrum-management teams are becoming more agile at localized allocations for enterprises**. B2B solutions teams can see if there is suitable "inventory" of unused public-network frequencies in specific locations that can be used for dedicated systems.
- **The device ecosystem (and especially IoT modules, gateways, and cameras) is adopting 5G more broadly, and is increasingly supportive of both 5G SA mode and a range of different frequency options** – although local bands in some countries are still mostly 4G-only.
- **5G RedCap (reduced capability) is starting to emerge,** aimed at optimizing 5G for lower cost IoT modules. It can be thought of as "5G light" and should be ideal for some private network scenarios in the future.
- **Industry groups such as CBRS Alliance, also branded "OnGo," are starting to certify 5G solutions,** which opens the market to a broader set of integrators and also allows easier interaction with the SAS authorization database providers.

Company / Location	Private 4G	5G Non-Standalone	5G Release 15 Standalone	5G Rel 16/17 Standalone
Availability	Wide, mature	Recent. Needs MNO 4G "anchor."	Recent, growing quickly	Not yet available
Suitable for <4GHz bands	Excellent	Good for MNOs	Mostly for bands 48, 77, 78	Mostly bands 48, 77, 78 (future)
Suitable for 4-7GHz bands	No	Limited opportunity	Bands 77, 79, maybe 96, 104	Bands 77, 79, maybe 96, 104
Suitable for mmWave band	No	Limited opportunity	Bands 257, 258, 260	Bands 257, 258, 260
Boliden	Sweden	Remote machinery & vehicles.	4G + 5G upgrade path	Telstra, Ericsson
Device support	Excellent	Good (OK for IoT)	Limited, growing	None yet
MNO role	Common but competes with fully private	MNO-only	Currently rare	None yet
Network slicing	Only basic QoS approaches	Only older QoS approaches	Basic 3GPP slicing possible	Advanced 3GPP slicing possible

The Role of mmWave in Private 5G

Up until now, almost all private cellular networks have been deployed at low-band <1GHz or midband 1-6GHz frequencies. This applies to both completely dedicated networks and customized enterprise installations by mobile operators (MNOs). There has been very limited use of high-band or mmWave frequencies above 20GHz for private or "vertical" networks.

There are a number of 5G-designated mmWave bands, which are also referred to as FR2 (frequency range 2) by 3GPP. Some of these have had limited deployments for public 5G, notably in the U.S., Japan, and South Korea – although primarily for MNO-delivered fixed wireless access and outdoor capacity enhancement in dense urban areas. However, deployment in enterprise settings — or in Europe and China for any applications at all — has been minimal.

A few ultra-dense public venues such as sports arenas and airport terminals have deployed mmWave indoor coverage systems, although there is little evidence of private networks as extra "tenants" on these.

There are several reasons for the historically limited adoption of mmWave for private networks:

- Few deployments by public MNOs of widespread mmWave 5G networks that could be extended for private/enterprise use.
- Few countries licensing mmWave bands for local/indoor shared use directly by enterprises.
- Very limited numbers of suitable mmWave-enabled devices, especially in categories most frequently used for private networks, such as cameras, vehicle gateways, IoT modules, and industrial handhelds.
- Typical poor range and propagation characteristics, meaning that mmWave 5G often struggles with mobility, or environments with restricted line of sight.
- Lack of suitable small cells and other infrastructure elements capable of dealing with mmWave bands.
- Several different mmWave bands used around the world, fragmenting potential demand.
- Only suitable for 5G use, so no existing base of 4G equipment/devices to stimulate the market.

Table: 5G mmWave Bands

Band	Name	Range, GHz	Countries available/planned
N257	28GHz, LMDS	26.5-29.5	Used for public 5G/FWA in U.S., S Korea, Japan, etc. Some availability for local/non-MNO vertical licensing in Hong Kong, S Korea, and Japan.
N258	26GHz, K-band	24.25-27.5	Licensed for MNO public 5G in Europe, China, etc. - Indoor use unlicensed in UK (low power) - Several countries allocating local licensing across some/all of the band, e.g., Germany, Finland, HK
N259	42GHz, V-band	39.5-43.5	Currently little used
N260	39GHz, Ka-band	37.0-40.0	Used in some locations in U.S. for MNO-offered FWA and potentially private 5G
N261	28GHz, Ka-band	27.5-28.35	
(unnamed)	60GHz	57-71GHz	Unlicensed. Used for Wi-Fi variants 802.11ad/ay, various proprietary wireless, and radar uses. Potential future 5G band for public/private networks.
(unnamed)	70GHz+		Potential use for various future 5G/6G applications

Source: Disruptive Analysis

However, the private 5G market is now starting to mature — or at least it is resolving into a better understood shape.

Existing MNOs with mmWave allocations are looking at enterprise use cases more keenly, while certain national regulators are allowing direct access to these bands by businesses and systems integrators. In Germany, Deutsche Telekom recently announced[3] a test of local-licensed 26GHz, combined with its national 3.7GHz and network slicing.

Ultimately, there will be a need for low/mid/high bands for both public and private 5G, although local spectrum availability and political considerations may leave some gaps.

The main rationales for introducing mmWave P5G include:

- **More spectrum available than in mid-band ranges,** with the potential for 100-800MHz allocations for enterprise usage. This allows for higher throughputs with multi-Gbps peak speeds.
- **Less politically contentious for regulators than "set-asides" of precious midband frequencies,** especially in countries with 4+ public MNOs battling for allocations.
- **Easier deployment of true ultra-low latency networks,** reaching 1ms response times or lower. In some midband ranges there are sometimes technical restrictions on the way spectrum is used, to enable coexistence with other wireless users in the band.
- **MNOs can often use existing licensed mmWave bands for private enterprise customers' sites, without impacting nearby macro networks.** Conversely, when using midband frequencies they may face more complex network planning scenarios to manage public and private domains' coexistence.
- **Potential to easily add private network capabilities to indoor mmWave neutral-host infrastructure.** A single network of small cells could support 3 or 4 public networks, plus a dedicated local network for the venue, each with separate tranches of spectrum.
- **Enthusiasm by some network and semiconductor vendors to find alternative markets for mmWave products, given limited uptake for public 5G services owing to short range.**
- **Growing ability to engineer enhanced mmWave coverage, especially with the addition of new indoor systems/small cells, plus new repeaters and range-extenders.**
- **Ability to have customised uplink/downlink ratios reflecting specific application needs,** or to using uplink carrier-aggregation to combine mmWave and midband 5G frequencies.

Typical use cases for mmWave private networks are likely to be a subset of those seen in the wider P5G/PLTE marketplace. In particular, the following are likely to be important applications:

- **High-resolution and multi-point camera networks, especially when linked to real-time video analytics and AI platforms.**
- **Control for static automated machinery, such as high-end robots on car factories' production lines.** These are typically articulated arms fixed to a specific floor-point, so it is possible to design networks so each robot has line-of-sight to two or more mmWave radios.
- **Mobile or autonomous vehicles moving along well-defined paths, especially on tracks or pre-defined roadways.** These would need careful network design to ensure reliable handover from cell-to-cell without risks of obstruction of line-of-sight.
- **Potentially AR/VR headsets and other wearables, especially in rooms or confined spaces with easily plannable coverage to avoid "dead spots."**
- **Sensitive scenarios where a building's walls avoid mmWave 5G networks' signal reaching outside.** For instance, at military warehouses or confidential industrial R&D facilities.

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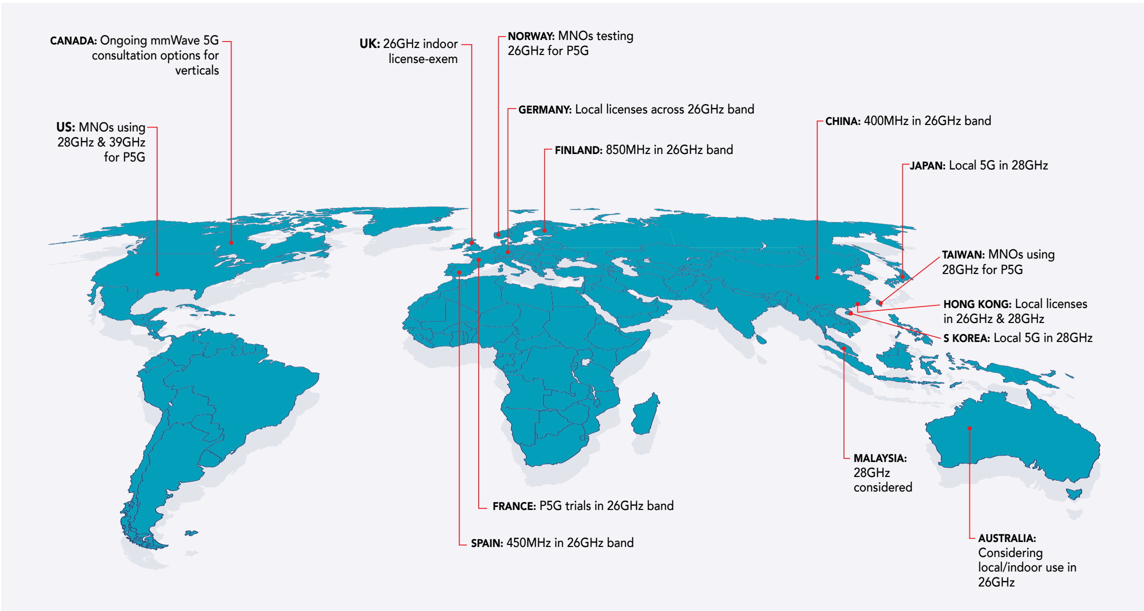
mmWave bands available for private, local & enterprise 5G



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It is notable that mmWave availability for P5G is currently higher in Asia than in Europe and the Americas. This may change during 2023-24, as European regulators seem to be refocusing on this band. Right now, there are no clear signs of mmWave P5G in Latin America or Africa.

Moving From Proof-of-Concept to Large-Scale Deployment

Another key trend for private networks in 2023 is the growing adoption of full "production" deployments, both for 4G/LTE and increasingly 5G infrastructure and applications.

While there are numerous examples of real-life, full-site networks in locations such as ports and mines, **other sectors such as manufacturing seem to be taking much longer.**

Fewer have progressed beyond initial trials or proofs-of-concept, or perhaps connecting just a single building on a large campus. However, while there will not be an across-the-board switch to rapid uptake, there should be significant improvement over the next 12-18 months in many areas.

This inability to scale beyond trials is a well-known phenomenon in technology. It is common for small experiments to be conducted by teams within companies tasked with exploring new concepts. They may get favorable terms from suppliers, be viewed as a low-risk source of publicity for "cutting edge" practices by PR teams and executives, and may also be suitable for government grants or other external funding sources.

However, **translating these projects into full-scale commercial adoption brings multiple challenges,** especially if they are seen as threatening to some

internal groups uninvolved in the testbeds. There are also numerous other obstacles, from technology dependencies to perceived regulatory complexity or vendor stability. Additional groups inside the business involved with compliance or risk-management may present hurdles, as well as external stakeholders involved with complex supply chains.

It is worth noting that many regularly discussed examples of P4G/P5G deployments are quite small in the contexts of the overall size of companies or sites mentioned.

Examples include:

- **A car manufacturer deploying two 4G/5G small cells in a prototype pre-production facility**. This installation was part of an industrial demonstrator and testbed setup, intended as a "lab" for a future full-scale factory that will be built in 2024-25.
- **A large city-based hospital and healthcare authority announced deployment of a P5G network.** The initial deployment was in fact for one specific building (and non-clinical applications) at a remote suburban campus site.
- **A metropolitan authority used a local 5G connection at a specific traffic junction, connecting cameras and sensors to a roadside unit for optimizing flows of public buses and bicycles.** This was a government-funded testbed, which has not yet resulted in scale-out to the rest of that city or elsewhere.

None of these are "failures" and may indeed result in longer term, much larger projects. But it is important for operators, integrators, and solutions vendors to dig a little more deeply into case studies before committing to particular sectors or business models.

Many of the obstacles to large-scale deployment of new private 4G/5G infrastructure are non-technical.

There are assorted finance, legal, and regulatory issues for enterprises to consider, especially in complex multi-stakeholder situations where there could be network operators, systems integrators, multiple vendors, cloud providers, and industrial automation suppliers "in the loop."

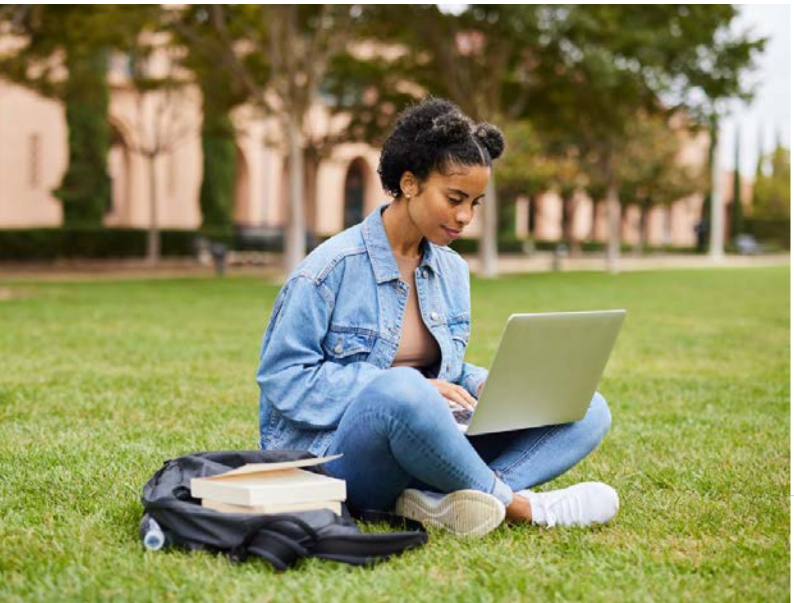
It is one thing for a firm's lawyers and compliance teams to OK an isolated testbed project with a <$1m budget, and quite another to apply the solution to a running factory where downtime could cost millions per day, and where worker safety is paramount and driven by 100% reliable communications or "stop" buttons.

The most difficult large-scale private networks projects are those that have new applications, new platforms, new business cases, and new networks, all at the same time.

Deploying a 4G critical-communications system for a utility provider by replacing an existing TETRA radio that is being "end-of-lifed" is a relatively simple decision. Conversely, a manufacturer hoping to use mmWave 5G standalone for ultra-reliable, low-latency robot connections and AI-powered quality-control cameras, in a huge new plant, is a much harder – and often slower – decision to make.

2023 should see various developments that ease decision-making. While these will vary by sector, application, and national market, some of the most important changes include:

- **Availability of 3GPP Release 16 networks and devices, with various maturing features for network quality, low latency, and positioning accuracy.**
- **A much wider pool of case studies, robust ROI models, and documentation about other deployments.**
- **More trained and skilled individuals capable of deploying – and running – private 5G networks.**
- **More regulatory authorities making spectrum available for enterprises,** with particular bands such as 3.8-4.2GHz becoming seen as (approximately) harmonized across multiple countries.
- **Greater maturity of "templated" models for private networks requiring less customisation for each site.** Some of these will be cloud-delivered "network-as-a-service" propositions while others will be more "network-in-a-box." Both should support scale better.
- **New financing and commercial models,** such as pay-as-you-grow cloud models, external bank loans or leasing approaches, bundling into larger industrial systems' CAPEX and depreciation schedules, or various CSP-based subscription or services frameworks.
- **Growing awareness and trust of private 4G/5G networks** by the enterprise IT functions, finance, and procurement teams, OT and industrial systems units, and various others.



The table below attempts to summarize the complexities of moving to large-scale production deployment of P4G/P5G in different vertical industries. It is a necessarily imperfect chart, as each industry has multiple sub-sectors or site types (e.g., marine oil-rigs vs. refineries vs. retail gas stations), but is intended to give a broad macro-level overview.

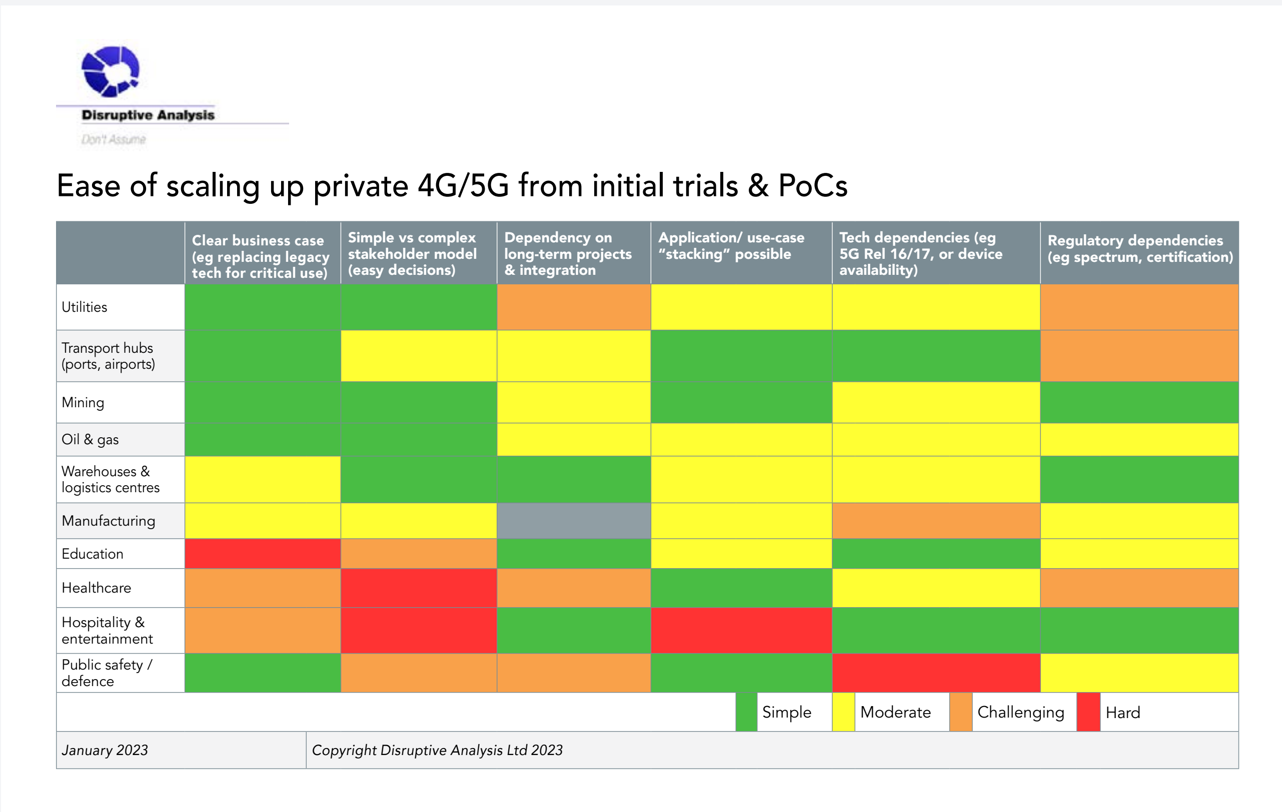
It scores each vertical industry against a set of six criteria, which collectively determine the challenges of moving from trials and testbeds to major production deployments of private cellular. *Green indicates a strong incentive for deployment while red means there are significant inhibitors.*

The criteria are:

- **Initial business case:** In some cases, there is an urgent operational need for a specific network where the costs are clearly small compared to the financial or operational benefit. The replacement of old critical-communications push-to-talk systems with modern 4G/5G upgrades in industrial or military environments is a good example. Conversely, deployments in universities may have less-clear applications, weaker financial business cases, or more alternative technology options.
- **Simple/complex stakeholder models:** Some deployments can be made by an individual company or government agency, on a specific site that it controls, with its own cash reserves, with few other parties involved in the decision process. Mining is a good example of this. Conversely, some sectors may involve a complex array of site-owners, network operators, integrators, tenants, infrastructure providers, government agencies, financiers, and so on. Inevitably the latter multi-stakeholder models are more cumbersome to negotiate, contract, and implement.
- **Long-term projects:** Some private network deployments are fairly "standalone" – for instance connections for perimeter security cameras at an industrial site. Other implementations are linked to much larger projects, such as creating an overall industrial automation system for a next-generation factory. In those cases, the private cellular deployment may be tethered to much longer timelines for decision-making and investment.
- **Use-case "stacking":** In some industries, an initial trial for a particular P4G/P5G application may not just be successful in its own right but also may highlight an array of additional follow-on applications that can make the business case easier after proving out the technology. For instance, in ports, an initial trial for cameras on cranes could stimulate interest in 5G for

drones, trucks, personal handhelds, traffic control, and so on. That "stacking" makes the investment decision much easier.

- **Technology dependencies:** Some industries or specific applications may be heavily dependent on technology evolution and maturity. Some industrial use cases of P5G are quite clear – but really need features in 5G Release 16 or 17, which may not be available yet. Others may work perfectly well with 4G LTE, with 5G as a future evolution option. This one is tricky to score, as a given site or company may have a mix of short and longer term technical needs.
- **Regulatory dependencies:** Some sectors may require particular regulatory developments in order to exploit private 4G/5G. Spectrum availability and usage rules are particularly important here – if a band is only available at low power or with short-term (e.g., 3 year) licenses, that may be prohibitive. Other regulatory issues may relate to industry-specific certifications, especially where there are questions around safety or interference (e.g., medical equipment and wireless).



Private Networks for Public Venues (e.g., Stadiums, Hotels, Airports)

2023 is starting to show a pivot of private networks from industrial settings to a much broader array of location types – especially those more oriented to visitors (and by extension, their smartphones).

Most recent private 4G/5G deployments have been for industrial applications or other locations that are broadly closed to the general public. Ports, mines, military bases, oil & gas facilities, warehouses, and manufacturing plants have been typical use cases. Others have had "closed user groups" and tight security for critical communications over wide areas, such as public safety agencies, utilities, and railways.

But there have been few deployments of private cellular in locations open to the general public — even airports have mostly featured networks in maintenance hangars or on the airfield "ramp" for vehicles rather than inside the passenger terminals.

This is very different from the traditional market for indoor wireless systems, such as DAS (distributed antenna systems). These tend to be more widely used in locations such as airport terminals, sports venues, shopping malls, large office buildings, hospitals and hotels, or convention centers.

Those have requirements for high densities of public network access on private property. Because they support MNOs' customers' requirements for indoor connectivity, there has been close agreement on the desirability of such deployments, although there is frequently a debate over "who pays?" or the specific technical characteristics demanded by the operators.

It has long been speculated that private networks could replace or integrate with such indoor systems in public venues.

Indeed, there are numerous *theoretical* uses for private 4G/5G in such locations:

- Onboarding of visitors' devices, to provide localized services with branded "Venue Mobile" icons on phone screens, or reduced reliance on public Wi-Fi or cellular roaming (especially in airports or hotels).
- Venue-owned "neutral host" networks on which public operators become (paying) tenants or roaming partners. This is especially relevant in remote locations with limited public network coverage, such as resorts or offshore islands.
- Dedicated wireless networks for venue IoT or automation systems, such as payment terminals, ticket kiosks, or security cameras.
- Monetization of the private network by providing it "as a service" for on-site tenants such as retailers, event management and broadcast, catering staff, and so forth.
- Segregated wireless networks for staff communications, for instance, on ruggedized handhelds.
- Property companies seeking to use private mobile networks as a value-add for business or residential occupiers, for building management/IoT purposes, or (as above) with the intention of becoming neutral hosts or enabling "offload" from public carrier networks. Many already provide fiber backbones, Wi-Fi access, or rent rooftops for mobile base-stations, so private 4G/5G seems a natural extension.

While all of these have obvious appeal for venue owners, many of these concepts have been slow to come to fruition until now.

There have been various reasons why these sectors gained limited traction prior to 2023:

- **There is a strong overlap between public venues and those which were most affected during the pandemic.** Hotels were empty, sports venues closed, and retail shifted largely to delivery models. Few had the confidence – or spare capital – to deploy a new and largely untested communications infrastructure. New models of operation reduced some of the use cases as well – for instance, hotel staff now clean rooms less frequently, so there is less need for a sophisticated new communications system.
- **Early private 4G and especially 5G systems were relatively expensive, especially for locations with limited direct monetization or demonstrable ROI.** While a mine can justify a private network's cost for improved worker productivity or enhanced automation, it is harder to argue similarly for visitors to a town hall or kiosks in a shopping mall.
- **Most of these venues already have Wi-Fi.** And while that has sometimes suffered with congestion or clumsy onboarding, those issues are increasingly being fixed with Wi-Fi6/6E/7, or simpler log-on pages, or automation with OpenRoaming or PassPoint. This makes private networks less easy to justify.
- **Onboarding of consumer/visitor smartphones to private networks is hard.** There are 100s of types, with various OS generations. While many now have eSIM or dual-SIM capability, many people are unfamiliar with using that function – or else it may be locked down by a carrier. There are questions over what happens with phone calls or messages on the user's normal phone number – critical in the days of 2FA security or SMS-delivered tickets. No venue wants to run a support desk for these issues.
- **Neutral host business models have proven tough to realize in practice.** There are regulatory hurdles for public/private hybrid networks in some markets, questions over trust and cybersecurity, complexities about integrating a venue-run network into an MNO's wider infrastructure and management system, and so on. Commercial models are still being tested.

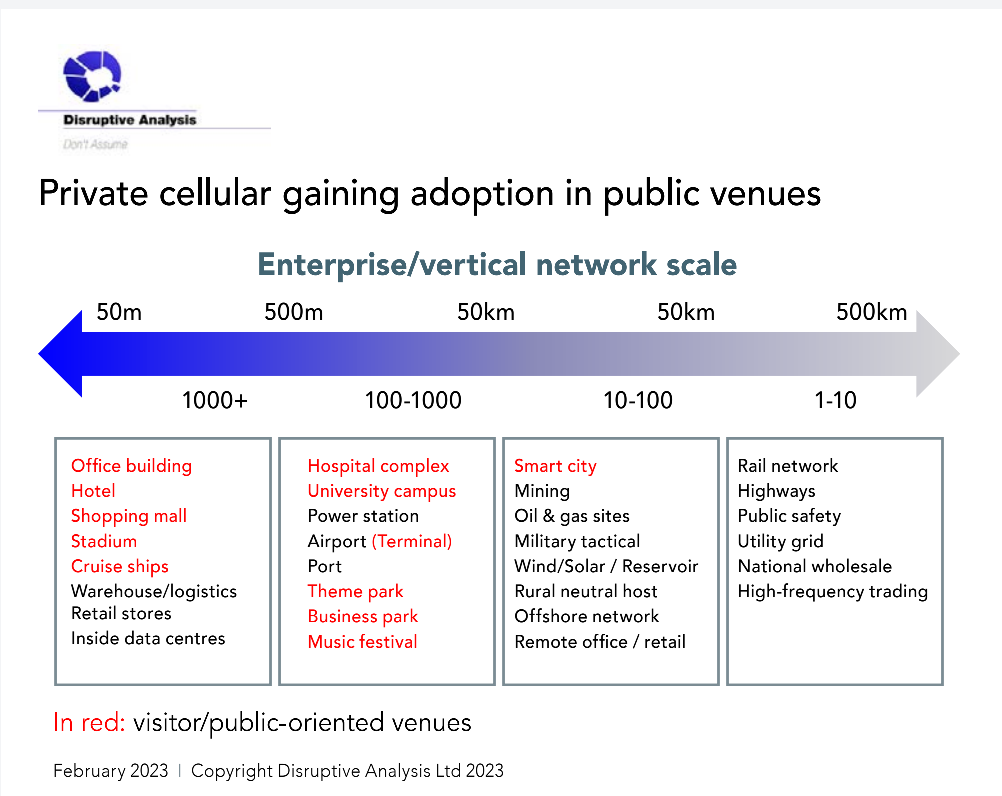
The net result is that public venue-based P4G/P5G has had a comparatively slow start. However, this is starting to change in 2023, with various recent and ongoing trends contributing to growth in these sectors.

- **Specific niches and use cases have been identified as having value.** Revenue-generating or safety-critical systems such as card-payment handhelds or gate-line ticket barriers need to be ringfenced from potential congestion on the public Wi-Fi network. Security cameras may need wireless backup connections in cases of cable cuts. It is easier to create business cases for such important applications.

- **Private 4G/5G costs and complexity are reducing fast.** The arrival of cloud-based solutions, and a general intention to make dedicated cellular "as easy as Wi-Fi" to install and operate are starting to bear fruit. Various vendors are creating packaged "in a box" solutions, as well as scalable pay-as-you-grow cost models.
- **End users are much more aware of private 4G/5G than they were in 2021.** Whereas vendors and even regulators were talking about the need for "evangelism," there is now mainstream coverage in technology publications, while Wi-Fi and enterprise solutions conferences will also now include sections on private mobile. Private wireless is discussed at industry-specific events for hotels, airports, healthcare, or "proptech" (property technology).
- **The ecosystem has expanded rapidly.** There are now vertical-focused specialist integrators and solutions providers for public venues such as sports arenas or hospitality. Various enterprise managed service providers (MSPs) have added private cellular to their existing portfolios. Planning and design tools are more readily available and understood.
- **Some public venues have adopted P4G/P5G for their outdoor areas in particular.** Retailers' parking lots, university campuses, business parks, and transport hubs often cover large expanses, which are impractical for Wi-Fi. While they may have public mobile coverage, few such sites are willing to pay per-GB for video footage from security cameras – and may want to link IoT systems more tightly into their IT platforms.
- **Rather than offering neutral-host capabilities as an add-on function to private networks, the reverse may prove easier.** Some DAS-type systems are starting to allow private networks to be offered as a secondary function on existing or new neutral-host platforms, depending on the frequencies supported.
- **There is likely to be a growing opportunity for "P5G-aaS," for instance with temporary networks being set up for festivals or pop-up sites.** This may require a bit more flexibility on the part of regulatory authorities, however – especially in markets where licensing of spectrum is done "manually" rather than via an automated system like a CBRS SAS.

To be fair, the onboarding of guest/visitor devices to private networks is still hard.

In an ideal world, someone arriving at a hotel or hospital would simply scan a QR code and download an eSIM with automated provisioning to the local network. Or, perhaps, the Wi-Fi roaming and federation system would work for P5G as well.



Such approaches need more time, although we will likely see some demonstrations and testbeds over the next 12-18 months.

Nevertheless, private 5G is seeing a clear trend towards deployment in public venues.

Expect 2023 to show more announcements of networks in retail stores, sport and entertainment venues, hospitals, and similar sites open to the general public. It will still be rare to see visitors connected to "free 5G" the same way they use Wi-Fi today, but that is likely to emerge in 2024 and beyond.

Combining Private 5G With Wi-Fi in Enterprises

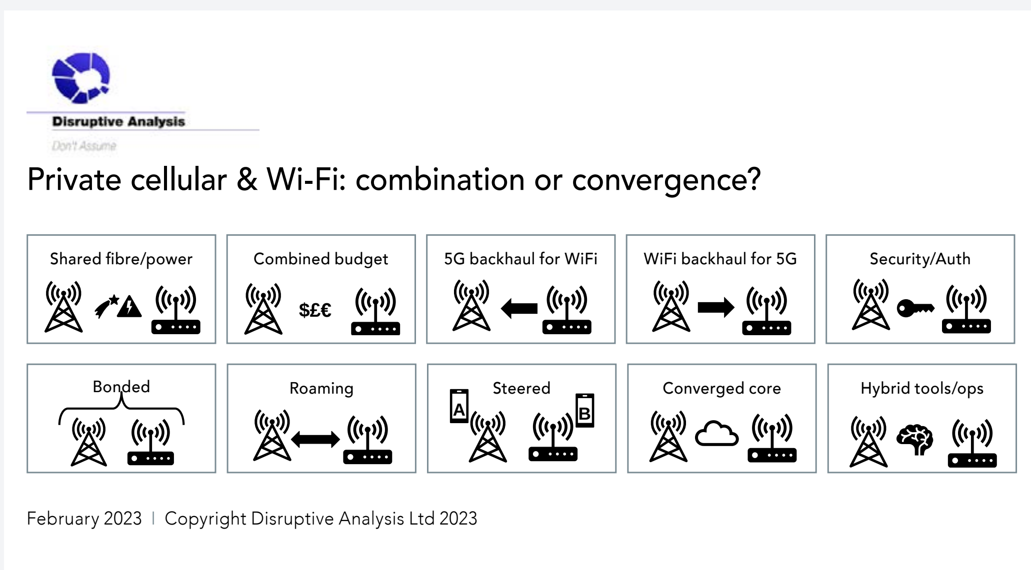
There is a lot of discussion about integrating or converging private 4G/5G with Wi-Fi, given that many enterprise sites need both technologies. However, the actual nature of the integration remains fragmented and multi-layer, with many deployments remaining "diverged" in technology terms, even if they come from the same integrated budgets or are managed by the same multi-disciplinary teams.

Some vendor solutions have cellular technology at the center, using the 5G 3GPP core as an anchor for alternative "access" radios. Others take the opposite approach, where a large existing LAN/WLAN infrastructure adds a secondary private 5G layer, perhaps for outdoor coverage or connecting vehicles.

There is has been continued evolution in 3GPP-centric standards[4] such as I-WLAN, ANDSF, N3IWF, and ATSSS to tie together the technologies via the core network and various gateways. There are mechanisms to map enterprise-grade security and identity models and certificates to mobile-type SIM/eSIM. Various vendors pitch platforms for linking mobile slicing to Wi-Fi QoS and VLANs. Others focus more on converging dashboards and management/diagnostics tools, device-management, backhaul, and power infrastructure – or even the physical housing of hybrid access points and small-cells.

For 2023 and 2024, Disruptive Analysis believes that "combination" of wireless technologies will still be more important than true technical "integration." Over time, there will likely be platform-level convergence as well, but it may prove quite rare – just as it is still unusual in public networks, despite almost 20 years of "cellular + Wi-Fi convergence" standards and concepts.

Words like "seamless" tend to be used, but in reality, many "seams" are actually useful boundaries and hard to remove without significant compromises elsewhere. Apart from gymnasts and swimmers, there is a reason that few of us wear seamless clothes!



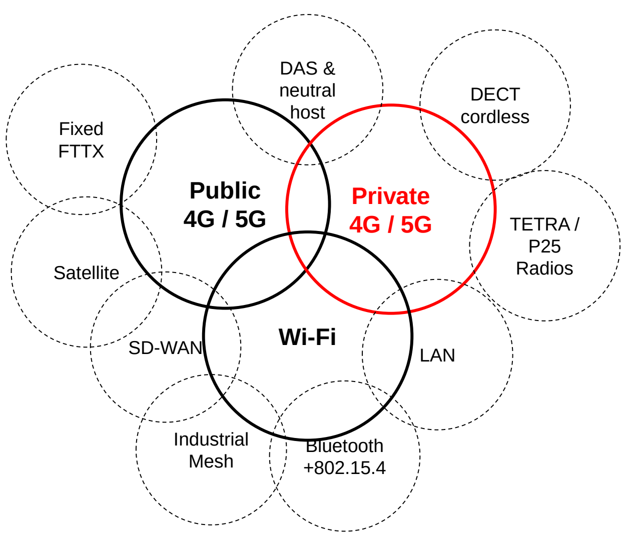
Some examples of private cellular and Wi-Fi combinations include:

- **Separate devices and applications using P5G and Wi-Fi in the same places, such as staff handhelds (P5G) vs. visitor smartphones at stadiums.** This can isolate different traffic types, as well as ring-fencing each domain in terms of security, interference, and congestion – and budget/administration.
- **P4G/P5G gateway units with local Wi-Fi deployed in vehicles or at remote enterprise structures, such as maintenance sheds.**
- CBRS or P5G backhaul from outdoor public Wi-Fi access points, where fiber runs are difficult or costly over longer distances.
- Conversely, Wi-Fi or 60GHz backhaul to 4G/5G small cells may prove be useful, where fiber runs are difficult over short (indoor) distances.
- Dedicated cellular networks (e.g., using CBRS) for fixed-wireless access for "unconnected" homes, deployed by education, healthcare, or local government agencies. These typically use on-premise equipment using Wi-Fi for final device connectivity.
- Handover of connectivity from one network to the other, for example an indoor Wi-Fi robot or AGV to switching to P5G for travel between buildings anchored in a 5G core network (For example, a multipath demo[5] from Deutsche Telekom for AGVs on campus networks).
- Production and sale of IoT devices (e.g., cameras) with pluggable or switchable modules for different customers and sites. They may accommodate 4G, 5G, Wi-Fi, or some combination.
- Devices which can bond or load-balance between multiple radios. Various approaches exist here, which may involve some sort of intelligent "combiner" unit in the network, or just connection-management software on the device combining independent connections. Technologies such as multipath TCP are becoming more helpful here.
- Combined planning, design, operations, and security tools, which cover multiple network types (likely P5G, Wi-Fi, and also the LAN/Ethernet infrastructure).
- Concepts for "offloading" public 5G inside buildings to both Wi-Fi and private 5G, perhaps for different MNOs' traffic or different classes of device.

There are many subtleties here around identity, security, investment cycles, systems integration, vendor choices, and device management. The result is that 2023 will not see a single "winner" architecture emerge, but we will certainly get more examples of proofs-of-concept, and probably a few "dis-proofs" as well.

Disruptive Analysis
Don't Assume

Network convergence is a multi-technology landscape



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It seems probable that – initially at least – various service providers (e.g., MNOs, enterprise MSPs, in-building neutral hosts) will be keener to pursue fully converged platforms than enterprises' own IT and networking teams.

It is also not just Wi-Fi that needs to work with (or around) private cellular either – many industries also use LoRa-type LPWAN for IoT connectivity, various industrial Ethernet and mesh systems for industrial automation, point-to-point wireless, DECT and TETRA radios, satellite communications, and so on.

Convergence is likely to be multi-technology, multi-layer, and multi-stakeholder. It will be an ongoing process which will likely take years and will be matched by simultaneous divergence as new point solutions are deployed as well.

Other Key Trends and Regional Differences

This e-book has highlighted five major areas where private network are evolving quickly, with 2023-24 expected to show considerable change compared to the recent past. That list is not exhaustive, however. There are obviously many other trends and developments, both technical and commercial, that could be expanded upon as well.

Some of the areas worth highlighting – and potentially topics for future reports (as well as social media posts and articles) include:

- **Open RAN and private wireless:** In theory, P5G should be a natural win for some new disaggregated models for building network infrastructure. However, most work on standards and equipment has focused on the macro RAN and carrier domain. A few vendors have focused on indoor and private network scale offers, but smaller budgets mean that customised "mix-and-match" integration and testing is hard to justify for individual private network projects. Instead, there will likely be more pre-integrated or single-vendor solutions which use OpenRAN-type interfaces internally, which gives futureproofing while still allowing the quick and simple deployment of small networks in the short term.
- **Government-run private networks:** A growing trend – albeit somewhat patchy across geographies – is the rise of government-focused verticals for P4G/P5G. This ranges from municipal networks deployed for smart-city applications or healthcare through to security and defense sites and bases. 2023 is likely to see a significant rise in the adoption of private networks for the public sector.
- **Combining private networks and neutral host:** This report has references neutral-host wholesale mobile networks in several places, although commercial development has been slow. This is starting to change more noticeably, and 2023-24 should see growing use of such hybrids as vendors, venues, and regulatory authorities start to understand all the various moving parts. That said, business models and technology gaps still need to be addressed, for example around cybersecurity/lawful-intercept and mechanisms for dealing with payments and monitoring QoS across boundaries.
- **Smaller private networks:** Most P4G/P5G networks have been deployed at campus-scale sites or larger wide-area domains like utility grids. As products become more standardized, easier to deploy, and automated ("zero touch"), the baseline should shrink considerably, especially with the use of cloud-based NaaS approaches. Companies with multiple similar sites, such as retail chains or hotels, could benefit from "cookie cutter" designs and rollout models. There will likely be important roles for new channel partners specialised in such verticals.
- **Cloud:** A growing number of P4G/P5G vendors are leaning on cloud-delivered or cloud-managed functionality, especially for core networks. We can expect this model to evolve further although mass-market deployment is questionable for 2023, but more probable for 2024-25, as companies such as Amazon AWS push new business models and "pay as you grow" approaches with little upfront cost and tighter integration with applications such as IoT and AI platforms. That said, there will still need to be customization to particular building designs, radio environments, and company-specific details that are hard to automate or deliver remotely. There will also always be a need for onsite surveys, installation, and maintenance.
- **Sustainability:** There is a growing focus on the environmental footprint of all connectivity and compute infrastructure, from energy consumption to CO2 "embodied" in equipment and device manufacture. Often, this compares to energy savings that are enabled by new automated and efficient buildings or processes, although the maths/accounting for carbon is complex and often debatable. For private networks, there will be opportunities in some new types of sites such as wind, solar, and hydrogen plants, while others such as coal mines and oil production may be challenged in the medium term. Elsewhere, smart buildings and cities generally require more connectivity, which is positive for this sector. The amount of energy used directly in P5G deployments tends to be low compared to the industrial or transport systems they assist.

International Differences for Private Networks

As noted throughout this e-book, the global market for P4G/P5G differs significantly, largely because of spectrum availability but also because of industrial structure and the needs of local industries.

Some markets such as UK, Germany, and Japan have well-designed regulations enabling shared spectrum to be obtained for specific factories or ports, although sometimes in unusual bands or for short periods of time for licenses. The U.S. now has a growing ecosystem for CBRS networks, but it can be difficult to access prioritized PAL licenses for small areas.

From a sectoral point of view, countries such as Chile and Australia have mines in remote areas requiring connectivity, while other countries see more P4G/P5G for major ports or airports. Germany is heavily focused on manufacturing use cases, while the UK seems to have a sizeable adoption among municipalities and construction sites. Some of these anomalies are just characteristic of early markets, so 2023-24 should see some of these effects "even out" over time.

Some examples of local spectrum accessible for the industry include:

Table: Examples of Locally Licensed Spectrum Options

Country	Spectrum bands	Licensing model
US	3.55-3.7GHz	Tiered licensing and dynamic access via automated SAS (Spectrum Access System) providers. Priority Access Licenses were auctioned on a county level basis. General Authorized Access is widely usable.
Germany	3.7-3.8GHz	Reserved for localized private network licensing, either with 4G or 5G equipment. Licensees can request rights for specific locations from the national regulator – typically for campus-sized facilities.
France	2.6GHz 3.8-4.2GHz	40MHz section of the 2.6GHz band has been made available for critical communications and industrial broadband use. New use of local licenses in Ban 77 is evolving & may be extended.
UK	3.8-4.2GHz 1.8GHz 2.3GHz	The 3.8-4.2GHz band is available for local 5G use, subject to protecting incumbent licensees. There are also small allocations at 1.8GHz and 2.3GHz. Another class of licenses is available for agreed secondary re-use of existing MNO bands in specific locations where they are unused.
Japan	4.6-4.9GHz	Local 5G licenses.
Australia	1.8GHz	30MHz set aside for enterprise and community groups.
Finland	2.3GHz 26GHz	Local licenses for industrial networks and other use cases.
Chile	2.6GHz	Local networks widely used for mining. Also, participation of MNOs allows use of national-licensed bands.
Denmark	3.7GHz	Leasing from MNOs is possible, albeit rare.
Canada	Various bands possible or under consultation	Remote areas have industrial SPs with various licenses around 700-950MHz, but Canada also considering CBRS-type models.
Taiwan	4.8GHz	
China	Various bands with MNO or government permission	Common participation of China Mobile and other MNOs in industrial projects, with government support on spectrum availability.
Source: Disruptive Analysis		

Key developments to watch in 2023/2024 include:

- **India:** Ongoing consultations and (often emphatic) debate between telco industry, government, and other stakeholders on suitable spectrum and rules for P5G.
- **Europe:** EU regulatory agencies and various individual nations are looking at new bands, especially in the 3.8-4.2GHz range, as well as updated strategy for its 5G "action plan" and the "digital decade" ahead. Norway has already opened this band, and France has some early test licenses.
- **China:** Early signs of a pivot towards direct allocation of spectrum to certain enterprises, perhaps in the 6GHz band. Until recently it has been very MNO-dominated.
- **Canada:** Canada does not have a direct equivalent of the U.S. CBRS band but has been examining the 3.0-4.0GHz range.
- **Middle East:** A number of countries such as UAE and Saudi Arabia have been investigating options such as the 4.0-4.2GHz range. There may be more movement in 2023.
- **South Korea:** Increasing emphasis on private 5G should pick up pace during 2023, including dual-connectivity solutions running in 4.7GHz and 28GHz bands. Samsung is aiming to be a major global participant and has support from the government, including building P5G for some agencies' own internal needs.

One other area of difference around the world is in the allocation of the 6GHz band for unlicensed use, and especially Wi-Fi 6E/7. Some countries such as the U.S., Canada, and Brazil have released the entire 1200MHz between 5.9-7.1GHz, while others have just allocated part of the band. 2023-24 will also see the launch of AFC (automated frequency coordination) for outdoor use.

While Wi-Fi and private 4G/5G are broadly complementary in use cases, there is *some* overlap and substitution. The position on 6GHz may drive medium-term differences – and the outcome of the World Radio Congress, WRC-23, at the end of the year is one to watch closely.

About the Author

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Network Technology & Futures Analyst/Consultant.

Dean Bubley (@disruptivedean) is the founder of Disruptive Analysis, an independent technology industry analyst and consulting firm based in London. An outspoken analyst & futurist with over 25 years' experience, he specializes in wireless/telecoms fields, with an eye on the broader technological, governmental, and societal contexts. He is one of the leading market observers and forecasters covering 5G/6G, Wi-Fi, FTTX, edge/cloud compute, enterprise private networks, IoT, and policy issues including spectrum, competition, and broadband wholesale. He has covered private cellular networks since 2001.

He is known as a contrarian and visionary, often with challenging opinions that go against industry consensus. Speaking at over 30 conferences and other events per year, and quoted by publications such as The Economist, FT, and Wall Street Journal, he is an authority and provocateur. He regularly appears in technology industry videos, podcasts, and blogs.

Mr. Bubley was formerly an equity analyst, covering communications stocks with the UK arm of investment bank Robert W. Baird. Prior to that, he spent eight years at UK research firm Datamonitor, where he co-founded the company's technology business and managed the internet and networking area and custom consulting operations, with roles of chief analyst and director of consulting. He holds a BA in Physics from Keble College, Oxford University.

References

[1] Industry association GSA registered 66 large (>$100k) new enterprises publicly deploying private 4G/5G in Q3 2022 in its database, implying a 250+ pa run rate. Given some enterprises have multiple sites, other installations are undisclosed, and many are smaller in size, a total of 1000+ is plausible.

[2] https://gsacom.com/technology/private-mobile-networks/

[3] https://www.telekom.com/en/media/media-information/archive/5g-millimeter-wave-technologies-for-industry-1024054

[4] IWLAN = Wireless Local Area Network (WLAN) interworking

ANDSF = Access network discovery and selection function

ATSSS = Access Traffic Steering, Switching and Splitting

N3IWF = Non-3GPP Access Interworking Function

[5] https://www.telekom.com/en/company/details/deutsche-telekom-demonstrates-multipath-for-fixed-mobile-convergence-on-campus-625838

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