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Disruptive Analysis

Don't Assume

PRIVATE LTE & 5G NETWORKS: **USE CASES, ECOSYSTEMS & OPENNESS**

WHITE PAPER

January 2020

INTRODUCTION

A key theme in the 2020s mobile industry will be private cellular networks – initially 4G-based, then transitioning to 5G as it matures. Enterprises, indoor structures, governments, IT solution providers, industrial players, cities, transport hubs and numerous other sectors will deploy, run and own cellular networks.

Various business models and architectures are emerging, supported by better availability of spectrum, more open platforms and broadening ecosystems of vendors, integrators and technology shifts. The US CBRS gold rush and the German industrial 5G initiatives are prime examples. UK, France, Japan, Nordics and others are also following.

KEY TOPICS IN THIS WHITE PAPER

This white paper article focuses on the following Open RAN architecture aspects:

- Demand and motivation for private cellular
- Technical and regulatory enablers
- Virtualization and cloudification
- Device & chipset support
- Small cells & Cloud/OpenRAN
- Use-cases & Applicatoins of Private LTE
- Roles for telecom operators in Private 4G/5G

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The mobile industry has been talking about "verticals" for some time, but this does not just mean "industry-specific solutions and customers," but entirely new and dedicated infrastructure and associated value chains for those verticals as well.

Sometimes this will be in collaboration with traditional mobile network operators (MNOs), partitioning and customising parts of their infrastructure for independent control. In other cases, the new networks will be completely independent of the telco world, exploiting new spectrum licenses, alternative investment models and flexible, cloud-based and open networks.

Businesses' historic mobile focus has been on phones and SIMs issued to their employees or connecting fleet vehicles and various terminals with mobile data. They have relied on the normal retail cellular services, networks and coverage of national mobile operators (MNOs), or specialised IoT- centric virtual operators (MVNOs) which repackage those same MNOs' spectrum and infrastructure.

Where businesses have directly invested in mobile networks, it has mostly been for indoor coverage solutions for guests, when MNOs wouldn't pay to install them. But even independently funded in- building systems have still relied on the MNOs to provide "signal sources" (small cell sites) – they haven't been standalone mobile networks. This is very different to Wi-Fi and specialised industrial wireless systems, where enterprises have been deploying and operating their own physical infrastructure for 10-20 years.

Some organisations have run their own private cellular networks – e.g., railways, utilities, mines and military. These have typically been expensive, mission-critical, and with special arrangements for spectrum. Collectively, they represent less than 0.1% of the world's 9.5 billion cellular connections (including IoT) – mostly focused on push-to-talk voice or low-speed data. From a vendor standpoint, this constitutes less than 1% of total capex spent on mobile infrastructure – very much a minor niche.

This situation is now changing rapidly. Easier access to spectrum, more flexible open network options and a growing ecosystem of integrators and niche Service Providers (SPs) is making private cellular far easier, even as demand grows with IoT and industrial transformation. And while private networks may never account for billions of connections, the broader impact on enterprise, network coverage and economic growth and productivity is likely to be disproportionately higher. This paper examines the trends and opportunities.

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BACKGROUND: HISTORY, DEFINITIONS AND MOTIVATIONS

20 years of evolution

Private cellular networks are not a new concept. The author of this report first discussed enterprise- grade (2G) small cells with a vendor in 2001. Local access cellular spectrum was first made available in 2006 in the UK. And around the world, about a million structures have some sort of in-building system for distributing cellular signals – although these are not full cellular networks, as they rely on the MNOs' radio equipment and spectrum.

Dedicated 2G, 3G and 4G private networks have been used for years at mining sites, oil and gas facilities, military bases, and locations where public cellular coverage is poor or unsuitable – and where Wi-Fi has also not been appropriate because of interference risks or mobility needs. Railways have used specialised GSM-R infrastructure for communications.

But today, private (or to use an industry term, "non-public") cellular networks are rare – maybe a few hundred have been implemented worldwide, often designed and deployed at considerable cost by specialist providers and managed by expert staff.

This situation is about to change rapidly. The next few years will see those 100s of private networks grow to 1000s or even 10,000s and beyond. In 2019 alone, numerous countries' telecoms authorities have announced new policies for localised or shared spectrum access, suitable for private 4G or 5G deployment. Key technical enablers such as cloud-based core networks and open, flexible small cells and disaggregated RAN (radio access network) components have started to mature.

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Demand and motivation for private cellular

And as well as supply evolution, there has been an upswing in awareness and demand among enterprises – from manufacturing companies to theme parks, and from ports to private jets.

There is a huge pent-up demand that revolves around "the four C's:"

> Coverage: organisations want improved connectivity indoors, in remote areas, or in other locations where the "macro" cellular coverage from MNOs is poor.

> Cost: enterprises often do not want the "per device, per month" or "per gigabyte" charges associated with commercial mobile networks, especially for onsite usage of IoT devices, employee smartphones, cellular-connected video cameras, etc. They would prefer ownership- based models similar to Wi-Fi connectivity.

> Control: businesses often want a greater level of visibility and accountability for their networks, especially where they are used for business- or mission-critical applications. They prefer their own security and data/subscriber-management policies, and optimisations/upgrade cycles tuned for their own needs.

Commercials: in some cases, private LTE/5G networks are used to offer revenue-generating services for other third parties. Landlords may want to offer mobile connections to tenants (individuals or companies).

Numerous reasons for enterprises wanting to adopt private cellular

Coverage	Control	Cost	Compensation
• In-Building	• Security	• Replace legacy LMR	• Productivity
• Rural	• Sovereignty	• Factory 4.0	• Private SIMs
• Industrial	• Customised	• Replace Fiber	• Roaming
• Offices	• Beyond Wi-Fi	• Avoid carrier per-GB fees	• Local MVNO
• Road / Rail	• Deployment	• Own IoT connectivity	• Govt funding
• Utility	• Lifecycle		• Local FWA
• Metro areas	• Mobility		• MNO offload
• Military / Govt	• Private QoS		

Source: Disruptive Analysis

Definitions

Private networks span a huge range of scale and scope. At one end, a single building (or even ship or plane) might have a local cellular network, based on a single small cell radio. At the other end of the scale, a railway network or utility grid could operate a national network that has better geographic coverage than normal commercial MNOs. In the middle are airports, cities, universities and industrial complexes.

It is important to distinguish between three definitions of "private mobile:"

> Dedicated data access mobile network services sold to enterprise customers, using the public cellular infrastructure and spectrum. Private APNs (access point names) have enabled enterprises' applications to bypass the public Internet and connect directly to their data centres, from cellular operators' core. This approach has been available for many years.

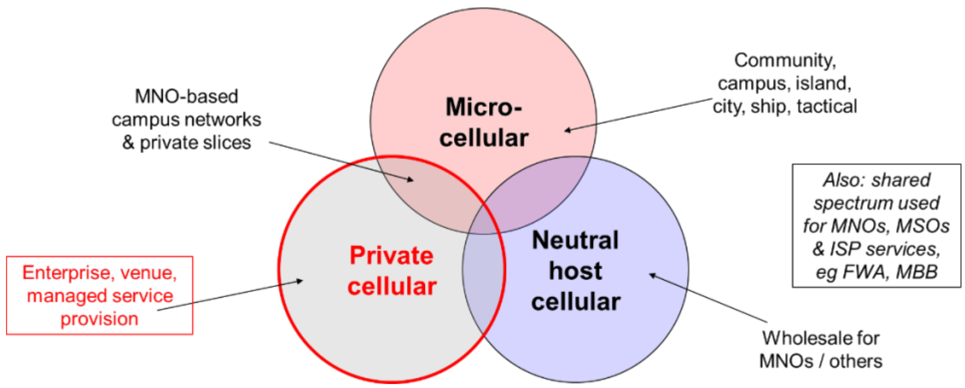
> Mobile networks can be optimised, extended or virtualised for industrial and enterprise requirements – for example, "campus networks" being pitched by major MNOs such as Deutsche Telekom and Swisscom for onsite use by major firms.

> Mobile networks built exclusively for, or owned by, industrial companies and other enterprises. These can be completely standalone networks that are entirely isolated from public mobile networks, or could have roaming or other interoperable capabilities, for instance when a truck leaves a logistics facility with a local private network and switches to an MNO while it's on the road.

This paper primarily focuses on the third category – private mobile networks – although there is some overlap with the second, especially with approaches like network slicing. There are also various hybrids and nuances, such as private networks where certain functions are installed by, outsourced to, or managed by MNOs.

Another emerging category is that of "neutral host" networks - wholesale 4G or 5G infrastructures used to host major MNOs in locations where access or economics are challenging for self-build deployment and operations.

Various overlapping categories of “non-public” mobile network are emerging



Source: Disruptive Analysis

Technical & regulatory enablers

There are demand and supply drivers for private cellular. Use cases and demand factors are considered in a separate section; here we look at the key technological evolutions and regulatory developments that are acting as catalysts for this new marketplace:

- Democratisation of 4G / 5G suitable spectrum
- Other forms of regulatory & policymaker support
- Virtualisation & cloudification of key control elements such as EPCs/5G Core, Edge Compute, eSIM and OSS/BSS
- Device & chipset support
- Small cells & Cloud/Open RAN
- Ecosystem readiness and maturity

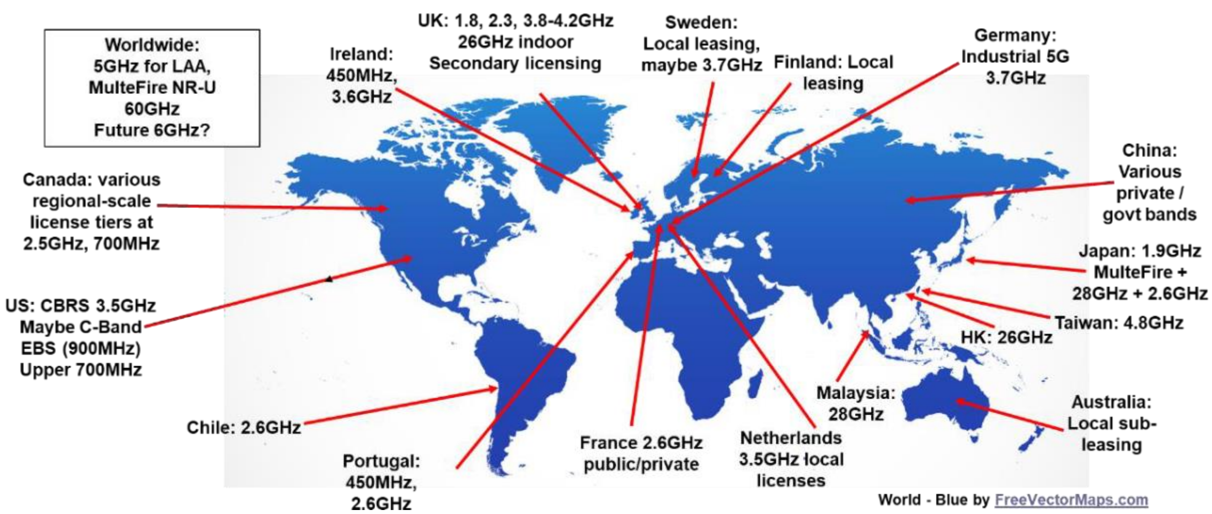
Democratising spectrum

Many conventional MNOs are working on “semi-private” networks for enterprise – typically campus networks which run in their normal spectrum bands, but which delegate some form of local autonomous control to an enterprise, via a private core network or virtual “slice” which is logically isolated from the main macro domain.

But what is far more disruptive is the advent of localised or shared spectrum allocations, which permit “non-public” networks to be built by enterprises themselves, or new classes of service provider and integrator. These can be standalone islands or can support roaming or sharing with the wider mobile universe.

Historically, local spectrum licenses have been available for point-to-point fixed links, temporary outside broadcast and events, private mobile radio and other purposes – but not in bands suitable for cellular networks.

Many countries are allocating spectrum suitable for private LTE / 5G networks



Source: Disruptive Analysis

Numerous countries have started to create flexible schemes suitable for private networks – although there is a large variability between national markets at present, in terms of rules, costs and license area sizes. Some interesting approaches include:

- **Dedicated licenses for specific sites.** For instance, Germany is releasing 3.7-3.8GHz frequencies for private 5G networks at industrial sites on a “first come, first served” basis. Swedish and Danish authorities are looking at something similar.

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- > **MNOs leasing spectrum** in specific areas to enterprises or specialist providers. This occurs in markets such as Finland and Australia, to cover ports, mining, etc.
- > **“Dynamic access” spectrum sharing,** with database-driven systems and sensor networks for temporary or opportunistic allocation of spectrum. The US CBRS model is an example of this approach.
- > **Secondary re-use of national bands,** where they are not being actively used by the main licensee. The UK has recently adopted this model. It is similar to earlier TV “white space” models that aim to increase the efficiency of spectrum usage.
- > **Indoor-only permissions** for bands that avoid long-range interference with incumbent users because the signals do not pass through walls easily. The UK is looking at this model for 26GHz.
- > National licensing of spectrum for specific networks, such as for utility company grid control and IoT. This approach is seeing traction in markets such as Portugal and Ireland.

Disruptive Analysis expects the 2020-2022 period to show which models work best, with a second phase of spectrum releases – perhaps from 2024-2026 - incorporating lessons and best-practices. This will also parallel growing sophistication and maturity in spectrum databases, as well as more dynamic marketplaces for spectrum trading and rental.

Other forms of regulatory and government support

In addition to new spectrum models suitable for private LTE / 5G, various other shifts in the policy and regulatory world are making enterprise and vertical networks more viable.

These include:

- > Recognition of private networks’ role in national broadband, 5G and industrial policy
- > “Barrier busting” task forces, which look at practical obstacles such as rights-of-way and cell tower / small cell siting regulations and processes
- > Government-funded testbeds and trials for 5G use cases and concepts
- > Government-owned cellular networks for public safety, transport, and metropolitan authorities
- > Other areas of telecoms regulation such as numbering, interconnect rules, applicability of lawful intercept rules and so forth

Although not technically "private" networks, some regulators are also allocating spectrum for wholesale "neutral host" use, either for government-run shared networks, or commercial operators assisting commercial providers with connectivity-as-a-service.

Yet more releases are spectrum issued to conventional MNOs, but with license conditions that mandate slicing, private campus/indoor provision, or deep MVNO wholesale access.

Taken together, all these approaches by government and regulatory authorities are easing the introduction of private cellular.

It is notable that in some markets there has been effective lobbying by some industries (e.g., automotive, manufacturing and utilities) which has helped accelerate the process by highlighting economic and operational benefits.

Virtualisation and cloudification

Along with the availability of spectrum and regulatory support for private networks, probably the next most critical ingredient is that of software. Historically, cellular core network infrastructure has been complex, expensive and requiring dedicated hardware and skilled engineers. Backing it up, operators have also needed considerable further investment in operational and billing software systems and a variety of other platforms for subscriber management, security and so forth.

While there have been lower-end solutions for smaller operators or specialist networks for utilities or mining, entry barriers and costs have still been substantial, especially where networks do not have an associated direct revenue stream and where the performance and security have needed to support business- or mission-critical use cases as well as phones. In the future, private networks will also need to support 5G capabilities (such as ultra-low latency and network slicing), and perhaps edge computing and other features.

This means conventional approaches to building cellular networks need to evolve, supporting easier scaling up and down in capacity, more automation, greater agility in terms of configuration, and lower resource overhead needed to support operations.

Disruptive Analysis sees two parallel and diverging trends:

- Cloud-based platforms for elements such as EPCs and 5G cloud-native core networks, as well as IMS, OSS/BSS and SIM/eSIM management and provisioning. These run on COTS (commercial off-the-shelf) hardware or public clouds, enabling lower costs than traditional vertically integrated suppliers tend to offer, in both commercial and open-source versions. These are likely to be the main engine for growth in the private cellular marketplace, especially for "mass market" sites such as hotels or transport hubs, or where companies like retailers require distributed cloud-based capabilities at multiple locations.

- "In-a-box" integrated solutions for 4G/5G networks running in isolation, where the company wants physical ownership and control over all components on-premise, without reliance on external data centres. This approach is most likely for remote oil, gas and natural resource sites, as well as certain manufacturing or defence / national infrastructure organisations which remain wary of cloud-based models.

In essence, this mirrors the development of IT overall – a mix of onsite, cloud-based and hybrid. In some verticals this could also be compared with the delivery of electricity – there is often a mix of national grid-based power and local onsite generators.

Device & chipset support

In the past, cellular devices have supported a very constrained set of frequency bands, which meant it was much harder for innovators to exploit non-standard spectrum allocations. There was a "chicken and egg" problem where device and silicon vendors only created products for national networks, operating in mainstream national bands.

Where innovators and enterprises could get hold of small slices of spectrum suitable for private use, they often couldn't get reasonably priced devices to exploit that resource, given the low volumes involved. While certain verticals such as public safety could afford custom units or IoT modules, this was beyond the economic reach of many other sectors. There was also no easy way for normal devices (e.g., mass market smartphones) to work on both private and public networks, especially if they needed different SIMs as well.

While some of these issues remain, the device ecosystem is now much more aligned with the private network opportunity. Bands such as CBRS in the US are now supported in key handsets and silicon platforms. Others are within "tuning range" of future radios or can be adapted from other global regions. There are so many 4G and 5G bands that it is likely that not all will be used for national-only MNOs in all countries.

The problem hasn't gone away completely – some proposed frequencies like the UK 3.8-4.2GHz local band are poorly supported today – but it is being fixed progressively. There are also numerous vendors of gateway products, so that a vehicle or shop or other location can use private LTE/5G, feeding "downstream" devices via Wi-Fi or Bluetooth locally

Added to increasing band support, we also see growing numbers of devices supporting dual-SIM or eSIM (for remotely provisioned SIMs), which means that enterprises and private networks can further reduce barriers for device onboarding.

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Small cells & Cloud/Open RAN

For many private cellular networks, conventional macro-scale radio networks will be inappropriate. Either the locations are indoors, user numbers are small, there could be power limits associated with particular spectrum bands, or perhaps they need a neutral host model which supports multiple MNO tenants on the same infrastructure.

A different set of reasons means that traditional distributed antenna systems (DAS) may not work well for private cellular deployments either – either because conventional DAS cannot deal with higher frequencies expected for 5G

(especially mmWave), or because it is poorly suited to supporting new features such as URLLC (ultra-reliable low-latency communication) connectivity and deterministic communication. DAS can also struggle with campus indoor / outdoor deployments, mobility for vehicles and so forth. More active, RAN-type solutions are needed.

All these and various other scenarios push infrastructure owners towards various forms of small cell and decentralised and disaggregated RAN. At the same time, that part of the industry is itself evolving rapidly with the advent of TIP (Telecom Infrastructure Project) OpenRAN and related architectures, supporting lower-cost radios, and the ability to support multiple software-based basebands and other features. Some players in the DAS space are also developing hybrid systems with greater degrees of control and functionality, bridging traditional in-building systems with OpenRAN-type approaches.

As networks evolve further towards 5G and higher frequency bands above 3GHz, these types of approach will become yet more relevant, especially in indoor scenarios, or for industrial campuses and smart cities. Multi-tenant RANs will be especially important for neutral host providers, or towerco's looking to diversify towards small cell-aaS models.

Ecosystem readiness and maturity

Conventional mobile operators have had decades to build up their expertise in planning, deployment and operation of their networks, aided by major vendors and consultancies, plus specialist sub-contractors to climb towers, lawyers to ensure regulatory compliance, and test labs to check that new devices work properly. Even then, the majority of usage has been straightforward – consumer phones, plus some connected machines, with primarily outdoor coverage, extending indoors as the (mostly low-band) spectrum allowed.

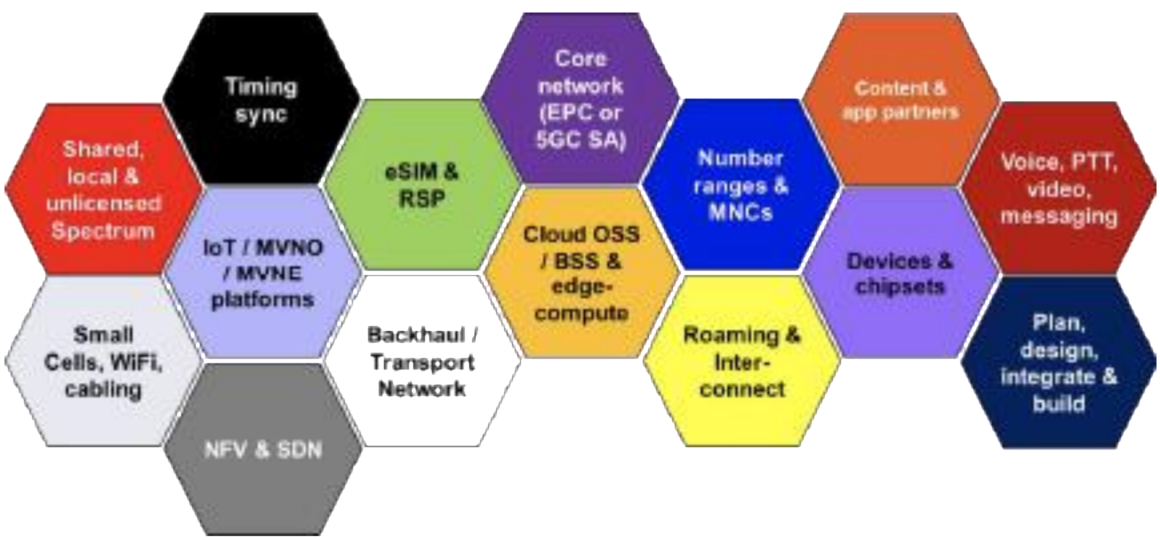
Most enterprises now considering private cellular have none of these resources or expertise internally, nor even among their normal array of IT suppliers and integration partners. Furthermore, the expectations for enterprise LTE and 5G is that they will be used for demanding applications such as mission-critical voice, vertical-specific industrial machinery, and latency-intolerant systems that could cause a danger to workforces. Even where the new networks are aimed at human guests or visitors, there will be difficulties around roaming, network sharing and commercial models.

For today's existing private networks, a variety of specialist integrators and niche service providers have emerged, mostly fuelled by a cottage industry of vendors of small cells and core network components. Some of larger mobile equipment players have developed "special projects" units, while existing providers of critical communications gear (such as TETRA mobile radios) have added 4G systems to their portfolios.

But this heavily customised "artisanal" approach is not scalable. The promise of truly "democratised" cellular, based on new spectrum releases and cloud-based platforms, will need more efficient channels and facilitators. The private LTE (and then 5G) sector will need to look more like the Wi-Fi industry, with "industrialised" deployment methods and multiple tiers of integrators and installers, especially for simpler and more straightforward implementations. Larger IT or industrial transformation projects will need to be able to incorporate cellular connectivity into their wider designs in routine fashion.

The real success of the new market will be heavily dependent on mature, accessible and diverse ecosystems. Ideally, industry organisations will bring together stakeholders, facilitate networking and partnerships, create baseline processes and design templates, publish case studies and identify gaps. There is also a need for training and certification.

Typical Maximum Power Consumption of a Single 5G Base Station



Source: Disruptive Analysis

The US marketplace for private cellular is probably the best exemplar of these moving parts. The CBRS Alliance has brought together a broad group of supporters, including end users, spectrum database providers, small cell suppliers, device/silicon vendors, integrators and, importantly, the traditional carriers and cable MSOs as well. It has catalysed “critical mass” for the new sector with a thriving array of stakeholders. Internationally, organisations such as the 5G Alliance for Connected Industries & Automation (5G-ACIA) are looking at both private and public network ecosystems and use cases for certain markets.

Ideally, similar approaches will be adopted in other countries, or internationally. Disruptive Analysis is aware of a number of initiatives that should lead in that direction already.

Use-cases and Applications of Private LTE

The previous sections describe different types of private LTE / 5G networks being deployed for a variety of industries, applications, organisation types, and underlying rationales.

Historically, the private cellular market has been driven by the most remote or challenging sectors such as mining, oil exploration and utilities. Now we are seeing a rapid expansion into almost all sectors of the economy and public sphere. Sports venues, manufacturers, ports, hotels, municipal governments and hospitals are considering the opportunities.

This section considers use-cases along three main dimensions

- Scale of deployment
- Industry sector (vertical)
- User / device class (horizontal)

There are too many use cases to consider individually – the following discussion is intended to give readers an idea of the scope of opportunity, and to recognise that even within a specific enterprise, there may be many different possible applications. This has significant implications for MNOs and integrators that want to target “verticals” – they should not underestimate the true breadth of work and expertise that will be involved.

For instance, consider a utility company: it may have huge connectivity needs internally inside power stations, for control systems across its national high-voltage grid, and for city or nationwide remote metering. Many IoT assets may be in locations not reliably reached by the public MNO networks – including pylons across mountain ranges, or hydroelectric dam turbines and subterranean ducts, encased in thick concrete. RF interference may be created by transformers or sparks. Those are all very separate problems with differing technical and business-model solutions.

Scale

Private networks are presently being deployed at scales ranging from a single access point and very limited coverage (perhaps for a small building, or even a ship or private jet), through to national-scale networks for rail or utility companies, which may even have broader coverage than the major MNOs' networks. In the middle are large campuses and buildings (for example, an industrial complex or large hospital with multiple buildings), or cities and broader metropolitan areas.

Obviously the overall size of the network tends to be proportional to the costs involved, both in terms of upfront capex and ongoing opex. However, there is more nuance to be considered by suppliers and service providers:

- The largest private networks are likely to involve "critical communications" and the reliability and security requirements that brings will tend to drive costs (and design principles) for other applications as well. In some larger deployments, there may be reluctance to rely on public cloud infrastructures.
- Smaller and mid-size networks include most "venues" and "buildings" which can expect visitors and access by the general public. These are most likely to demand neutral-host or MNO roaming capabilities, and are also likely to have high capacity requirements from cameras, visual displays etc. They will also likely need good Wi-Fi in most of the same places as 4G / 5G. The application mix is likely to evolve rapidly – and maybe unpredictably – over time, as well as the need to onboard new SPs. This will drive a focus on flexibility and openness / programmability.
- Campus-sized networks will often vary considerably, potentially with very different needs and applications in different locations – consider an airport's terminal vs. the outdoor concrete apron, or the hangars and maintenance areas.
- In the more-distant future, we may well see "micro-networks" emerge, perhaps for individual retail stores or even vehicles. However, in many cases these will not be wholly independent – there will likely be an aggregation layer (say, for a retail chain's store networks). That could drive cloud-based cores and other functions.

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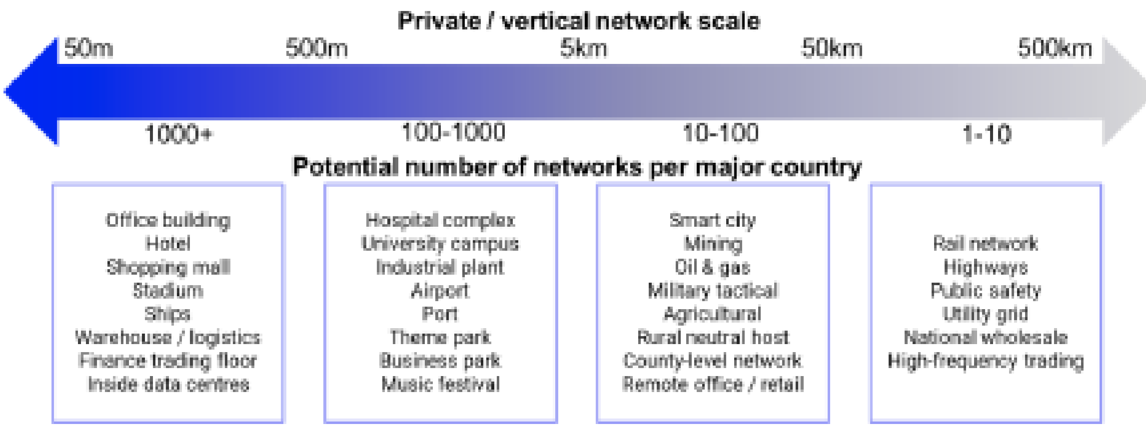

Source: Disruptive Analysis

Industry sectors

It is common in telecoms and IT industries to divide the enterprise market by vertical – retail, healthcare, finance, oil and gas and so on. This is sensible, driven by the need to create specific technical solutions, marketing approaches / channels, and sales strategies.

However, it is critically important to recognise that even within an industry, there can be many different physical environments (e.g., healthcare = hospital + clinic + pharma R&D + patients' homes and so on). From a private LTE / 5G point of view, this means that SPs, integrators and vendors need to think of each vertical group as a "practice" rather than a specific solution. Certain verticals are a bit more homogeneous – perhaps ports, for instance. Others are so diverse – such as smart cities or major mixed-use property developments – that they embrace multiple vertical domains.

The early growth in private cellular has been mostly in:

> Oil & gas
> Transportation hubs
> Utilities
> Public safety & military

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That has been driven by spectrum availability and because these have often been cost-insensitive. Many are unable to use Wi-Fi or fixed connections for many of their applications, especially vehicular or push-to-talk.

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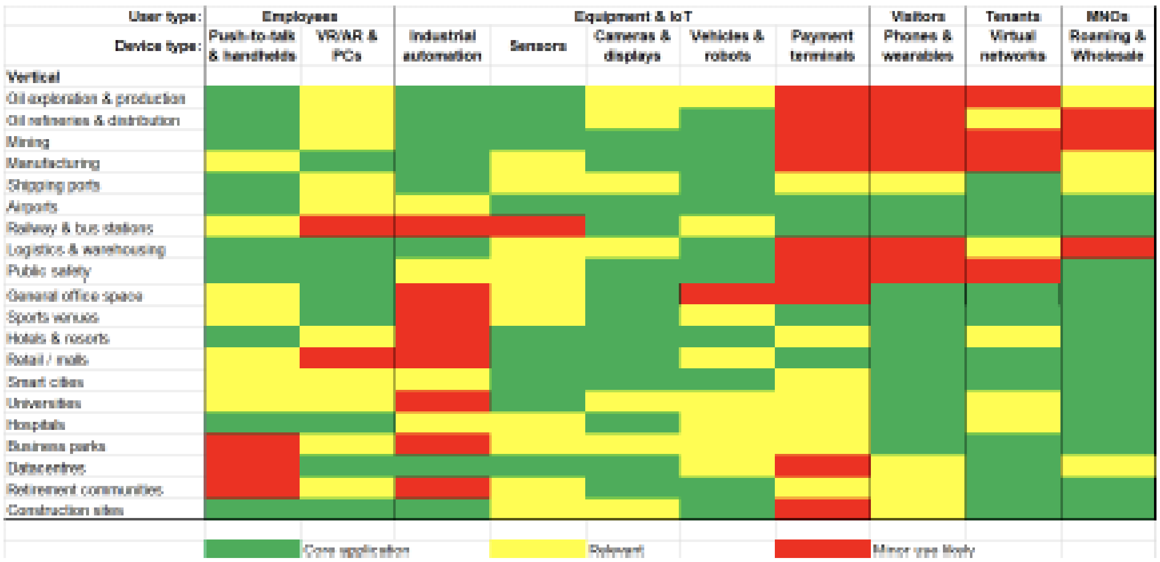


Source: Disruptive Analysis

Over the next 5 years, readers should expect much stronger growth in private LTE/5G in:

- Manufacturing (although with long design / prototype cycles)
- Logistics and warehousing (very IoT-centric e.g., robots in fulfilment centres)
- Sports and entertainment venues (initially for “back office” users like broadcasters)
- Smart cities & business parks (with a lot of diversity in early usage & applications)
- Airports (especially “airside” rather than “landside”)
- Hotels & resorts (initially staff, then moving to guests and neutral host over time)

Many other sectors and case studies will no doubt emerge as well. Certain countries' industrial structure and local spectrum licensing policies may benefit particular sectors disproportionately. In the long term, pretty much the entire economy has the potential to exploit private LTE / 5G in some way, much as they do today with Wi-Fi.

As well as segmentation by industry, it is also useful to consider usage models and device/application types that most benefit from cellular connectivity (public or private).

The chart above gives a high-level view, across the 10 most important horizontal use cases:

- **Employees:** enterprises have large connectivity requirements for their workforces.
    - The use of private 4G / 5G for push-to-talk, replacing older two-way radio systems with smarter multi-function units or smartphones, is a prime driver for investment. These can be "critical communications" tools for sectors like rail and public safety, or more general business tools such as mobile staff in a hotel or entertainment venues.
    - There will also be a desire to connect other employee-borne devices, such as barcode scanners and, increasingly, AR/VR headsets for hands-free access to maintenance data or other applications.
- **Equipment and IoT:** This is a category in its own right, with multiple sub-divisions:
    - **Industrial automation:** Diverse classes of equipment, such as conveyors, industrial controllers, power systems, HMI (human machine interfaces), pumps, welding and joining systems, analytics and so forth. Typically these will all have some form of embedded compute capability, often connected today with Wi-Fi, proprietary wireless or fibre. Some of these systems will have very low latency requirements or need precise "deterministic" networks. Later versions of 5G, capable of URLLC or Time Sensitive Networking (TSN), will drive more innovation in private cellular usage here.
    - **Sensors:** Many IoT applications need to monitor and collect data from sensors. There are hundreds of types, covering variables such as temperature, vibration, pressure, movement, air quality, chemicals, fluid flow, radiation and so on. Often, they are battery-powered, requiring energy-efficient protocols. Some private 4G / 5G networks may use NB-IoT or other "massive IoT" standards, either in licensed or unlicensed spectrum.

  - **Cameras and displays:** A large % of wireless data is expected to be driven by images and video – either capturing / uploading from camera or display via the ever proliferating numbers of digital displays. There are many use cases here, from security cameras, to advertising boards, to real-time image analysis for quality control in manufacturing.
  - **Vehicles and robots:** Many industries employ moving systems on their campus sites or across wider areas. These will almost always need wireless connectivity for control, or perhaps remote-driving or onboard communications. This includes autonomous guided vehicles (AGVs) in factories or ports, tractors in agriculture, human-transportation pods in retirement villages, drones for aerial inspection on construction sites or chemical plants, and many others. These systems need careful network planning, prioritisation, latency and reliability, especially for safety reasons.
  - **Payment systems:** Many high footfall locations have transaction-based systems such as payment terminals, ticketing machines, ATMs and so on. Today, many use the same (congested) Wi-Fi that staff and visitors use for smartphones and other devices. They may be deep inside buildings, with little coverage from outdoor MNO networks. As they are often business-critical, there is a clear desire to offload the connections to localised, private-managed and uncongested cellular. There is also a strong security-based argument for putting these on an isolated network.

- **Visitors and guests:** In many locations, visitors expect continuous coverage from their normal MNO. But they may prefer to obtain new, local connectivity – for example to avoid international roaming fees. While Wi-Fi is prevalent, there is also a need for cellular connectivity, both for smartphones and other devices. Private LTE / 5G networks could also enable venue owners to offer “free 5G,” similar to Wi-Fi, perhaps monetising with advertising or social media connections. Contractors on enterprise sites (for instance auditors, or sub-contract construction engineers) could also use the local connectivity provided by the IT staff.
- **Tenants:** Some private 4G / 5G networks will operate like a small public MNO, where the tenants (individuals or separate businesses) are their “subscribers.” This includes residential multi-dwelling units (which already provide fixed broadband to apartments), or locations such as airports or shopping malls or shared office space, with onsite businesses wanting connectivity for their employees and other systems. This model already works – Heathrow Airport offers telecom services to caterers and maintenance companies, and Southern Linc (part of a US utility firm) offers managed push-to-talk for other critical-comms users in several US states.

- **MNOs:** Many venues need to provide good connectivity for members of the public to their chosen cellular provider. While many shopping malls and airports have good cellular in-building systems, these do not always have the capacity for future-proofing, nor do they support bands needed by many 5G networks. Other buildings such as offices, smaller retail outlets and mid-size hotels often do not have cellular coverage solutions at all. Here, we may see “neutral host” models emerge, where the private network supports inbound roaming, or some other form of wholesale core network connectivity, from the main outdoor cellular network providers.
- **Other:** There are various other use cases for private cellular beyond these, that relate to specific verticals. For instance, there could be localised private fixed wireless access in a caravan park, or to multiple tents and food stalls at a music festival. Some sites will have specialised applications such as broadcast systems.

ROLES FOR TELECOM OPERATORS IN PRIVATE 4G/5G

The previous section outlines the huge diversity in enterprise use cases and applications, which will drive demand for onsite or wide area cellular connectivity.

But the uncomfortable truth for the mainstream cellular industry is that it does not have the expertise – nor workforce – to deal simultaneously with hundreds or thousands of unique “special projects” for enterprises.

As the world’s businesses set out on transformation journeys, deploying IoT systems, or servicing employees and guests, in locations with unusual radio environments, sector-specific safety rules, and economic models that do not map to conventional subscriptions, traditional MNOs will have to pick and choose certain sectors on which to focus.

Few MNOs will be able to deal with installing network components and sensors around explosive gases in an oil refinery, as well as a custom network at an airport where moving A380s can block wireless signals. Instead, we will see those organisations take matters into their own hands, either deploying networks using their own IT teams, or working with specialists that better understand the applications and sectoral constraints.

A theme park may want to connect ticketing systems, digital signage, onsite vehicles, security cameras, staff push-to-talk radios, payment terminals and so forth – as well as providing good cellular network performance for guests in the park and inside hotels and stores. Most of these systems might be covered by the national MNOs’ network, but this could be cost-prohibitive and hard to re-engineer as the resort evolves – for example, when a new attraction or ride comes online.

That does not mean MNOs will lose out: they will still have numerous services and capabilities to provide, even if they cannot offer complete solutions. These include “retail” offers sold direct to the enterprise and “wholesale” options to other SPs and integrators:

> **Campus networks:** Some MNOs offer dedicated onsite infrastructure for major enterprises such as manufacturers and ports. This can cover both indoor and outdoor areas and may include dedicated extra radio equipment for ubiquitous coverage. In some cases, a separate on-premise core network is offered, or a separate virtual cloud instance, with the enterprise gaining some measure of administrative rights and control. Future evolutions could leverage Open RAN technology and the enterprise’s own in-building fibre infrastructure. Unlike pure-play private networks, it is easier to interoperate the onsite connectivity with wide area service if an MNO is involved.

> **Shared in-building systems:** In some markets, MNOs will cooperate to create –and sometimes fund - shared indoor wireless networks. In the UK, for example, the major MNOs have created the Joint Operator Technical Specification model. Potentially, flexible Open RAN variants of this could also support private networks as well as the main MNOs.

> **Network slicing:** In later versions of 5G, it will be possible to create partitions of MNO networks for different applications, customers or demand profiles. Although often slices will be nationwide - essentially next-generation MVNOs - there is also potential for geographic slicing, with different network configurations (perhaps local break-out, for instance) and even external control provided to third parties.

> **Spectrum leasing:** Some MNOs have national licenses but have not built-out their networks in certain areas – for instance, remote or mountainous territory. Where enterprise facilities are located in those areas – perhaps mines, pipelines, ports and shipping terminals – they can assign spectrum to a business or an integrator, either through a lease or localised resale. This is already common in a number of markets such as Australia and the Nordics.

> **Implementation and operational services:** There is an analogy between private LTE and the historical market for business phone systems (PBXs). PBXs gave businesses control of call-switching, local numbering, applications like contact centres and voicemail, and free unmetered calls between extensions. Yet many telcos viewed enterprise telephony as a good business – they sold PBXs, installed them, maintained them, provided direct dial-in numbers, leased lines and trunks. Disruptive Analysis expects a similar set of service elements and components to exist around private LTE / 5G. It could be that MNOs even design and install the systems, but let the IT staff own, operate and control them. Various classes of managed service will likely evolve – whether that is for security, subscriber / SIM management, RF planning and monitoring and various other necessary roles.

- **Cloud-based functions:** As discussed previously, building a private LTE / 5G network involves numerous software components – the EPC / 5G Core, operational systems, the software part of the (increasingly disaggregated) radio infrastructure, interconnection with other networks, perhaps systems for regulatory compliance and so on. While many vendors are attempting to sell cloud-native components direct to the enterprises or their integrators, we may also see conventional MNOs offer their own multi-tenant cloud elements, perhaps even hosted in their own edge compute infrastructure.

The open question is whether MNOs will genuinely seize these opportunities. At the moment, some seem to be taking an "all or nothing" stance, hoping to provide complete vertical solutions for IoT and other purposes. In part, they are hoping to persuade policymakers that they should avoid "set-asides" of spectrum for private networks, instead incentivising national MNOs to offer tailored enterprise-centric services like the campus networks mentioned above.

Disruptive Analysis believes that MNOs will eventually recognise they have a sizeable network element / supporting service opportunity, even if they cannot provide integrated solutions.

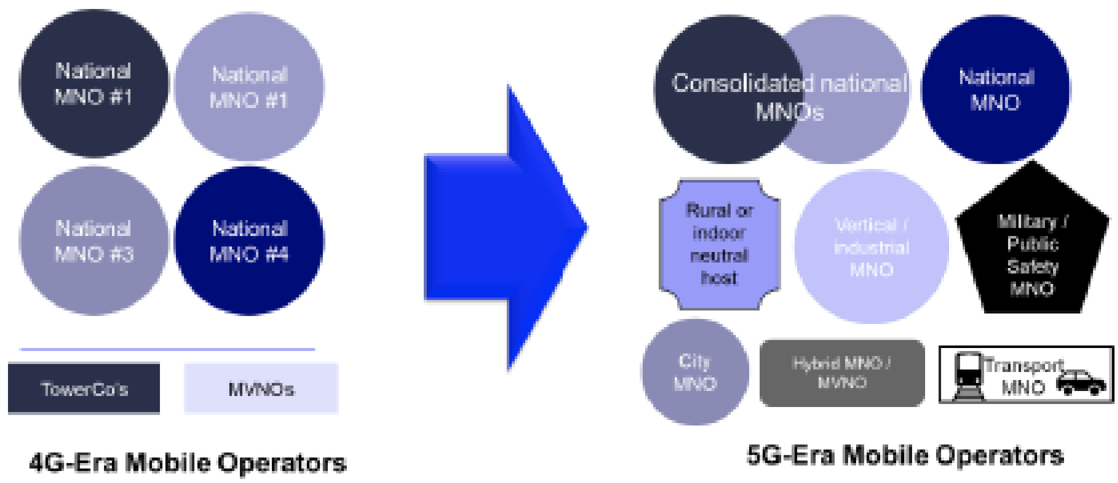
Other Communications Service Provider (CSP) types

As well as discussing "what is the role of telcos and MNOs" in private LTE / 5G, there's a slightly more "meta" question to address in parallel: What exactly is a mobile operator, in the 2020s, the "5G era?"

How should an existing MVNO, which adds a limited radio network of its own, be categorised? Or a cable operator, using LTE or 5G fixed wireless access outside its normal footprint? Satellite and

"HAPS" (high altitude platform system) operators are being integrated into the cellular worlds as well. Overall, we can expect almost all forms of CSP to develop a mobile footprint to some degree, even if they are not classical "MNOs."

Typical Maximum Power Consumption of a Single 5G Base Station



Source: Disruptive Analysis

While a single enterprise running its own internal network, solely for its employees and IoT devices, cannot really be described as a service provider, the definition gets much cloudier when you consider metro-scale MNOs (for instance, in Austria, where recent spectrum auctions created four new regional-scale operators or consortia).

We will also see the entry of various “new telcos” as well as IT and industrial solution integrators operating in new shared-spectrum bands, on behalf of their enterprise clients. Sometimes they will obtain frequencies directly through the various new release mechanisms, and in other cases they may lease or rent spectrum from incumbent MNOs.

Overall, Disruptive Analysis expects the distinction between “public” and “non-public” network to become far less clear. This will prompt re-evaluation by regulators, investors and enterprises themselves.

STRATEGIC ISSUES & FORECASTS

Market sizing

This white paper is not intended to provide a full quantitative model and forecast for private LTE / 5G. Nevertheless it is important to identify the core trends that are likely to occur – as well as accelerants and risk factors.

- Today, private cellular networks account for <1% of total mobile industry capex & <0.1% of overall SIMs (under 10 million), although some utility companies in China may soon exceed that number with smart meters, as they deploy private wide area networks for cellular IoT.
- By 2025, potentially 3-5% of cellular capex could be on "non-public" networks (out of a rough estimate of $100bn total). There are many variables here, but it is a significant value, especially since it implies considerable extra revenue pull-through in software, integration, maintenance and so on.
- As a cross reference, the enterprise Wi-Fi market is worth around $6bn per year and is mostly indoor-only. It is not unreasonable to imagine private cellular growing to a substantial fraction of that figure, especially given that Wi-Fi spending is often on upgrades rather than initial installs.
- Estimating the number of networks is hard, as some may be very small (e.g., a single store or ship), but managed in groups (a retail chain or shipping fleet). Others may be national-scale, such as private LTE / 5G networks deployed by utility companies. However, it is reasonable to think in terms of thousands and then tens of thousands over a five-year time horizon.

The main growth markets are expected to be:

  - The US, where the CBRS ecosystem appears to have reached critical mass, with diverse use cases and large numbers of interested parties.
  - Germany, where both large and mid-size manufacturing companies are keenly investigating private networks, with a roadmap to 5G and industrial automation. Initial deployments may be LTE-based, with 5G developments subject to thorough testing, evaluation and pilots – many of the potential users are quite conservative, and highly security-focused. MNOs are keen to be involved, but it remains to be seen how successful they can be.
  - The UK, where the regulator has developed several highly innovative (and inexpensive) approaches to obtaining local spectrum.

- Japan, where numerous industrial companies and metropolitan authorities are keen to build out their own networks – and perhaps export the expertise as well.
- China is something of a special case, where government and state-owned enterprises can potentially get access to spectrum where needed. Though it is less likely to be a fully open market for any enterprise.
- Other European markets are likely to follow the early leads of Germany, UK or Netherlands models, although the French regulators seem to lean more towards MNO-centric approaches, except for the largest organisations like transport hubs and rail.

Relationship with other networks

Private LTE and 5G networks will not exist in a vacuum – most enterprises will maintain and grow various other connectivity platforms. A manufacturing campus will likely retain a large amount of direct fibre connectivity, Wi-Fi, and various proprietary wired and wireless technologies, for instance.

Some key trends are likely to be:

- The majority of deployments in 2020-2022 will be private 4G, not 5G. The true benefits of 5G (such as URLLC) will only emerge with the maturing of standalone 5G cores, which will need time for both products and expertise to hit the mass market.
- In theory, the same networks can service both private (enterprise) and public (MNO roaming /interconnect) use cases. In reality, we can expect many installations to have these isolated with a private overlay network. While seemingly “inefficient,” this will ease conflicts around ownership and control – as well as liability in case of failure.
- Wi-Fi will not be generally displaced by private (or public) 4G or 5G, except in specific areas of overlap, with particular demanding applications involving mobility or IoT systems that cannot risk interference and network congestion. Anywhere where basic connectivity is needed for guests and visitors (e.g., hotels, shared office spaces), Wi-Fi will proliferate – and, with the advent of Wi-Fi6 – much more capable. In some cases, we will see integrated Wi-Fi + Private Cellular systems, although in others they will be kept separate.
- We can expect more focus over time on low-power/low-cost versions of private LTE, such as NB-IoT and LTE-M. At the moment, these tend to be lower priorities.
- In the industrial space, there are many niche and proprietary wireless technologies, often integrated with specific automation vendors’ systems, and linked to deterministic networking, mesh-based resilience, and other features. These may start to be displaced

by standards-based cellular networks over time, but vendors and SPs should not be overly optimistic about the speed of transition.

- Sensors and low-power IoT devices will regularly use other technologies such as Bluetooth, LoRa, SigFox and so on, over both local and wide areas. We may however see more gateways for these connected with private cellular (e.g., in an agricultural environment or across a smart city deployment).

Complexities and “Gotchas”: what could go wrong?

It would be wrong to describe private 4G (and later, private 5G) as an inevitable success. It is important for SPs and vendors to consider potential problems up front and address them proactively, rather than just waiting for the inevitable to occur. Some will have long timelines to fix them – especially if they involve regulatory or legal obstacles.

- Ecosystems: At the moment, the US CBRS industry is probably the only mass-scale private LTE / 5G marketplace. New groupings for collaboration, partnerships and lobbying will be needed elsewhere for the market to scale rapidly.
- Inertia from telcos: MNOs may view the creation of, or interconnecting with new networks, as a potential competitive obstacle – and attempt to limit adoption.
- Regulatory barriers: It is unclear which regulatory considerations will apply to private networks, such network identity and whether existing rules on lawful intercept and record-keeping. These will vary over time and by country.
- Fragmentation: as this report shows, private mobile networks will vary in size, architecture and vendor/owner alignment. Scale economies may be elusive.
- International coordination for multinationals: Spectrum strategies in different countries vary widely. This could be a limiting factor for major companies.
- Device support is a significant issue, especially for unusual spectrum bands.
- Skills and resources are huge problems, especially for the 5G core and advanced radio technologies such as mmWave or massive MIMO. Training and certification must be addressed.
- Security will be a central concern. It remains unclear whether private LTE and 5G will present new attack surfaces – but it should be expected that some organisations will be very wary and conservative in this regard.
- Planning, design & monitoring will need new tools, and new processes alien to many enterprises. Given the suggestion that private LTE / 5G will be central to mission-critical systems, this will drive extra focus on the operations platforms.

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- Geopolitics is a major issue across all areas of telecoms and networking at present. Vendor choices, trade barriers and other issues are highly fluid.

RECOMMENDATIONS FOR ACTION

This white paper has given a broad overview of why and how private LTE and 5G networks are coming to the mass market of enterprises around the world. Both demand and supply sides of the equation are evolving rapidly and will drive thousands of new deployments in coming years.

In many cases, cloud-native software, plus open and flexible radio networks will help catalyse the market's evolution – although some companies and sites will need more self-contained and simple "in a box" alternatives.

While every stakeholder's opportunities, market context and risk-appetite will vary, it is possible to make broad recommendations. For more detailed and customised advice, please contact this report's author or its sponsoring vendor Mavenir.

Recommendations for enterprises

- Identify current and potential future use cases of cellular connectivity, starting with today's 4G capabilities. Examine 5G closely but be pragmatic about timelines.
- Ask existing systems suppliers (IT, industrial, etc) about their intentions and roadmap for using 4G and 5G.
- Work with MNOs to see if they can provide solutions at low enough cost, with enough control delegated to your organisation. Compare against internal / 3rd-party integrated options, including consideration of future upgrades / changes.
- Engage directly with regulatory authorities or industry groupings, to influence future spectrum releases and other rules that could facilitate private cellular networks.
- Familiarise yourself with the opportunities and key technologies involved in 4G and 5G, in order to make informed build vs. buy decisions, and vendor / SP choices.

Recommendations for conventional MNOs

- Depending on your resources, choose 1-5 competence areas in particular verticals or horizontals to build deep expertise, reach, partnerships and unique solutions.
- Participate in trials, testbeds, proofs-of-concept and industry forums – although be wary of the speed/practicality of creating commercial offers.

- Consider alternative architectures / suppliers of core and RAN for private networks, which can offer better flexibility or cost.
- Do not take the stance of "whole solutions or nothing." Start examining the more granular service and wholesale opportunities, selling components and enablers for private cellular to enterprises, specialist SPs or systems integrators.

Recommendations for alternative/new SPs

- Address specific vertical markets with defensible skills and customer references.
- Identify upcoming spectrum releases, as well as existing owners that could lease or partner. Where possible, work with regulators for future localised availability.
- Be wary of small details, such as supporting SIM / eSIM user journeys, or emerging regulatory requirements for enterprise networks.
- Avoid too much dependency on partnerships / interconnect with major MNOs.

Recommendations for vendors, integrators & developers

- Expect the vendor space for private cellular to fragment hugely – and then consolidate again in the medium term. Balance quick wins with defensible "moats."
- Predict likely moves by "big fish" from cloud, telecom and sector-specific solution vendors. Either proactively seek to partner, or view acquisition as an exit path.
- Collaborate with (or start) private cellular trade associations and other groups to grow awareness and ecosystem depth. The US CBRS community is a good model.

Recommendations for regulators & governments

- Be wary of over-confident forecasts, or superficial economic-impact analyses.
- Speak to as wide a range of stakeholders as possible – note that some may not even realise the opportunities around private 4G / 5G and may need extra outreach.
- Design spectrum releases and terms in a way to avoid the risk of "hoarding."

About Disruptive Analysis

Disruptive Analysis is a technology-focused advisory firm focused on the mobile and wireless industry. Founded by experienced analyst & futurist Dean Bubley, it provides critical commentary and consulting support to telecoms/IT vendors, operators, regulators, users, investors and intermediaries. Disruptive Analysis focuses on industry domains with complex value chains, rapid technical/market evolution, or labyrinthine business relationships. Currently, the company is focusing on 5G, Wi-Fi, NFV, IoT networks, spectrum policy, operator business models, the Future of Voice, AI, blockchain & Internet/operator ecosystems and the role of governments in next-generation networks.

Disruptive Analysis attempts to predict - and validate - the future direction and profit potential of technology markets - based on consideration of many more "angles" than is typical among industry analysts. Where appropriate, it takes a contrarian stance rather than support consensus or industry momentum. Disruptive Analysis' motto is "Don't Assume".

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It should be read by CIOs, strategy executives, CTOs, CMOs, facilities management &

planning/operational staff at major enterprises, property firms, communications service providers, information providers, software vendors, IoT firms, cable operators, ISPs, integrators, developers, XaaS providers, investors, and similar organisations. It is also aimed at policymakers, regulators, and others in public administration, who intersect with telecoms and broader infrastructure-development concerns.

Mentions of companies and products in this document are intended as illustrations of market evolution and are not intended as endorsements or product/service recommendations.

For more details, please contact information@disruptive-analysis.com

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About Mavenir

Mavenir is building the future of networks and pioneering advanced technology, focusing on the vision of a single, software-based automated network that runs on any cloud. As the industry's only end-to-end, cloud-native network software provider, Mavenir is transforming the way the world connects, accelerating software network transformation for 250+ Communications Service Providers in over 120 countries, which serve more than 50% of the world's subscribers.

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