GSMA Intelligence

Exploring 5G private network opportunities in Asia Pacific

February 2023

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www.gsmaintelligence.com

info@gsmaintelligence.com

@GSMAi

Authors
Kenechi Okeleke, Director, Regional, Social and Policy Research
James Joiner, Lead Analyst, Network Strategy

Contributors
Jeanette Whyte, Head of Public Policy, Asia Pacific
Yi Shen Chan, Director, Spectrum, Asia Pacific

Contents

Executive summary

Private 5G takes centre stage

Private networks are not new, having been deployed on LTE spectrum for several years. The Global mobile Suppliers Association (GSA) has catalogued deployments by 955 organisations globally, as of September 2022. The majority of these are LTE (57%), with around 20% being 5G and the rest having both capabilities. The arrival of 5G has given new impetus to private networks, with many performance advantages over LTE, including faster data transmission and lower latency.

Private 5G networks will play a central role in the digitalisation efforts of verticals, helping them to reduce operational inefficiencies and maximise business performance. The potential to customise private 5G networks to meet specific needs, such as coverage, bandwidth, security and latency, make them ideal for deployment across multiple verticals. As a result, private 5G will benefit every sector of the economy, including agriculture, healthcare, manufacturing and utilities.

Private 5G is gaining momentum in Asia Pacific[i]

Private 5G is gaining traction as verticals accelerate their digital transformation plans. To date, private 5G activity in Asia Pacific is concentrated in the region's most advanced countries, such as Australia, Japan, South Korea and Singapore, reflecting the higher levels of digitalisation across the public and private sectors. Elsewhere, momentum is beginning to grow, as evidenced by developments in India and Thailand. Industry 4.0 and increasing ecosystem readiness and maturity are among the key drivers of this.

There was growing appetite in 2022 for private 5G deployments across various sectors in Asia Pacific. More deployments are expected in 2023 and beyond, as growing competition in the private 5G ecosystem provides more choice and lowers costs for enterprises. The availability of new 5G spectrum in many markets and the virtualisation of network solutions are among the main factors attracting new entrants (including cloud providers, specialist vendors and startups) into the private 5G ecosystem.

Realising the private 5G opportunity for operators

A GSMA Intelligence survey found that 16% of operators in Asia Pacific expect private networks to account for over 20% of enterprise revenues by 2025. Connectivity and IoT are expected to account for nearly two thirds of revenues from private networks. However, operators should also explore opportunities in other areas, such as security, professional services and spectrum management.

Furthermore, the changing competitive landscape means that operators will need to develop new expertise and commercial relationships to realise the private 5G opportunity. This report identifies five considerations for operators:

[i] Unless otherwise stated, Asia Pacific in this report excludes Greater China (mainland China, Hong Kong, Macau and Taiwan).

- adding new services on connectivity to enhance value proposition for verticals
- considering open-source solutions for private 5G networks and use cases
- building partnerships within the private 5G ecosystem
- developing testbeds to help verticals explore real-world scenarios
- leveraging the hybrid private network opportunity

Government support is also important; as part of ambitions to become digital nations, governments across the region have outlined plans to integrate digital technologies and services into every sector of the economy. Fast, secure, reliable and low-latency networks will no doubt play a key role in enabling innovative solutions in many sectors, but this will require efficient spectrum management and an enabling environment for the deployment of private networks and the development of use cases to thrive.

1. Private networks: what, when and why

Private wireless networks have come back in vogue

A private mobile network (referred to as 'non-public networks' by the 3GPP) features network infrastructure that is used exclusively by devices authorised by the end-user organisation, usually an enterprise or public institution. The infrastructure, including base stations, small cells and other radio access network (RAN) infrastructure, is typically deployed in one or more specific locations owned or occupied by the end-user organisation to deliver targeted coverage, capacity and other capabilities. Private networks use licensed, shared or unlicensed wireless spectrum to transmit voice and data to edge devices, including smartphones, embedded modules, routers and gateways. Devices that are registered on public wireless networks will not work on the private network unless specifically authorised.[1]

Private networks are not new, having been deployed on LTE spectrum for several years in sectors such as mining and utilities. However, the arrival of 5G has given new impetus to private networks, with many performance advantages over LTE, including faster data transmission, lower latency and the ability to connect to more edge devices. Operators around the world began their 5G deployment efforts with the non-standalone (NSA) version of the technology, which is based on the LTE core. 5G NSA supports enhanced mobile broadband (faster speeds) due to higher channel bandwidth (of 3.5 and 26 GHz bands) and increased spectral efficiency.

However, 5G standalone (SA) deployment, based on dedicated 5G network architecture, is beginning to ramp up. This comes with more advanced capabilities for consumers and verticals,[ii] such as cloud gaming, enhancements for industrial IoT (IIoT) and innovations to support time-sensitive communication. 5G SA also enables network slicing, a prominent feature of 5G that allows operators to tailor connectivity and data processing to customers' specific requirements.

The launch of 3GPP Release 18,[2] expected in 2023–2024, will mark another major evolution in 5G technology, ushering the industry into the 5G-Advanced era. This will lay the foundation for additional capabilities and a wider range of use cases to serve new market segments, including smart power grid control, industrial automation, real-time financial transactions and truly immersive user experiences based on extended reality (XR) features. 5G-Advanced is also expected to deliver enhancements for private networks, drones and multicast-broadcast services.

Meanwhile, the digital transformation programmes of verticals have continued to gather speed in spite of (and sometimes because of) the Covid-19 pandemic. Public institutions and private enterprises around the world are accelerating plans to integrate digital technology and services into their operations to boost productivity, reduce inefficiencies and improve service delivery for customers. This is driving demand for advanced connectivity and security solutions that private networks are well suited to deliver. Table 1 summarises the main demand-side and supply-side factors driving the growth of private networks.

[ii] Defined as companies, industries and public sector organisations operating in a specific sector.

Table 1: Demand-side and supply-side drivers of private wireless networks

Source: GSMA Intelligence

Demand-side drivers	Supply-side drivers
Digital transformation: The broader trend of digitalisation across verticals that underpins investment in private wireless solutions (and related technologies such as cloud compute, 5G, AI and analytics) continues to gather pace as enterprises seek to modernise their IT stacks and overhaul operations to be remotely or digitally controlled.	**5G:** The benefits and advancements of 5G (e.g. latency, density, reliability, bandwidth and security) open up a range of mission-critical industrial use cases for private wireless networks.
Control: Verticals principally choose to deploy a private network to gain more control over their network, which allows them to support applications with more stringent networking requirements.	**Supplier diversification:** Various players, such as operators and network equipment and industrial vendors, are eyeing the private wireless opportunity. Competition is on the rise, with different players bringing core capabilities and expertise to the table. This is also increasing the scope for coopetition.
Data security: The increased security offered by isolating data from public networks is an attractive benefit of private networks (this may be required by law in some sectors and countries).	**New models of spectrum ownership:** In some markets, governments have made spectrum available to verticals so they can build their own networks; shared spectrum initiatives also lower the barriers to entry for new suppliers in the private wireless space.
Wi-Fi limitations: Historically, Wi-Fi has been the connectivity choice for private networks. However, mobile technologies (LTE and 5G) are better suited to operational technology network requirements of high volume, high reliability, mobility and always-on operations.	**Standards for private networks:** 3GPP Releases 16 and 17 offered specific capabilities for the industrial space, with private 5G set to play a key role in delivering those capabilities. Release 18 will include 5G architecture enhancements and additional capabilities for new market segments.
Cable substitution: Private networks remove the restrictions of ethernet cables and other physical connections, allowing devices freedom to move around more freely, across a factory floor or port facilities, for example.	**Emergence of private '5G in a box':** As private 5G networks take off around the world, vendors are starting to miniaturise private 5G network components. This condensed and streamlined form of 5G SA, often referred to as 5G in a box, aims to simplify the complexity of typical private 5G deployments.

Private network adoption to date and outlook

The GSA has catalogued private network deployments by 955 organisations globally, as of September 2022.[3] The majority of these are LTE (57%), with around 20% being 5G and the rest having both capabilities. The true number of private networks may be higher given that a number of deployments are not publicly announced. Even if the true count is higher, however, there is a big gap between the current reality and the theoretical potential.

Some estimates have put the potential addressable market for private networks at up to 15 million locations.[4] Most of these sites are expected to be factories or warehouses, many of which will be in China, India, Vietnam and other industrialising Asian countries. While such estimates assume that any factory is in the addressable market, less than 1% of factories in the world have so far been made 'smart' (i.e. production and maintenance tracked and adjusted via cloud analytics). This reflects the challenge of realising this potential, given the lengthy life cycles (up to 20 years or more) of investments in machinery and equipment in the manufacturing sector.

According to the GSA, Europe and North America account for almost three quarters of private 5G network customers, largely driven by enterprise digital transformation initiatives. For example, 78% and 66% of manufacturing firms in the US and Europe, respectively, have adopted at least one digital technology.[5] Private 5G networks are also gaining traction in Asia Pacific as operators launch private 5G solutions and established companies and startups in infrastructure and the software networking space aim to make their mark in the burgeoning private 5G network market.[6]

As the pace of digital transformation across different industries accelerates, Berg Insight forecasts 13,500 private wireless networks by 2026, equivalent to a 10-fold increase in the number of deployments from 2021.[7] Private 5G networks will play an important role in the future growth of private networks in general: the total addressable market for private networks – including the RAN, mobile-access edge computing (MEC), core and professional services – is forecast to increase from $3.7 billion in 2021 to more than $109.4 billion in 2030, of which $47.5 billion, equivalent to 43.4%, will be spent on private 5G networks.[8]

2. Private 5G deployment scenarios and ecosystem mapping

Private wireless networks are delivered in diverse forms, with varying levels of infrastructure managed by the operator or enterprise. This disaggregation of control further feeds into the opportunity to leverage open-network technologies and new vendors supporting different functions. In some cases, public networks will be combined with local infrastructure to support private networks. For prospective enterprise customers, these options entail trade-offs centred on cost versus the level of service customisation.

Table 2: Private network options vary in customisation, control and cost

Source: GSMA Intelligence, GSMA Internet of Things Programme

Public network	Public network with SLAs	Public network with slicing	Public network with local infrastructure	Private network (operator spectrum)	Private network (new 5G spectrum)
• Efficient use of infrastructure and spectrum • MEC within public network	• Operator expertise and spectrum portfolio • Superior customer support and SLAs	• Dedicated and customised network resources • Higher data isolation, security and privacy	• Dedicated network equipment • Choices regarding localisation of data/control • On-site MEC	• Isolated network • Managed service or leasing of spectrum • Customised design, operations and deployment	• Direct responsibility for spectrum access and usage • Independent design, operation, procurement and radio plan

Private 5G network deployment scenarios

There are several deployment scenarios for private 5G networks (and private networks in general) that reflect the customisation, control and cost factors mentioned above. In this report, we group these deployment scenarios into three broad categories (see Table 3).

Table 3: Private 5G network deployment scenarios

Source: GSMA Intelligence

Standalone enterprise-led	Standalone operator-led	Hybrid (based on operator's public 5G network)
• Can be built by enterprises or mobile operators • Uses allocated new 5G spectrum • Meets stringent reliability, security, availability and latency requirements • Costly and requires dedicated operational personnel	• Built by mobile operators on behalf of enterprises • Uses the operator's licensed 5G spectrum • Meets stringent reliability, security, availability and latency requirements • Benefits from the operator's long-standing experience in network management	• Based on a 'slice' of an operator's public network • Uses the operator's licensed spectrum • Shares use of the operator's public 5G resources (e.g. RAN, core, cloud) to varying levels • Quicker and easier to set up and manage than standalone variants

Case study (standalone enterprise-led): Fujitsu rolls out private 5G network at its manufacturing site in Japan

Context: In Japan, local 5G licences in the 4.7 and 28 GHz frequency bands can be allocated by local governments to non-mobile operators seeking to deploy private 5G networks. Fujitsu was awarded a local 5G licence in 2021 to deploy a private network at its Oyama plant in Tochigi Prefecture.[9]

Solution: Fujitsu used 4.7 GHz spectrum to deploy automated guided vehicles (AGVs) to transport goods around parts of its factory. It also used the 28 GHz band to transmit images of products and work procedures, which are taken by multiple 4K cameras installed in its factory.

Impact: The deployment of AGVs inside the factory has helped to reduce the costs associated with manually loading and unloading parts and products. Meanwhile, real-time AI image analysis on the footage taken by the 4K cameras provides instant feedback to workers on whether they are performing the correct movements during assembly.

Case study (standalone operator-led): Airtel deploys India's first private 5G network

Context: Against the backdrop of rising labour and material costs, manufacturers are increasingly looking to adopt lean and automated manufacturing processes to boost production efficiency. This requires robust and reliable connectivity.

Solution: Private 5G networks can benefit the manufacturing sector through various use cases: ultra-reliable low-latency communications (AGVs), higher bandwidth (digital twins) and data security and isolation. With this in mind, Airtel deployed a private 5G network at Bosch's electronics factory in Bengaluru, utilising trial 5G spectrum allocated by the Department of Telecommunications.

Impact: The private 5G solution helped Bosch to significantly reduce the time it takes to assess the quality of goods produced in its factory while also enabling shop floor managers to identify and resolve issues with machinery in real time, reducing average repair time at the factory.[10]

Case study (hybrid, based on operator's public 5G network): KT builds UAM-dedicated 5G network

Context: In February 2022, South Korea's Ministry of Land, Infrastructure and Transport announced plans to commercialise urban air mobility (UAM) in central cities by 2025 under the K-UAM Grand Challenge programme. Participants come from different sectors, including aviation, automotive and telecoms.

Solution: In October 2022, KT completed the first 5G network dedicated to the K-UAM programme.[11] The dedicated network, based on a slice of KT's public 5G network, allows the UAM to run without any coverage or interference gaps. Distinguishing between dedicated and general traffic ensures the quality of communication services and the reliability of control and command data transmission for the UAM programme.

Impact: The aviation network is expected to offer consistent 5G service at the UAM-operation altitude of 300–600 metres due to the application of KT's network slicing and optimal 3D coverage technologies.

Mapping the private 5G ecosystem

The private 5G market offers opportunities for a growing number of ecosystem players, from traditional telecoms industry players to new entrants taking advantage of the enterprise digitalisation potential. At the centre of this are verticals seeking enhanced and secure connectivity solutions to support modern and efficient business operations and a safer work environment for their staff. Table 4 highlights the key private 5G networks players and their roles in meeting the growing demand for private 5G solutions from verticals.

Table 4: Key private 5G ecosystem players

Source: GSMA Intelligence

Ecosystem player	Activities in the private 5G market	Example companies
Mobile operators	Activity by public network operators in the private 5G space is driven by the need to monetise investments in 5G networks and the significant opportunities in the enterprise segment. Operators have a number of advantages: existing expertise on how 5G networks work and access to all the required hardware; the scale and reach to support enterprises of various sizes and in various locations; and access to their own the spectrum.	Airtel, AIS, Singtel, SK Telecom, Telstra, Verizon.
Network equipment vendors	Network equipment vendors provide the hardware and some of the software required to build and operate private 5G networks. Vendors serve as suppliers both to enterprises and operators looking to deploy private 5G networks. Their advantage in this space comes from their years of experience in building RAN and core equipment, along with other networking components, for public networks.	Ericsson, Huawei, Nokia, Samsung.
System integrators	System integrators support enterprises in deploying private 5G networks by helping them to identify suitable RAN and core equipment providers while also taking responsibility for sourcing and handling the network build. Working with system integrators can offer enterprises more customisation options and opportunities to address issues around interoperability, as they interface with equipment vendors, operators and other ecosystem players. There is also scope for system integrators to deliver pre-integrated solutions, particularly in countries with dedicated spectrum for enterprise verticals.	Accenture, Aqura, Capgemini, IBM, NEC, Tech Mahindra, TKK Communications, Wipro
Cloud providers	Major cloud providers offer support for private 5G networks. These so-called hyperscalers are keen to take a growing share of the private 5G market by integrating private network offerings in their edge offerings to increase the number of touch points with the end customers. Simplicity will be key to their go-to-market strategies, as demonstrated by their plug-and-play private 5G-in-a-box solutions. In 2021, Amazon Web Services (AWS) introduced a pre-packaged solution comprising radio and core components, along with compute platform (Outposts) and spectrum (CBRS).[12]	Amazon (AWS), Alphabet (Google Cloud), Microsoft (Azure)

Specialist vendors and managed services providers	A number of specialist vendors specifically focused on rolling out 5G networks can provide network design and installation, as well as ongoing security and operations monitoring and turnkey managed solutions. In the US, Federated Wireless sells its private wireless solution as an end-to-end managed service through AWS Marketplace and Microsoft Azure Marketplace.[13] The partnerships with the cloud providers help to simplify the process of ordering and paying for the service.	CTS, Boingo, Fujitsu, Kajeet, WWT
Tower companies	Tower companies are looking beyond the traditional cell site business model to explore new opportunities in the connectivity value chain. Private 5G has emerged as a key area of interest of tower companies, building on their existing assets and experience in hosting public networks to form partnerships with other ecosystem players. In the US, American Tower Company (ATC) is testing the performance of a private 5G wireless network in an indoor mall in Las Vegas in collaboration with AWS,[14] while Cellnex is collaborating with Nokia on private network projects in Europe.[15]	ATC, Cellnex, Edotco
Startups	Besides the established players, a new wave of tech startups focusing specifically on deploying private 5G is beginning to emerge. These startups are taking advantage of the increasing commoditisation of the core infrastructure and the opportunity to provide a differentiated networking service to enterprise customers. For example, they can combine vertical domain expertise, networking knowledge, physical infrastructure and system integration to meet specific end-user needs.	A5G networks, Celona, Chuan Chih, Inseego, Cradlepoint, Sierra Wireless

3. Private 5G in Asia Pacific: key verticals and opportunities

Private 5G networks will play a central role in the digitalisation efforts of verticals, helping them reduce operational inefficiencies, maximise business performance and improve customer experience. The potential to customise private 5G networks to meet the specific needs of different industries, such as coverage, bandwidth and latency, make them ideal for deployment across multiple verticals and a wide range of applications.

In Asia Pacific, private 5G activity is concentrated in the most advanced countries, such as Australia, Japan, South Korea and Singapore. This reflects the higher levels of digitalisation across the public and private sectors, for which private 5G networks will be an important enabler. In Singapore, for example, Singtel has partnered with Hyundai Motor Group to deploy a 5G campus network with mobile edge core solution at the Hyundai Motor Group Innovation Centre, enabling the manufacturer to expand the use of robotics and provide a digital twin of the factory to optimise operations remotely.[16] Furthermore, these countries are among global leaders in the development of 5G networks, including 5G SA, and solutions ecosystems.

Elsewhere in the region, the momentum for private 5G networks is beginning to grow, as evidenced by recent announcements in India, Indonesia and Thailand. While commercial 5G services arrived in these countries several years later than in the region's advanced markets, the growth prospects for the private 5G market in such countries is increasing due to a growing emphasis on digital transformation and Industry 4.0, increasing ecosystem readiness and maturity, and enabling regulations.

In December 2022, India's Department of Telecommunications initiated a process to identify 5G spectrum bands, particularly those with less potential to be used for commercial purposes by mobile operators, that can be administratively allocated to companies for rolling out captive private 5G networks.[17] Earlier in the same year, Adani Group secured 400 MHz of spectrum in the 26 GHz band to deploy 5G private networks to support the company's connectivity needs. Adani aims to commence the launch of private 5G networks in 2023.[18]

Key verticals and use cases

Countries in Asia Pacific are implementing the three private 5G deployment scenarios (see Table 3) across various verticals. The considerable resource requirement means that the standalone enterprise-led option is more dominant in advanced markets, such as Japan and South Korea. The rollout of 5G SA in Australia, Singapore and Thailand is driving the adoption of the hybrid option, utilising the network slicing feature. Meanwhile, the standalone operator-led option is most prevalent in markets where spectrum has not been assigned to non-operators, such as Indonesia.

There was a marked uptick in private 5G network activities in Asia Pacific in 2022, with deployments across a wide range of industries and use cases (see Table 5). More deployments are expected in 2023 and beyond, as growing competition in the private 5G ecosystem provides more choice and lowers costs for enterprises. Government support is also important; as part of ambitions to become digital nations,[19] governments across the region have outlined plans to integrate digital technologies and services into every sector of the economy. Private 5G networks

will no doubt play a vital role in enabling innovative solutions in many sectors where network security and reliability are imperative.

Table 5: Examples of recent private 5G deployments in Asia Pacific

Source: GSMA Intelligence

Date	Country	Sector	Enterprise	Ecosystem partners	Primary use case(s)
January 2022	Australia	Agriculture	AgriFood Connect	Telstra, Ericsson	Real-time monitoring of machinery
May 2022	Australia	Education	University of Technology Sydney	Nokia	Digital twins
July 2022	India	Manufacturing	Bosch	Airtel	Automated visual inspections
December 2022	India	Manufacturing	Mahindra	Airtel, Tech Mahindra	Improved speeds for software flashing
September 2022	Indonesia	Mining	Freeport	Telkomsel	Safety applications and remote control of mining operations
June 2022	Japan	Education	Nara Institute of Science and Technology	Nokia	High-definition live streaming of lectures
March 2022	Japan	Manufacturing	Omron	Nokia, NTT Docomo	Real-time monitoring and control of industrial equipment
June 2022	Singapore	Manufacturing	Hyundai	Singtel	Digital twins
May 2022	Singapore	Manufacturing	Micron	Singtel	Augmented reality (AR) for operations and maintenance

August 2022	South Korea	Healthcare	Ewha Womans University Mokdong Hospital	Samsung	3D rendering of computed tomography
August 2022	South Korea	Utilities	Korea Electric Power Corporation	Samsung	Digital twins
August 2022	South Korea	Manufacturing	Korea Industrial Complex Corporation	Samsung	AI-based smart monitoring system
November 2022	Thailand	Mining	Siam Cement Group	AIS	AGVs
October 2022	Thailand	Manufacturing	Delta Electronics	Chunghwa Telecom	AR for remote collaboration, AGVs

Selected sector case studies

Aviation: Edotco deploys private 5G at Langkawi International Airport in Malaysia

Legacy networks solutions are making it difficult for airports to ensure the necessary connectivity for staff, passengers and all of the assets within an airport. Meanwhile, new and improved airport terminals increasingly utilise connected devices to improve security and efficiency throughout operations. Private 5G networks provide the most secure, robust wireless connection possible, enabling the required infrastructure for security cameras, passport scanners, lighting and wearable tech, such as augmented glasses, at airports.

Malaysian tower company Edotco and US-based telecoms company Peatalk Corporation have installed a private 5G network using 3.5 GHz spectrum at Langkawi International Airport.[20] The companies have focused on four initial smart airport use cases: asset management via smart devices installed on airport trolleys; air-quality monitoring; real-time facial recognition for enhanced security; and improved public Wi-Fi. Private 5G gives airport operators full visibility and control over their wireless infrastructure – from planning and deployment to operations and upgrades.[21] This makes it easier for airport operators to manage their assets efficiently and introduce innovative new services such as the ones seen at Langkawi International Airport.

Healthcare: Samsung deploys private 5G networks for healthcare services in South Korea

Private 5G can enable dedicated communications for hospital emergency departments, without impacting labs or other testing facilities. This could mean better performance and reliability, lower latency and improved data security and privacy for patients. Healthcare facilities can also leverage private 5G to improve the efficiency of healthcare delivery, given the strain of ageing populations on healthcare systems. A host of other public sector services, such as education, law enforcement and emergency services, can benefit from the dedicated connectivity and enhanced security provided by private 5G networks.

In South Korea, Samsung has forged private 5G agreements with two local hospitals to implement enhanced medical services and immersive use cases for the healthcare industry:[22]

- Ewha Womans University Mokdong Hospital will introduce smart medical services, such as a 3D rendering of computed tomography (CT), rapid reconstruction of medical images and real-time long-distance surgical collaboration using virtual interaction.
- Samsung Medical Centre will leverage 5G to enhance its medical education programme, including remote training using AR glasses, virtual simulation of live surgical scenarios and live-streaming of 360-degree recordings of surgical operation.

Manufacturing: AIS deploys private 5G to unlock the potential of mobile robots

Multiple use cases involving manufacturers using private 5G to automate assembly lines are currently in testing or live operation. These include stationary and mobile robotics, AGVs (for transporting goods), digital twins and drones (for site surveying and security). AR-based software is also in consideration because of its latency demands (sub-20 ms). Training, maintenance, visualisations and remote demos are further use cases that can offer cost savings and efficiency gains.

Industrial and logistics robots have generally been confined to a limited area of factory floors due to the range constraints of Wi-Fi.[iii] However, private networks can address this challenge and provide the connectivity for robots to roam around manufacturing plants. The manufacturing sector is diverse, with different segments such as automotive, electrical equipment, machinery and computer equipment offering significant opportunities.

In Thailand, mobile operator AIS deployed a private 5G network at an electrode manufacturing plant run by Yawata Electrode in Nakhon Ratchasima.[23] Following this, Yawata Electrode rolled out an autonomous robot solution developed by AIS in conjunction with Lertvilai and Sons, a long-standing supplier of industrial robots. Yawata Electrode increased its goods transportation efficiency by 24% from deploying two autonomous mobile robots at its factory and plans to deploy more robots in the future to further increase production capacity.[24]

[iii] The range of a typical Wi-Fi router is in the tens of metres and this could prove a challenge in larger structures.

Maritime: M1, IMDA and MPA collaborate on 5G maritime testbed in Singapore

Ports are challenging environments, as they require the utmost efficiency, safety and security. Delays and congestion due to factors such as debris, theft, poor weather or accidents can be expensive and disruptive to local and international supply chains. As a result, the automation of port operations has become imperative. Private 5G is increasingly being tested and deployed to enable a variety of use cases and applications in the maritime sector. These include remote-controlled cranes moving containers between the ship and the dock with precision, drones employed for surveillance and deliveries, AGVs, sensors to measure and monitor environmental conditions, and connected cameras to track assets and maintain security across the port site.

The Maritime and Port Authority of Singapore (MPA) plans to develop a 5G testbed at sea as part of Singapore's ambition to become a global maritime capital.[25] The Infocomm Media Development Authority (IMDA) is collaborating with MPA to achieve the goal of full 5G SA coverage over Singapore's anchorages, fairways, terminals and boarding grounds by mid-2025. An initial use case will focus on remote assisted pilotage advisory for automation, productivity and human safety. Maritime 5G will also enable remote piloting of ships from a shore-based control centre through real-time video imagery. Working with MPA and IMDA, local mobile network operator M1 will provide a dedicated 5G network slice over the area.

Military: ST Engineering develops 5G-in-a-box solution

Key features that make private 5G attractive to industry verticals also make it appealing to the military, notably secured connectivity for communicating classified military information. Private 5G networks can also allow the operation drones for security and other AGVs on military bases, and can be rapidly deployed for military field operations, enabling military personnel to remotely control drones for surveillance and delivery of supplies to conflict zones.

In 2022, ST Engineering, a Singaporean multinational technology and engineering group in the aerospace, smart city, defence and public security sectors, introduced a 5G-in-a-box solution, which combines MEC and a 5G mini-core network into a single box.[26] The solution enables ad-hoc, rapid deployment of private 5G network where ruggedness, space, weight and power are major concerns.

Mining: Telkomsel deploys private 5G for smart mining in Indonesia

Deploying new technologies in extractive industries to improve worker safety can be challenging, as companies frequently operate in remote locations. As a result, the mining industry is roughly 30–40% less digitally mature than comparable industries, such as automotive or chemicals, according to BCG's Digital Acceleration Index.[27] An important feature of private networks is that they can be installed in areas yet to be covered by public networks. This makes them suitable for deployment in hard-to-reach places (including underground and offshore), where mining and oil and gas companies often have their installations. Key use cases include mission-critical push-to-

talk, asset/people tracking, IoT sensors to detect gas leaks and temperature fluctuations, autonomous vehicles and unmanned drone inspection, and smart ventilation systems.

In Indonesia, Telkomsel and ZTE have installed a private 5G network for PT Freeport, one of the world's largest mining companies, at the Grasberg mine in the Papua region.[28] The private 5G implementation delivers the improvements in network performance needed to introduce advanced applications such as AI-based underground video analysis, unmanned driving and intelligent tunnelling. Private 5G has improved production efficiency at the Grasberg mine, with claims of a 25% rise in productivity, cost savings of 40% and a 20% reduction in energy use.[29] This demonstrates the potential of 5G to enhance productivity and efficiency in the mining sector.

Utilities: Samsung deploys private 5G networks for utility companies in South Korea

The utility sector can deploy private 5G at sites such as power stations and wind farms to automate operations and improve worker safety. Private wireless networks are most commonly deployed at specific sites but can also work as distributed grids across a larger range (over 50,000 km^2) to monitor transmission networks and other assets. This allows companies to monitor distribution, pre-empt faults and automate grid operations that can be managed from a control centre. Private 5G can also enable a smart grid to become more reliable and efficient and can be deployed in hard-to-reach areas, such as a wind farm, for specific connectivity requirements.

Samsung is deploying private 5G solutions for Korea Electric Power, Korea Industrial Complex and Korea Water Resources. For Korea Electric Power, Samsung will deploy smart grid technologies and build digital twins to enhance safety and efficiency in the workplace. This is expected to save time and resources and enable real-time monitoring of the working environment of employees to ensure safety. Samsung will also build a robust, AI-based smart monitoring system for detection of fire hazards and any other security risks or emergencies in real time for Korea Industrial Complex, and build digital twins to precisely visualise water flow and predict water-related hazards, such as flood damages, for Korea Water Resources.

In addition to the above sectors, private 5G networks have the potential to benefit a host of other sectors, including: live stadium entertainment to provide real-time game-day stats, immersive reality applications and multi-angle viewing; warehouse operations to enable solutions to track and monitor the condition of parcels and devices; and media and broadcasting to provide adequate bandwidth to transfer live or pre-recorded content with low latency and constant speeds and reliability. These and other solutions will be deployed in Asia Pacific over the coming years, in line with trends in other regions.

4. The private 5G opportunity for mobile operators

The upbeat outlook for the private 5G market, the availability of new 5G spectrum in many markets and the virtualisation of network solutions are among the main factors attracting new entrants in the private 5G ecosystem. For incumbent mobile operators the challenge is to maximise the potential of the budding private 5G market amid lowering entry barriers, changing competitive dynamics and disruption of the traditional telco model.

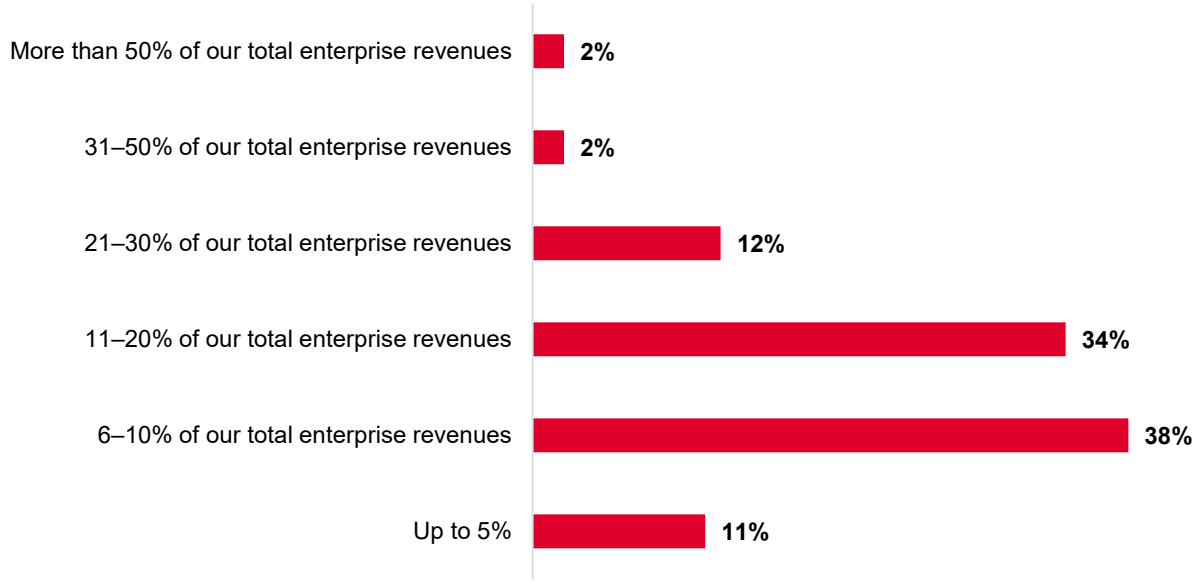
GSMA Intelligence survey insights

The GSMA Intelligence Operators in Focus: Enterprise Opportunity Survey 2022 captures the perspectives of 100 decision-makers from operators around the world on the enterprise market opportunity. Below is a breakdown of some key insights from respondents in Asia Pacific on the private networks[iv] opportunity in the region.

Figure 1: Private wireless networks revenue contribution

Thinking about revenues for your company generated by private wireless networks, how do you expect such revenues to contribute to total enterprise revenues by 2025? (Percentage of respondents)

Source: GSMA Intelligence Operators in Focus: Enterprise Opportunity Survey 2022



Note: Totals may not add up due to rounding.

More than 15% of operators in Asia Pacific expect private networks to account for over 20% of their total enterprise revenues by 2025, while the majority expect a double-digit percentage revenue contribution by the same period. This underlines the importance of private networks more broadly, and private 5G in particular, to operators' ability to maximise the enterprise 5G

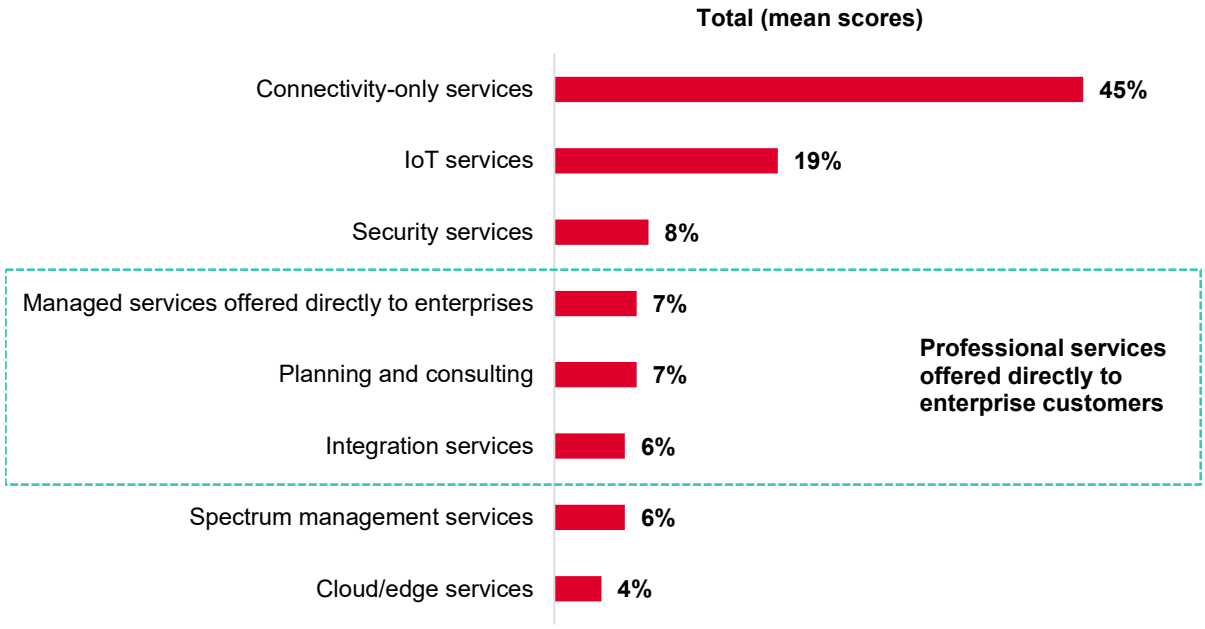
[iv] Private wireless networks in general, including LTE.

opportunity. It is worth noting, however, that operators are not always the first partner of choice. Our survey shows that less than a third of enterprises in Asia Pacific rank operators as their preferred partner for building a private network (compared with 55% for network vendors). This suggests that operators need to do more to demonstrate the value of their private network offerings to enterprises.

Figure 2: 5G private wireless networks revenue distribution

Thinking of revenue opportunities coming from 5G private wireless networks, what is the revenue distribution that you expect by 2025? Select percentage value (0–100%)

Source: GSMA Intelligence Operators in Focus: Enterprise Opportunity Survey 2022



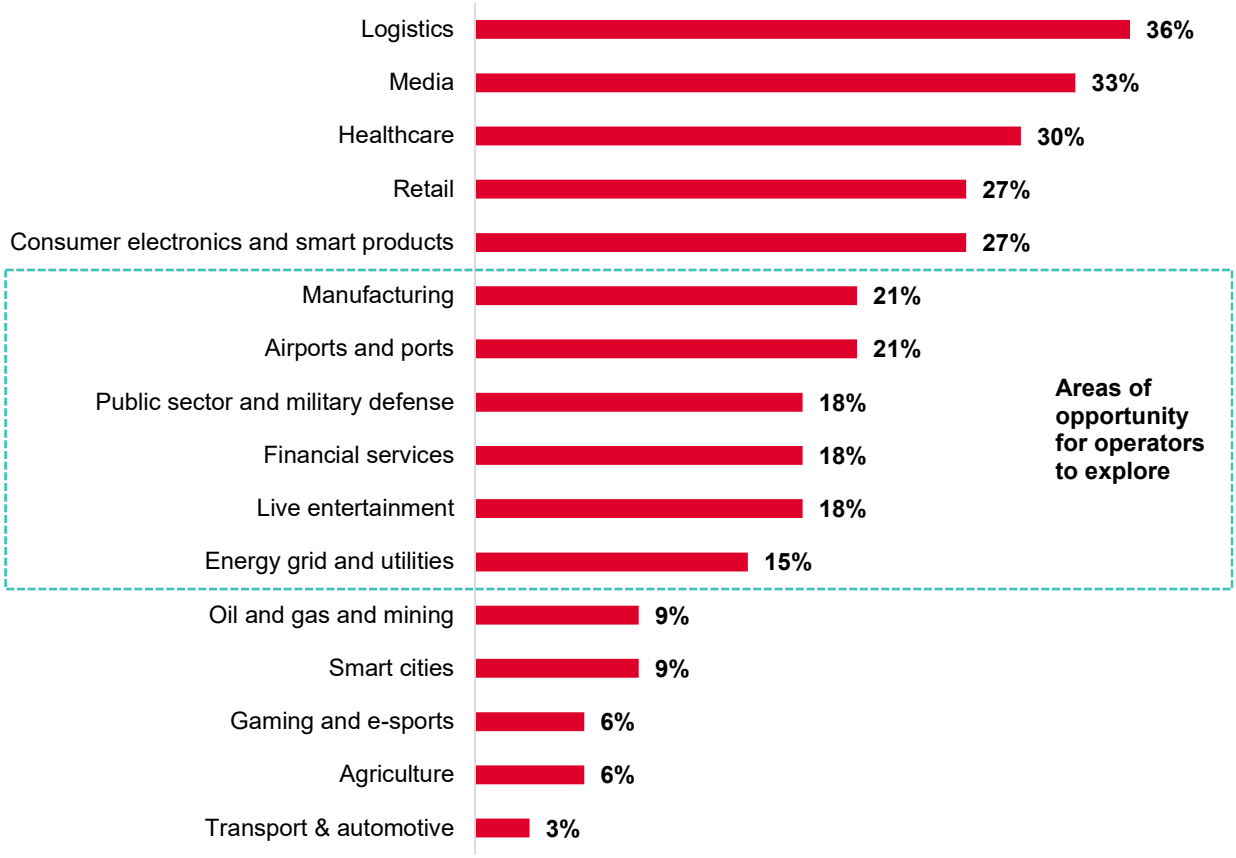
Note: Totals may not add up due to rounding.

Operators expect connectivity to account for the largest share of revenues from private 5G. This is not surprising since connectivity is the core business of operators and something they need to maintain leadership in during the 5G era. However, operators need to grow their expertise in other areas to maximise the private 5G opportunity. Besides IoT services, in which operators in Asia Pacific are already recording considerable growth, operators should focus on security services (implementing logical isolation mechanisms and physical radio layer protection solutions) and professional services (acquiring expertise in end-to-end managed services as well as planning and consulting for private network deployment).

Spectrum management and system integration services come further down the list for operators in Asia Pacific, but both areas can be quick wins for operators, given their existing experience and expertise on spectrum-related issues and extensive knowledge of network design and orchestration.

Figure 3: Vertical demand for private wireless networks
What are the top industry verticals that you see the highest demand for private wireless networks (4G/5G)? Select top three (percentage of respondents)

Source: GSMA Intelligence Operators in Focus: Enterprise Opportunity Survey 2022



Operators in Asia Pacific see the most demand for private networks in logistics, media and healthcare. This may be due to the fact that enterprises in these sectors are more likely to adopt operator-led solutions (standalone or hybrid) compared to other industries, where the likelihood of enterprise-led networks may be higher. The other sectors with high potential may reflect the significant activities of other ecosystem players, notably equipment vendors and specialist network providers.

Based on trends in Asia Pacific and elsewhere, operators should explore opportunities and use cases in several other sectors that are currently seeing moderate demand, including:

- manufacturing (digital transformation and Industry 4.0 initiatives)
- airports and ports (process automation to improve security and efficiency)
- public sector and military (secure and reliable connectivity requirements)
- financial services (secure, real-time transactions based on low latency connectivity)
- live entertainment (interactive and immersive user experiences)
- energy grid and utilities (worker safety and training, systems monitoring and tracking).

Realising the private 5G opportunity

Private networks are an extremely important 5G business case for operators and will become more prominent as global 5G rollouts continue around the world. But in a changing competitive landscape, defined by the emergence of diverse new ecosystem players, operators will need to develop new expertise and commercial relationships to realise the private 5G opportunity. Here, we highlight five emerging strategies and considerations for operators.

Add new services on connectivity to enhance value propositions for verticals

Connectivity remains at the core of operators' services, including private 5G. Beyond connectivity, however, operators should consider layering additional services and applications that demonstrate value to enterprise customers. For example, Verizon's On Site 5G offering comes as a fully managed, monitored and maintained all-inclusive solution covering professional and managed services, network infrastructure and spectrum management.[30] Multiple verticals can be served by the solution, including manufacturing, oil and gas, ports and mining.

Operators should explore various means to acquire new capabilities that can enhance their private 5G offering, including partnerships and acquisitions. For example, Telstra Purple[v] acquired Alliance Automation and Aqura Technologies in 2022 to bolster IoT and system integration capabilities in Australia. In Thailand, AIS has partnered with Mitsubishi Electric Factory Automation and TKK Corporation to deliver various 5G use cases in manufacturing.[31]

Case study: NTT launches private 5G platform[32]

NTT launched a private 5G network-as-a-service platform for enterprises that comes pre-integrated with network and software partners. The platform can be delivered via the cloud, on-premises or at the edge. It is targeted at global enterprises in the industrial, manufacturing, automotive, healthcare and retail industries that want a single 5G private wireless network platform across multiple regions or countries, with one partner to eliminate points of friction. The platform brings a suite of digital app development and system integration capabilities, as well as workflows that integrate the private network into back-office enterprise resource planning systems.

Consider open-source solutions for private 5G networks and use cases

5G is significantly changing the network infrastructure and digital services landscapes, with much of the technology's potential only realised with the application of specialist knowledge, capabilities and solutions across various disciplines. For operators, the choice is between developing those capabilities and solutions in-house or exploring new opportunities in an open ecosystem of partners.

A number of open-source initiatives have emerged in recent years to support the cost-effective deployment of private 5G networks, such as the Telecom Infra Project's (TIP) open-source solutions for private 5G, with solutions from Tech Mahindra and NTT Data.[33] The GSMA's

[v] Telstra Purple is the technology services division of telecoms operator Telstra.

Operator Platform Group brings together operators, platform developers, edge cloud providers, standards developing organisations, open-source projects and market participants to develop requirements and deliver a common solution to the ecosystem in the 5G era.[34]

Open-source principles can also be leveraged in the development of innovative use cases that enterprises find appealing. Here, operators should open their APIs to internal teams and even external partners to create and scale new solutions. In India, the government plans to roll out its 5G stack – built by a consortium of the Centre for Development of Telematics, Bharat Sanchar Nigam Limited and Tata Consultancy Services – across the country in 2023. India Stack is a collection of open APIs and public digital resources, which, when used together, can create powerful digital solutions to address large-scale problems. The funding for this project will be offered by the government and everything else will be facilitated by the private sector.[35]

Case study: Japanese consortium develops open-source software for private 5G[36]

In November 2022, a consortium of Japanese partners, including the University of Tokyo, Internet Initiative Japan, Apresia and Fujitsu, developed open-source software for private 5G/6G networks to realise a domestically produced, low-cost 5G core network. This will allow users to introduce private 5G networks at lower cost for use in practical settings, leading to the wider adoption of private 5G in various verticals. The companies expect the combination of multiple private 5G networks and public 5G services from mobile operators to deliver more versatile communication environments than individual private 5G networks alone.

Build partnerships within the private 5G ecosystem

The competitive implications of private 5G networks are complex and varied. This is in part because the technology is still being developed and innovated on, and even more so because of co-opetition among ecosystem players, whereby companies targeting the private 5G opportunity must take a balanced approach by maintaining relationships with existing clients competing in the space.

For example, operators are tapping into cloud solutions from hyperscalers as they seek to move parts of their network functions to the cloud, as well as using cloud infrastructure from hyperscalers to offer edge solutions to enterprises. At the same time, cloud players are expanding their footprint in the private 5G market with offerings that can directly compete with operators.

For operators, and the wider ecosystem, collaboration is crucial to build synergies and leverage key strengths to realise the private 5G opportunity. Mobile operators can benefit from the large enterprise footprint, cloud services and software development capabilities of hyperscalers and the established expertise in network hardware production and managed services capabilities of vendors. Likewise, vendors and hyperscalers can benefit from operators' spectrum assets, local footprint and existing portfolio of enterprise services.

In addition to vendors and hyperscalers, operators should cement agreements with other technology companies, such as application developers and vertical-focused system integrators, that allow them to offer end-to-end private 5G solutions, such as the below examples:

- AIS teamed up with a number of industry partners, including Huawei, to deploy a private 5G network for Siam Cement Group.[37]
- Dtac launched a 5G private network targeting the retail, manufacturing and logistics sectors on AWS's cloud platform and a dedicated core, which is integrated with edge computing using the operator's 26 GHz spectrum.[38]
- Telekom Malaysia Bhd announced that it will be collaborating with Cisco to build a private 5G network sandbox for enterprises and vertical industries. The partnership includes a 5G-as-a-service innovation platform that will demonstrate 5G enterprise use cases to allow businesses to visualise and implement private 5G frameworks and solutions that address unique business challenges.[39]
- Airtel partnered with Tech Mahindra to deploy a private 5G solution at the Chakan manufacturing facility, making it India's first 5G-enabled auto manufacturing unit. The solution has resulted in improved speeds for software flashing, a critical operation for all vehicular dispatches.[40]
- M1 Singapore formed a strategic collaboration with Accenture to drive 5G growth for enterprises, with an initial focus on the maritime, energy and utilities, and smart estates industry verticals.[41]

Develop testbeds to help verticals explore real-world scenarios

Innovation labs and testbeds offer enterprises the opportunity to explore the potential of private 5G solutions in an environment that would be difficult to replicate in-house. This can reduce the cost and technical burden of verticals looking to introduce 5G-enabled solutions and try out multiple use cases. Operators can also take advantage of initiatives by governments and other ecosystem players around 5G labs and test beds to develop new use cases for their private 5G offering. Two examples of this are as follows:

- In January 2023, the government of India announced plans to establish 100 5G labs in engineering institutes across the country to develop applications and drive enterprise use cases around areas such as smart classrooms, precision farming, intelligent transport systems and healthcare.
- In February 2023, Nokia announced plans to open a dedicated device testing facility in India to accelerate digital transformation efforts around cloud and private networks for verticals. The facility in Bangalore will house the testing of third-party devices compatible with automated equipment running on its digital automation cloud technology and 5G modular private networks.[42]

Case study: KT establishes private 5G tested in South Korea

KT plans to build a specialised 5G testbed running on the 4.7 GHz band, with the aim of enabling multiple customers to access a slice of its public 5G core network to test enterprise solutions. When operational, it will serve as a one-stop service for testing private 5G solutions and interoperability with devices and conducting network operations and inspection. The testbed would allow enterprise customers to connect to KT's cloud-based private 5G network core, without having to directly build their own 5G SA network.

Leverage the hybrid private network opportunity

While demand for standalone private 5G networks is growing, the cost and other resources required to deploy and manage such networks mean that uptake is mostly limited to large enterprises. For many medium-sized, and even small enterprises, a hybrid private wireless network with shared network resources presents a quicker, easier and more cost-effective route to private wireless solutions. The challenge for operators, however, is that in the majority of cases, public 5G networks have been deployed as NSA i.e using the LTE core. Although network slicing can be done on LTE and 5G NSA, it requires a 5G core – effectively a 5G SA network – to really work effectively.

There is growing momentum behind the deployment of 5G SA networks globally and the Asia Pacific region is leading the way, but mass availability is still some way off. As of January 2023, within Asia Pacific there were live 5G SA networks in Australia, Japan, the Philippines, Singapore, South Korea and Thailand, while operators in several other countries, including India, Malaysia, New Zealand and Sri Lanka, have announced plans to deploy 5G SA networks.

In the interim, operators should hone the required skills and build up a customer base through the existing private LTE network solution. In some countries, enterprises that become aware of and are looking to adopt private 5G are likely to start with private LTE first. This is because the network technology and necessary equipment, such as devices, are more widely available, especially in less mature markets. Successful deployments of those private LTE solutions will increase enterprises' appetite to upgrade to private 5G once equipment and spectrum are widely available.

Also, sellers of private LTE solutions can engage with enterprises on use case and business model discovery, gain deeper expertise in vertical industries and use this experience to set themselves up for success with private 5G. According to data from the GSA, there were 167 private networks in Asia Pacific (including Greater China) as of September 2022, of which LTE-based networks accounted for more than half.

Spectrum considerations for private networks

Governments and regulators that manage spectrum are increasingly under pressure to respond to the huge amount of interest and demand from a wide variety of use cases. Measures to address the spectrum needs of private networks should be carefully considered. While private networks are an integral part of 5G, supporting their growth does not have to mean resorting to asymmetric spectrum carve-outs or set-asides. Such measures are an aggressive regulatory tool with a huge economic cost.

Spectrum is a limited resource, and with 5G services still at a relatively early stage of development in most markets, set-asides for industry verticals in prime 5G bands can jeopardise the ability of 5G to meet its potential. Spectrum set aside exclusively for private networks or local licences in prime 5G spectrum, such as 3.5 GHz, is at risk of being underused and can undermine fair spectrum awards. For example, in Germany the decision to set aside 100 MHz in the 3.4–3.8 GHz range for private networks, leaving 300 MHz for mobile operators, led to artificial scarcity, which resulted in auction prices being inflated by up to €3 billion – funds which could have been better invested into improving network coverage.[43]

Mobile operators are making a significant contribution to the growth of private networks. With 5G's advanced capabilities supporting end-to-end network slicing and MEC, commercial mobile operators are able to address the needs of a wide variety of private networks. Furthermore, spectrum leasing or, when carefully planned, other types of spectrum sharing can be viable options for supporting industry verticals or enterprises interested in building private networks while also avoiding harmful impacts on the wider success of 5G. For example, in Finland the 3.5 GHz licensees are obliged to either participate in tenders for private network contracts in localised areas or else sub-license their spectrum to the relevant entity so they can build their own network.[44]

Spectrum measures for private networks need to be considered as part of the broader 5G spectrum roadmap. There is no one single approach to best meet the needs of verticals using mobile spectrum in all markets. Policymakers should examine their options carefully and consult stakeholders to ensure they support the needs of verticals most efficiently without undermining other spectrum users. These crucial spectrum decisions are best guided through a regulatory impact assessment, including quantitative cost-benefit analyses to weigh the trade-offs of different assignment options.[45] The success of mobile spectrum management has been built on providing reliable, affordable and fair access to support competition and long-term investment and enable technology evolution.[46] It is vital that 5G spectrum planning and approaches to supporting the needs of industry verticals continue this trend.

5. Conclusion

Private 5G networks will feature prominently in Asia Pacific's connectivity landscape, driven by a combination of demand-side and supply-side factors. On the demand side, private 5G is an important tool for verticals to accelerate their digital transformation journeys, increase productivity and resilience in their operations, and improve safety and service delivery for citizens. On the supply side, growing competition in the private 5G network ecosystem is driving innovation and reducing the barriers to adoption for verticals.

For mobile operators, private 5G network provision is an important business case in the 5G era, with opportunities to create new revenue streams and serve additional enterprise customers. Operators already have a host of assets and capabilities to capitalise on, including access to spectrum, extensive local footprints and experience in network deployment and operation. However, the entry of new players in the supply ecosystem calls for a rethink of market strategies and commercial partnerships in order to realise the private 5G potential.

Governments and policymakers have a key role to play in supporting the sustainable growth of the private 5G market and, by extension, facilitating digital transformation across the economy. Fundamentally, governments need to make spectrum available to deploy private 5G networks in a cost-effective way. There is no one single approach to best meet the spectrum needs for private 5G in all markets: the state of the evolution of mobile networks, the number of mobile operators, evolving data traffic demands, the availability of core mobile bands, incumbency issues in bands and the level of demand from verticals will vary in different markets. To this end, policymakers should properly consult all stakeholders to ensure that their plans for addressing the needs of verticals are technically and commercially feasible and attractive.

Further reading

5G for the enterprise: headway, hurdles and the horizon for operators, GSMA Intelligence, 2022

Enterprise Opportunity 2022, GSMA Intelligence, 2022

Hyperscalers get serious about private 5G, GSMA Intelligence, 2022

IoT and enterprise markets: five trends to watch in 2023, GSMA Intelligence, 2022

The edge opportunity in the enterprise market: progress, challenges and future outlook, GSMA Intelligence, 2022

References

[1] https://www.gsma.com/iot/manufacturing/private-networks/private-networks/

[2] https://www.3gpp.org/specifications-technologies/releases/release-18

[3] Private-Mobile-Networks December-2022 Summary Report, GSA, 2022

[4] "European Private Wireless Market Astonishing Growth", PrivateLTEand5G.com, January 2022

[5] Who is prepared for the new digital age?, European Investment Bank, 2020

[6] IoT and enterprise markets: five trends to watch in 2023, GSMA Intelligence, 2022

[7] "Private networks are still a big opportunity for operators", UK5G, May 2022

[8] "Global market for private networks to exceed $109 billion in 2030: Study", RCR Wireless News, February 2022

[9] "Fujitsu Launches Private 5G Network to Realize 'Smart Factory' at its Oyama Plant", Fujitsu, March 2021

[10] "Airtel deploys India's first private 5G network at Bosch facility", Airtel, July 2022

[11] "KT Completes South Korea's First UAM-Dedicated 5G Network", W.Media, October 2022

[12] "AWS surprises with AWS Private 5G", Fierce Wireless, November 2021

[13] "Federated Wireless loops Microsoft Azure, AWS into CBRS connectivity-as-a-service", RCR Wireless News, February 2020

[14] "American Tower seeks permit to carry out 5G private network trials", RCR Wireless News, October 2022

[15] "Cellnex and Nokia strengthen partnership to deploy dedicated Private Wireless Networks to Enterprise Customers", Cellnex, June 2022

[16] "Singtel partners Hyundai Motor Group to develop advanced manufacturing facility of the future with 5G" Singtel, June 2022

[17] "DoT looks to identify spectrum bands to allocate for private 5G network", The Economic Times, December 2022

[18] "Adani Group to launch 5G network services in 2023", The Hindu BusinessLine, January 2023

[19] Digital Societies in Asia Pacific: Progressing towards digital nations, GSMA, 2022

[20] "Edotco debuts the first 5G private network at Langkawi International Airport", Malay Mail, January 2020

[21] "Transforming airports with private networks", Ericsson, May 2022

[22] "Samsung Electronics To Deliver Private 5G Network Solutions to Korea's Public and Private Sectors", Samsung, August 2022

[23] 5G Brings Autonomous Robots to Life, GSMA, 2022

[24] For more information, see 5G in Action in Asia Pacific, GSMA, 2022

[25] "Singapore, the first country to extend public 5G standalone coverage to sea for maritime operations", Infocomm Media Development Authority, January 2023

[26] https://www.stengg.com/5g-in-a-box

[27] "Racing Toward a Digital Future in Metals and Mining" Boston Consulting Group, February 2021

[28] "Telkomsel and Freeport Indonesia implement the first 5g underground smart mining in Southeast Asia", Telkomsel, September 2022

[29] "Telkomsel Pioneers 5G Smart Mining in South-East Asia" CCS Insight, December 2022

[30] https://www.verizon.com/business/en-gb/solutions/5g/on-site-private-5g/

[31] AIS 5G, Mitsubishi Electric and TKK together revolutionize Thai industry Successful trials lead to "real use cases" of Total Industrial Solutions for e-F@ctory Powered by AIS 5G, the first of its kind in Thailand", AIS, August 2021

[32] "NTT launches private 5G platform aimed at CIOs", Fierce Wireless, August 2021

[33] "TIP 5G Private Networks solution group paves the way to transform private network economics and introduces blueprint", Telecom Infra Project, November 2022

[34] https://www.gsma.com/futurenetworks/5g-operator-platform/

[35] "Full-stack indigenous 5G to be commercially available by March: Telecom secretary", ET Telecom, November 2022

[36] "Consortium of Japan partners successfully promote domestic production and cost reduction for 5G core technology, the basis for next-generation communication standards", Fujitsu, November 2022

[37] "Thai operators push Industry 4.0 with private networks", Mobile World Live, November 2022

[38] ibid.

[39] "Cisco to provide private 5G network to enterprises in Malaysia with TM", Tech Wire Asia, July 2022

[40] "Airtel partners with Tech Mahindra to deploy captive private network at Mahindra's Chakan Facility", Tech Mahindra, December 2022

[41] "M1 Works with Accenture to Accelerate the 5G Journey for Enterprises", M1, April 2022

[42] "Nokia to open India lab in digital push", Mobile World Live, February 2023

[43] "Private Fashion: Vertical Set-Asides Versus Spectrum Capacity for Operators", GSMA, January 2023

[44] Spectrum Leasing in the 5G Era, GSMA, 2022

[45] Maximising the socio-economic value of spectrum, GSMA 2022

[46] Mobile Networks for Industry Verticals: Spectrum Best Practice, GSMA. 2021

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