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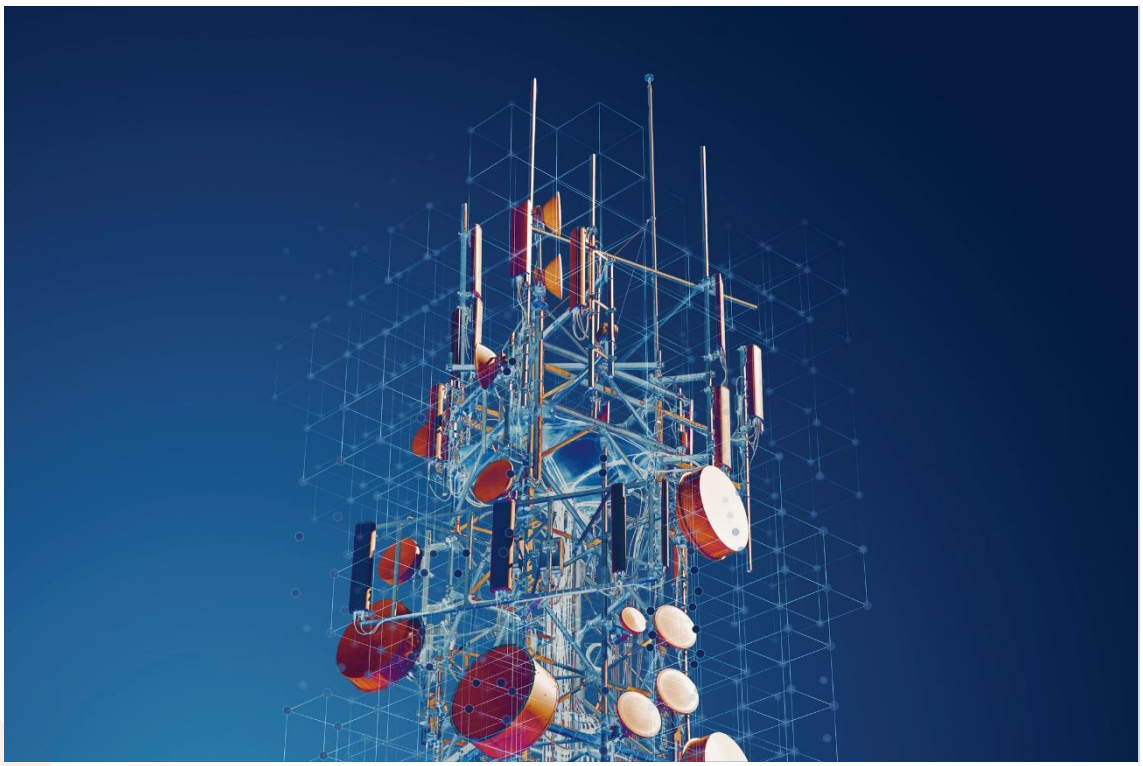
Executive Briefing

SLICING AND PRIVATE NETWORKS: SUBSTITUTES OR COMPLEMENTARY?

As dedicated private mobile network deployments expand, and slicing becomes a reality, we expect them to become complementary technologies solving distinct enterprise needs. How should operators prepare?



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Executive Summary

Preparing for a future with mixed deployments

With commerical services of public network slicing anticipated as early as next year, there is an open question as to whether it will challenge private networks and become the enterprises' main pathway to adopting full 5G. In this report, we argue that public network slicing will complement private 5G. In reality, public network slicing and private 5G will co-exist to serve diverse enterprise needs. The bigger question for operators should be how to prepare for a world with mixed deployments. In our view, they should:

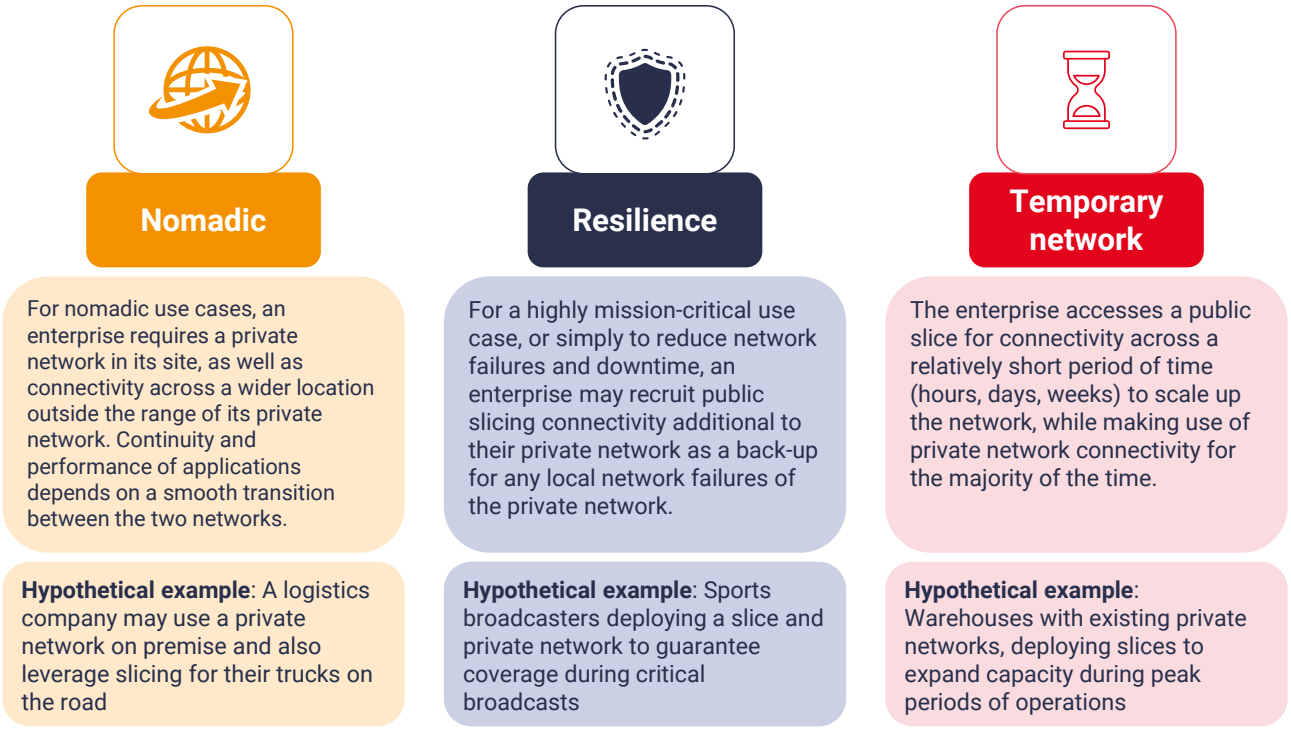
- Be prepared to support a variety of deployment types based on the customer's use cases and environment
- Pioneer new business models that adopt cloud principles and conform to enterprise demand
- Invest in capabilities to unify and automate operations across both public and private networks

Enterprises will pick 'n' mix between mobile network services

Enterprises will opt for one or more of the available mobile network types based on their unique use case, operations, and application requirements. For some enterprises, the deployment of a private mobile network will be highly preferable; for example, in situations with a large number of devices to be connected. For others, access to the public 5G network will suffice in the form of either static or dynamic slicing, which offers wide area coverage at low (or no) capex.

In some cases, as we explore below, enterprises will look to leverage both private mobile networks and public network slicing (see Figure 1).

Figure 1: There are three scenarios in which enterprises require both a private network and network slicing



Source: STL Partners

Commercial models across private networks and network slicing will converge on four key principles

If traditional telcos want to grow revenues from static or dynamic network slicing, they must make it a financially attractive alternative or add-on to private network deployments. We have identified the following key principles telcos should adhere to in this context:

1. **Simplicity**: Unless the enterprise has advanced network management capabilities, it would look for a network provider to remove the complications of operating multiple networks and managing applications across different forms of edge and cloud infrastructure.

2. **Flexibility**: Enterprises will look for flexible commercial models that allow them to switch services on and off or scale them up and down based on evolving needs within their operations.

3. **Minimising upfront capex**: Customers are still in an exploration phase of 5G, and the use cases associated with it. Operators should ensure they offer services that require minimal investment in physical equipment or infrastructure to minimise the risk for the enterprise and encourage enterprises to adopt 5G services sooner.

4. **Going beyond connectivity:** Most of the value is in the application which 5G enables and telecoms operators must seek to help enterprises unlock that value, rather than solely focusing on providing pipes and infrastructure.

Five service models for network slicing and private networks

Given the reticence of enterprise customers to consume 5G services through capex models, we anticipate that commercial models will, in general, centre on service-based charging, which will leverage subscription or usage-based models; for example, subscribing to a premium 5G service to achieve an SLA. In the case of usage-based charging, the customer would pay based on what they consume, e.g. bandwidth or edge compute resources. You can read our report here where we address the link between private networks and edge.

To enable these commercial models while prioritising the principles outlined above, we believe that telecoms operators will use one of five service models (see Figure 2). The most basic of these service models is 'Connectivity service', which uses a subscription-based commercial model with the telco just offering 5G connectivity via either the private or public network. However, going forward, we anticipate innovative service models that provide mixed private network and 5G slicing services to wholesale and retail customers.

Figure 2: Potential service models for telecoms operators

Service model		Commercial model	Breadth of offering	Example
Connectivity service	Similar to current model for providing 5G and private network services	Subscription (# devices or bandwidth) plus potential capex for equipment		DT 5G campus networks offering currently charges customers on a per-device basis
Wholesale for multi-tenancy	Network and infrastructure for wholesale customers with multiple tenants (e.g. business park)	Usage-based considering consumption from sub-tenants on aggregate		Crown castle provided a private network in multi-tenant office building using CBRS
5G & MEC-as-a-service	Network and infrastructure provided in a cloud-based model	Usage-based for network and infrastructure consumed		KPN provides 5G in a "coverage on demand" offering
Turnkey 5G solution	Productised E2E solution, without significant customisation and integration required	Connectivity bundled into solution (charged on usage basis)		Verizon 5G edge AGV (5G and edge) Etisalat private 5G slicing for industrial IOT
Custom solution	Bespoke offering for a customer to design, implement and manage an E2E solution	Project fees (for design, etc.) and managed services		AT&T's offering includes design, installation and support

Key: Connectivity; **Compute** (Grey denotes this potentially being part of offering); **Application**; Systems integration

Source: STL Partners

Automated orchestration and operations are essential to mitigating future complexities

The mixed deployment scenarios that we anticipate will include enterprise connectivity deployments that are more complex and diverse in nature. As 5G services and slices become more dynamic, with deployments across public, edge, and private clouds, including diverse resources and applications, manual operations become unfeasible. Telecoms operators will need to create environments where

these processes are highly automated to meet stringent QoS and SLA commitments for enterprise customers, and do so across verticals and partner ecosystems. These types of automation will be required or possible at different points in time; operators will need orchestration and sophisticated OSS capabilities that allow them to automate how services are designed, deployed, updated, optimised and assured across the network and customer site, for example:

- Intelligent placement of resources onto the right on-premise, network edge or cloud platform (this is a current requirement/capability that operators are building)
- Zero touch deployment, provisioning and configuration of hybrid services and slices (this will become especially critical in the next one-two years as dynamic slicing matures)
- Continuous service and slice lifecycle management with scaling on demand, regular network updates with zero downtime and self-healing to maintain the SLA or optimise network performance (this capability will likely mature in the next 1-3 years, depending on the operator)
- Dynamic slicing across operator networks (national or international) with agreed slice models to maintain consistent SLAs (it will take about 3-4 years for operators to develop this capability, which will be essential for the success of network slicing)

Next steps for telecoms operators

STL Partners will continue supporting telecoms operators and other ecosystem players to accelerate enterprise adoption of private networks, slicing and edge computing. To learn more, read the following reports on similar topics:

- Telco Cloud Deployment Tracker: 5G core deep dive
- Telco edge platforms: Balancing speed vs value
- Private Networks: Lessons so far and what next

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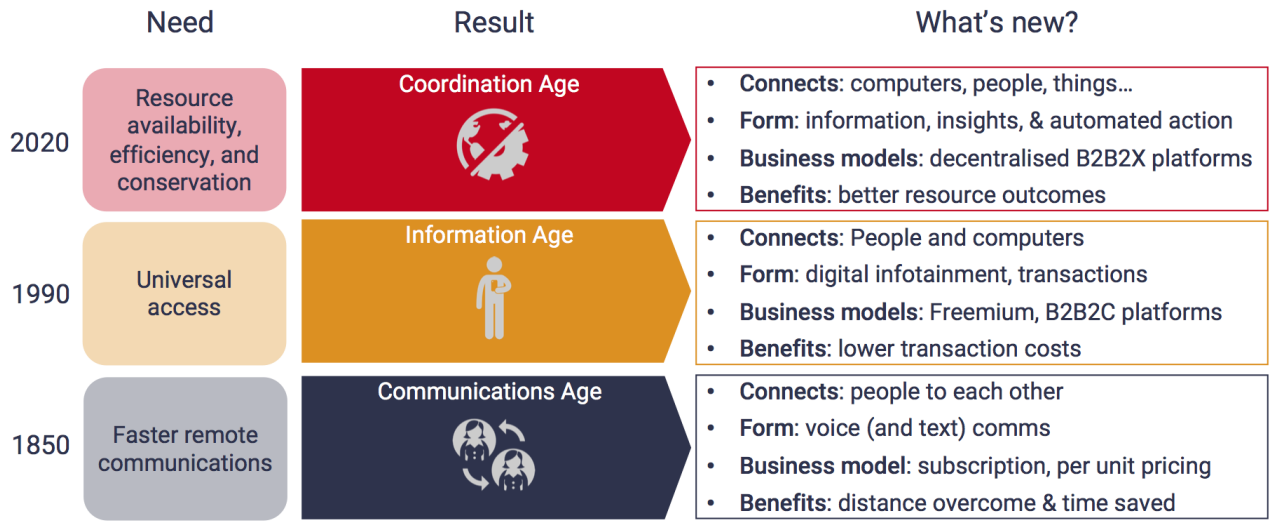
Introduction: the evolution of 5G

Telecoms is transitioning from the Information Age to the Coordination Age, where networks do not only play a role in connecting people and delivering information but connecting objects, ensuring outcomes, and solving business problems. The advent of full 5G promises to change what is possible for enterprises by offering customisable cellular connectivity that is tailored to their needs. Enterprises will deploy new use cases to make their environments safer, more efficient, and more resilient (see Figure 3Figure 3).

Figure 3: The Coordination Age



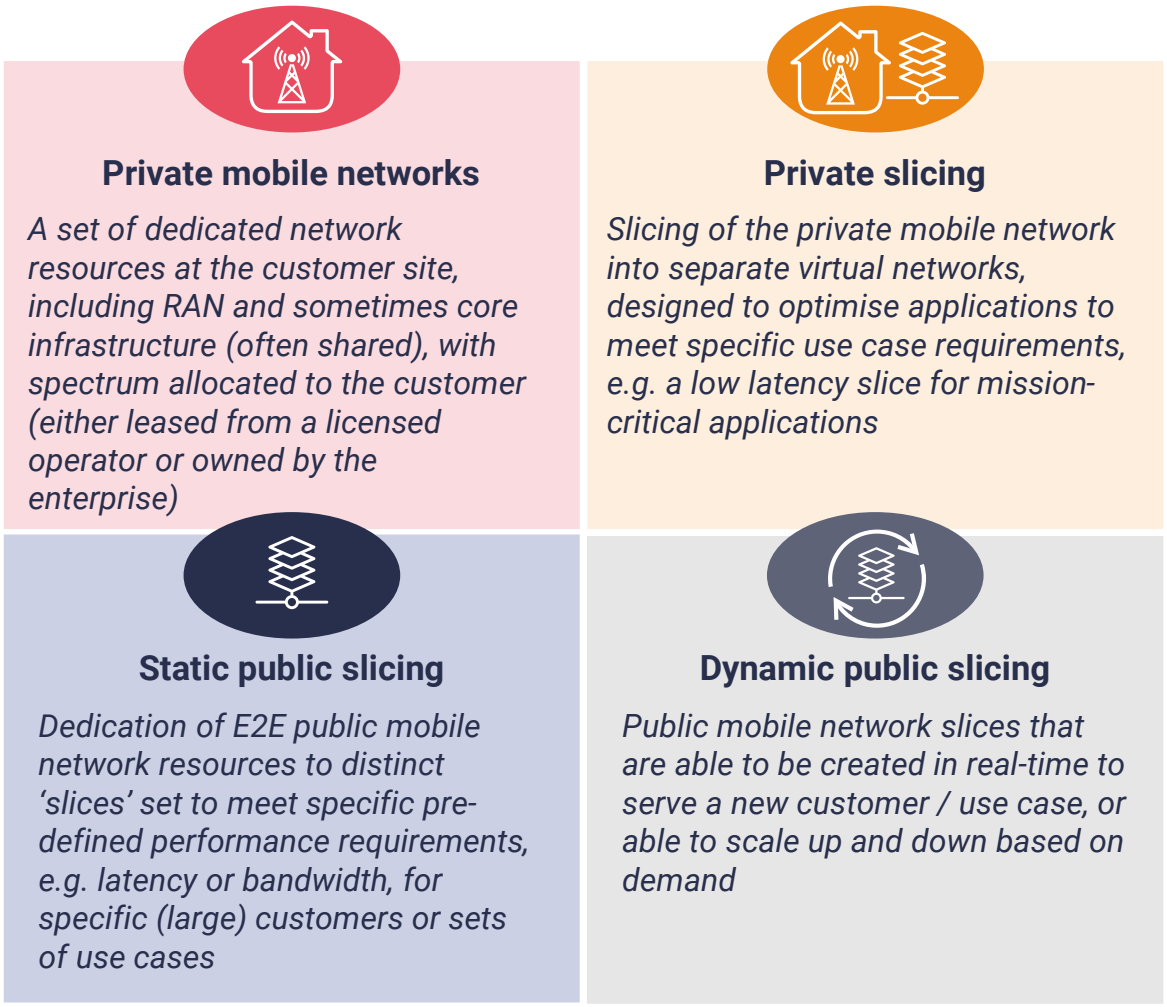
Source: STL Partners

Today's 5G networks do not encompass the "full 5G" technology, as they have been primarily an upgrade to the radio access network only. Full 5G is the evolution of the entire network, including the core network, and its ability to be a flexible platform catering to the needs of diverse use cases, devices, and requirements. Beyond connecting mobile phones, for which previous generations of cellular technology have been sufficient, full 5G is able to extend connectivity to a wider range of devices, such as robots, sensors, drones, cameras, and machinery while meeting the latency, throughput, and bandwidth requirements of the associated use cases and applications. There are two ways to deliver on these full 5G requirements – through a private 5G network or through public 5G with slicing.

Slicing of the public 5G network is not commercially available yet (largely constrained by the rollout of 5G standalone core) meaning that dedicated private 5G networks have taken the limelight as enterprises have an urgent need for full 5G solutions. However, with the advent of 5G standalone core and edge computing, the options for enterprises to access the benefits of full 5G grow. This includes the ability for distributing the 5G core and using network functions and applications that address the specific needs of an enterprise customer. Additionally, augmenting their networking capabilities with edge computing, enterprises will be able to ensure their data remains secure, and the network (latency,

reliability etc.) and application performance are optimised to their needs. Figure 4 provides an overview of the different ways for enterprises to have dedicated resources to support their use cases.

Figure 4: There are different ways to provide dedicated 5G services to enterprises



Source: STL Partners

There is speculation that network slicing may challenge or even replace private networks when dynamic slicing becomes available if it offers a lower cost and easier to deploy alternative to dedicated infrastructure at customer premises. This report evaluates the role of private mobile networks and slicing and presents the argument that these should be seen as complementary options. They address different enterprise needs and challenges, as highlighted in extensive conversations with operators and enterprises globally through our Private Networks and Edge Computing practices. In fact, operators are anticipating significant demand for the combined deployments of network slicing alongside private networks and see these two technologies working to coextensively expand the range of use cases that are available to customers, for example, drones for inspection or automated guided vehicles (AGVs) for transportation.

As enterprises' demands for cellular connectivity become increasingly complex it becomes more challenging for operators to coordinate the different connectivity and application requirements across

different enterprise networks. Operators will need to find ways to manage this effectively to achieve scale, simplify the connectivity offer for enterprises and meet the requirements that their customers are looking for.

Private networks and slicing technology will address different enterprise needs and challenges

Telecoms operators we have spoken with have all outlined that the adoption of 5G solutions for enterprises will be driven by their use case requirements. Some use cases will map better to a private network deployment and some to deployments of network slicing. Enterprises will have alternative reasons for pursuing one option over another, with cost, control, capacity, and availability or feasibility being primary drivers.

When compared with network slicing, two of the core features of private networks are that they offer high bandwidth capacity and a higher degree of control (see Figure 5Error! Reference source not found.). In countries where regulators have allocated some spectrum for private networks, enterprises can choose the type of deployments that suit them and might be inclined to explore a more dedicated type of deployment. In other countries where local spectrum regulations are strict, network slicing might be more desirable, given that the technology for network slicing is available. At least today, enterprises may be able to gain access to higher allocation of spectrum, particularly in remote areas.

Figure 5: With different features, private networks and slicing meet different use case requirements

Source: STL Partners

The high bandwidth afforded through a private 5G network can support significantly high numbers of devices within the network. This is important for use cases with thousands of devices, such as those in a highly automated Industry 4.0 factory with dozens of IoT sensors on each machine. A private network has the capacity to support operational technology applications in large scale industrial production environments with extremely stringent reliability and latency requirements (as low as 5 milliseconds).

Enterprises that have developed network management capabilities such as railway operators can take on control and management of the network. This means that they can configure the network to their

needs, further ensuring ultra-reliable low latency communication (URLLC) in the network based on their evolving connectivity needs day-to-day and minute-to-minute. Additionally, the user plane can remain on premise which is important for enterprises that want to keep data local for security related concerns.

The available spectrum for private networks deployments and network slicing may vary between markets based on their specific regulatory environment. In the German market, for example, a German operator can only dedicate 10 MHz of spectrum for a single enterprise customer via a slice of the public 5G network, whereas an enterprise is able to acquire up to 100 MHz of spectrum from the public auction of spectrum to use in a private network deployment. This, of course, significantly impacts the available bandwidth in a private network compared to the deployment of a public network slice. However, this advantage for private networks is specific to the German market and will vary across markets depending on their specific regulatory environment.

Where a private network boasts high bandwidth, control, and potentially greater access to spectrum, the promise of public network slicing is a far less costly option for enterprises which requires fewer management capabilities from the enterprise. Network slicing will purportedly have a simple set up, offering superior connectivity compared to the public network, and is anticipated to have a relatively lower cost to access than a private network. At the moment, these benefits of network slicing are unproven as slicing is not yet ready, and network slicing will likely fail to scale commercially unless it can offer them. However, while dynamic slicing may not be commercially mature, one European telecoms operator shared that it currently charges for access to a static slice based on number of devices. For 50 SIMs, they charge €750 per month and, for 1,000 SIM cards, this is €12,000 per month. For uncapped access to dedicated 5G connectivity, this works out to a price as low as €12 per device per month for highly reliable connectivity. We can expect the cost of dynamic slicing to vary from the cost of static slicing, especially as the commercial model is likely to change.

Beyond cost, for many enterprises, having the 5G network managed by the telco or other 3rd party rather than in-house will be preferable. Many businesses do not have the network capabilities that are required to operate the deployment of a private network. Even if it is delivered as a managed service, the physical infrastructure on premises will result in a deployment cost for the enterprise. Given the low or non-existent infrastructure implementation required for the deployment of network slicing, getting devices set up should be a relatively simple and seamless process. Taking out the complexity of deployment and network management means that for many enterprises, network slicing will often be an attractive alternative.

Finally, the coverage offered by a slice of the public network is far greater than that offered by a private network for the simple fact that the network slice can be deployed across an area as large as the public network itself. This opens the opportunity to leverage a slice regionally, nationally, or internationally which may be attractive for businesses with many sites across an area for example in retail stores or for use cases that require mobility such as in the transport and logistics vertical. The constraint to this is, of course, that where there is no public network coverage, an enterprise will need to deploy a private network if they wish to access 5G cellular connectivity.

Private networks will continue to be deployed as we move into a world with network slicing

In this report, we explore the factors that will shape the market with private networks continuing to be adopted alongside network slicing, addressing several elements of the mixed deployment landscape:

- **The timelines for private 5G networks and slicing of public 5G networks**: operators are at different stages in their readiness to offer slicing of the public 5G network, largely inhibited by not yet deploying a 5G standalone core.
- **The use cases that will drive mixed deployments** relate to specific enterprise needs that are not supported by the current legacy network architecture. We discuss the unique scenarios and applications that will be best enabled by private networks and network slicing together.
- **Identifying appropriate commercial models**: this explores the commercial models that operators may employ for mixed deployments, including where they will play in the value chain.
- **The challenges of deploying mixed networks at scale** include the technical readiness of 5G standalone and the maturity of slicing technology. However, operators will also face challenges in standardising their offer to enterprises, automating or coordinating the maintenance of networks as well as developing orchestration capabilities to enable this.

Why mixed deployments? Private networks and slicing will co-exist

There are multiple reasons why private networks and network slicing will co-exist in a mixed world:

- **Different timelines**: Private networks are an established offering to enterprise, with the first instances of public network slicing anticipated to be market ready around Q1 2023, as operators deploy 5G standalone cores and develop the capabilities required for slicing. As network slicing matures, we can expect to see it deployed, with some use cases or private networks migrating to slices, while also seeing continued deployments of private networks.
- **Different use cases**: Private networks and network slices will offer different benefits to enterprises, with one being chosen over the other on a case-by-case basis, often driven by the enterprise's requirements and the use cases they wish to deploy.
- **Mixed customer deployments**: There will be instances where enterprises need, or benefit from, both private networks and network slices at the same site. We explore three such scenarios driving this: nomadic use cases, resilience, and temporary networks.

Timeline: private networks are already being deployed today; dynamic slicing will take 2-5 years to mature

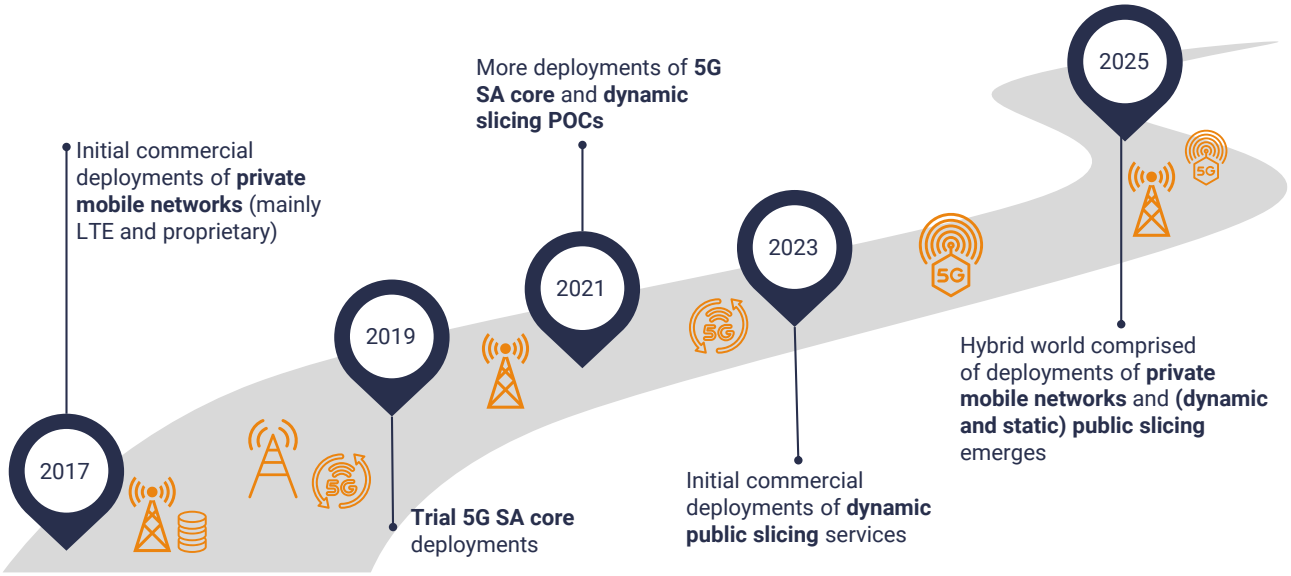
Deployments of private mobile networks have been underway for a number of years in specific cases, e.g. to provide connectivity to a remote site such as an oil rig. Private LTE networks have been available since 2017, with private 5G networks being deployed as early as 2019. For example, A1 Telekom Austria installed a private 5G network in Vienna Airport in March 2019. This deployment primarily enabled AGVs and luggage track and trace services across the airport premises. Private networks are now an established technology with adoption across multiple verticals, such as transport and logistics, manufacturing and healthcare.

Slicing, even static slicing, is at a much earlier stage and most operators are still conducting proof of concepts in lab environments. Dynamic slicing is the end goal of slicing, with the ability to create and terminate large numbers of slices on-demand with specific QoS and SLA requirements. Unlike static slices, dynamic slices are not pre-defined and are able to match the specific needs of the use cases/applications that they support. By definition, dynamic slicing will necessitate new orchestration systems to automate the design, deployment and full lifecycle management of each slice to maintain the slice SLA at all times.

> "We launched a virtual private LTE network as a predecessor for the upcoming slicing-based solution in 2019. Our dynamic 5G slicing product will be ready early in 2023.
>
> ***Deutsche Telekom***

Discussions with operators from across the world have revealed that the readiness for full dynamic slicing varies significantly from one operator to another. This is often a result of varying levels of maturity in the deployment of a standalone 5G core, and the recruitment of orchestration capabilities required for automating slicing alongside recruiting the edge compute needed to meet stringent QoS needs. However, it is also the result of operators choosing to invest in developing their slicing capabilities which depends on their appetite to take a leading role in seeding the market and whether they see a clear business case to invest in this technology. In some cases, the choice to invest may result from the fact that regulatory bodies in an operator's market have not allocated spectrum for private networks use, such as in Canada., This means that network slicing will be the only way for operators to effectively offer 5G services to enterprise. Some operators are not sure why they need dynamic slicing, not having identified or established the use cases that will drive demand for slices. The technical challenges involved in realising full dynamic slicing are more likely to be prioritised by operators who see a clear and compelling business case for solving them. Some operators interviewed anticipated being able to offer dynamic slicing commercially by the start of 2023. However, most other operators we interviewed saw dynamic slicing as a capability that would reach maturity over the next two to four years, as late as 2027 (see Figure 6Error! Reference source not found.).

Figure 6: Network slicing will become available from 2023, with mixed environments to emerge from 2025 onwards in earnest



Source: STL Partners

The focus of this report is on the interplay between private networks and public network slicing; however, it is important to note that already today there is the possibility to slice the private network itself. This would be the dedication of an element of the physical private network – a slice – for a specific purpose. This is largely about maximising the use of a private network and using the network resources most efficiently. In doing so, enterprises can provide enhanced connectivity to mission critical use cases or applications with heightened requirements such as URLLC.

In the context of a manufacturing environment, slicing of a private network may be employed to provide individual slices for different types of applications, with each slice optimised to the use case requirements. For example, for push-to-X applications (whether voice and/or video), the private slice would be optimised for video and voice which enables critical communication between workers at a manufacturing site. From a health and safety perspective, the traffic on the private slice can be prioritised over others to keep vital communication running with a high degree of reliability, lowering the risk of accidents. The same manufacturing enterprise may deploy another slice for quality assurance on its production line, which is less mission critical and has fewer specific requirements. While high reliability is desired in this instance, it is less important than for the push-to-talk use case as accidents arising from a failure in communication comprise a worse outcome than minor delays to quality inspection processes arising within the production line.

Private networks and slicing address different use cases

Enterprises can opt to deploy both a private network and network slicing in cases where they have an application requiring slicing and they have other use cases that are best served by a private network. As dynamic slicing is not a mature or available technology right now, adoption of network slicing alongside private network deployments is limited to static slicing and is rare. However, as the technology for slicing matures, we can expect to see deployments of both at the same enterprise site.

Taking the transport and logistics industry vertical, and ports specifically, there are multiple use cases that are increasingly being adopted as ports digitise and automate their day-to-day operations. Drones for inspection and maintenance is one such use case that, as described previously, will leverage public network slicing. Ports are also increasingly deploying AGVs for automated transportation alongside gantry cranes for the automated moving and sorting of cargo containers, and there are port authorities deploying private networks to facilitate these use cases. Yangshan Port in Shanghai currently leverages a private 5G network to facilitate both AGVs and gantry cranes as well as leveraging public network connectivity for the gantry cranes at the site too. It is not a stretch to imagine that once dynamic slicing reaches maturity, port authorities would enhance their digital transformation efforts by further leveraging 5G use cases requiring slicing of the public 5G network.

Figure 7: Key verticals for private networks and network slicing

Use cases & verticals	Private 5G	Public Slicing
Healthcare	Secure medical data transfer between departments	Back up for mission-critical procedures e.g., surgeries; connected ambulance
Ports & logistics	Computer vision for employee safety in ports/security in airports	Drone surveillance/drone maintenance of ships
Manufacturing	AGVs to transport goods between manufacturing plants	Smart trucks to transport goods to/from manufacturing sites
Stadiums	Broadcasting during high-profile events	Slice for consumer experience use cases during live sporting events/concerts

Enterprises across numerous verticals are already leveraging private networks for various use cases, and we anticipate that many would also leverage dynamic network slicing once the technology is

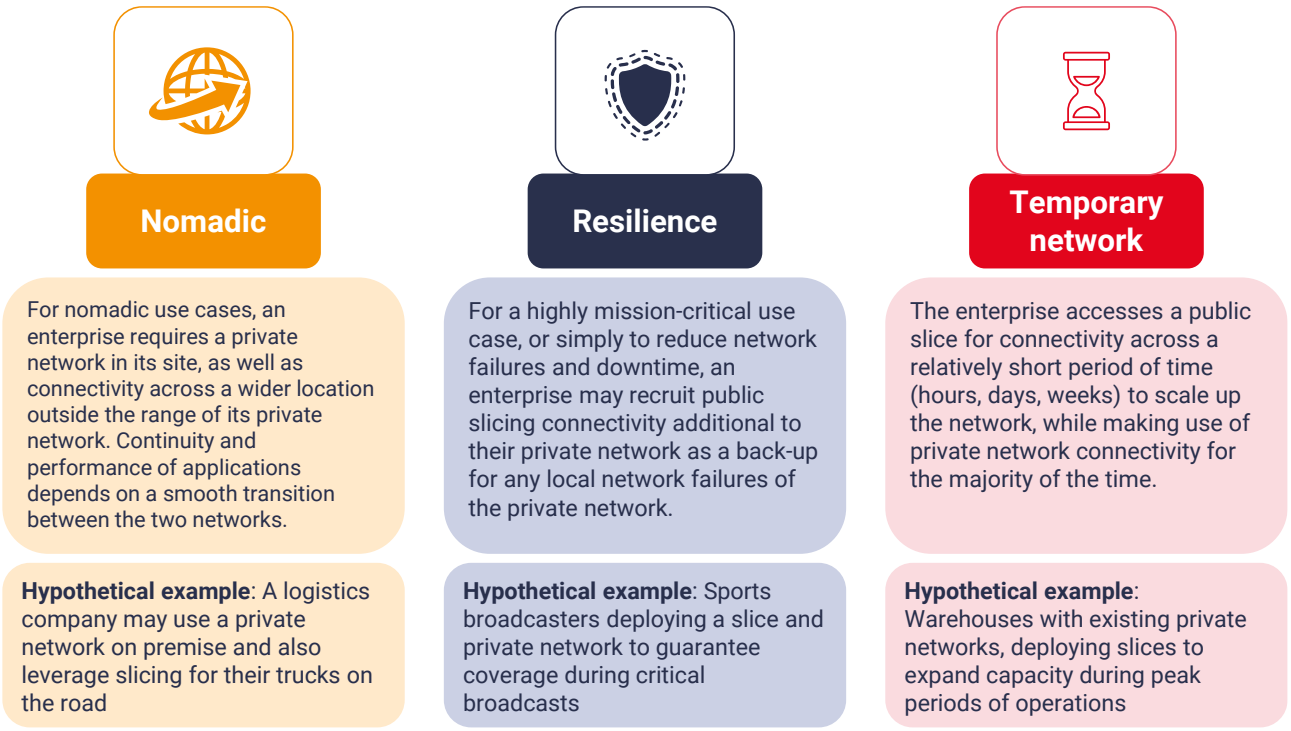
available. We consider four verticals and example use cases for private 5G and public network slicing (see Error! Reference source not found.Error! Reference source not found.).

Source: STL Partners

There will be specific scenarios requiring mixed deployments

Moving beyond the fact that private networks and network slices will co-exist in the same world of mixed deployments, we explore the deployment scenarios in which enterprises would leverage both technologies in the same sites as mixed deployments (see Figure 8).

Figure 8: The three scenarios that drive enterprises to deploy both private networks and slicing



Source: STL Partners

Nomadic use cases may need to move between private and public networks

A nomadic use case is an application or device that moves around a large area to fulfil its function. For example, the Port of Hamburg in Germany deploys autonomous drones for maintenance purposes. The drones examine areas of port infrastructure that are difficult or time consuming for human operators to reach, and in this case, the drones leverage a public 5G network slice to coordinate their activity in real time.

There are other situations where the device needs to be connected to the public network as it leaves the area covered by the private network. Examples include connected cars, connected ambulances,

remote monitoring & asset tracking of fleets, fleet monitoring, remote health monitoring and connected smart glasses for in-field maintenance.

As is the case with the Port of Hamburg, the enterprise may be able to operate a nomadic application use case by using a slice of the public 5G network without the need for a private network. An instance where a nomadic application roams between a private network and a network slice would be where the application operates across areas with both good and bad coverage of the public network and leverages a slice where coverage is good. This could be a scenario in transport and logistics where a smart truck, enabled with real time inventory management and asset tracking, uses a public network slice while making deliveries. However, the logistics hub that the truck docks at may have poor public network coverage, and so the truck roams on the private network instead.

> "One of our customers in the healthcare vertical leverages a private network for internal operations and the public network for their visitors.
>
> ***Global Tier 1 Operator***

In these instances, enterprises need the assurance that applications will be able to connect across both the private network and the network slice. From an operator perspective, this means ensuring that the system, which includes the application or device located on one of the 5G networks, can automatically detect and facilitate the transition from one network to the other. For example, when an enterprise's device is on-premise and connected to a private network, then roams to a network slice, this transition should look seamless to the enterprise without needing manual intervention from either the enterprise or the operator. This will only be possible through automation of network management and orchestration. Some service providers are exploring how to combine the public and private sub-networks to create a single pane of glass for the operator and customer.

For nomadic use cases, such as a drone that traverses large areas, there may be situations in which the drone leaves the area covered by the private network and moves away passing through multiple operators' networks. In this case, to guarantee a continuous (low latency) connection, the ability to switch between multiple operator networks is required. Operators trialling this technology are referring to it as network slice stitching, having opted for a new technical solution over roaming because the preference for a primary provider in traditional roaming may degrade the available QoS. The technology to enable this is being developed with multiple operators and vendor partners. For example, Orange, Jio, Telenor, e& and Vodafone have teamed up with Netcracker, Oracle, SigScale, and Whale Cloud to pilot the technology that has enabled drones to travel across different operator slices by Copenhagen Malmø Port in Denmark[1]. Information about the proof of concept can be found here.

Slicing supports private networks to improve resilience

For a highly mission critical use case, an enterprise may use network slicing connectivity in addition to an existing private network as a back-up for any local network failures of the private network, e.g. if

[1] Tmforum, 5G Flyers – Phase II, https://myaccount.tmforum.org/networks/22-0-309/index.html

the hardware running the network goes down. Once dynamic slicing is available, the enterprise would have the option to automatically spin up a slice to strengthen the guarantee of 5G connectivity for that use case. Alternatively, there could be a static slice available and reserved for the enterprise permanently to support these situations.

An example of where a network slice may be leveraged to enhance the resilience of an enterprise's 5G connectivity would be in sports broadcasting. The broadcaster may leverage a private network within an advanced stadium for the purpose of ensuring the best connectivity for broadcasting live sporting events. Given the risk and costs associated with delays in streaming and airing sporting events for broadcasters, the use of a dedicated slice of the public network would help manage such risks, especially for highly anticipated and watched sporting events such as the Champions League Final.

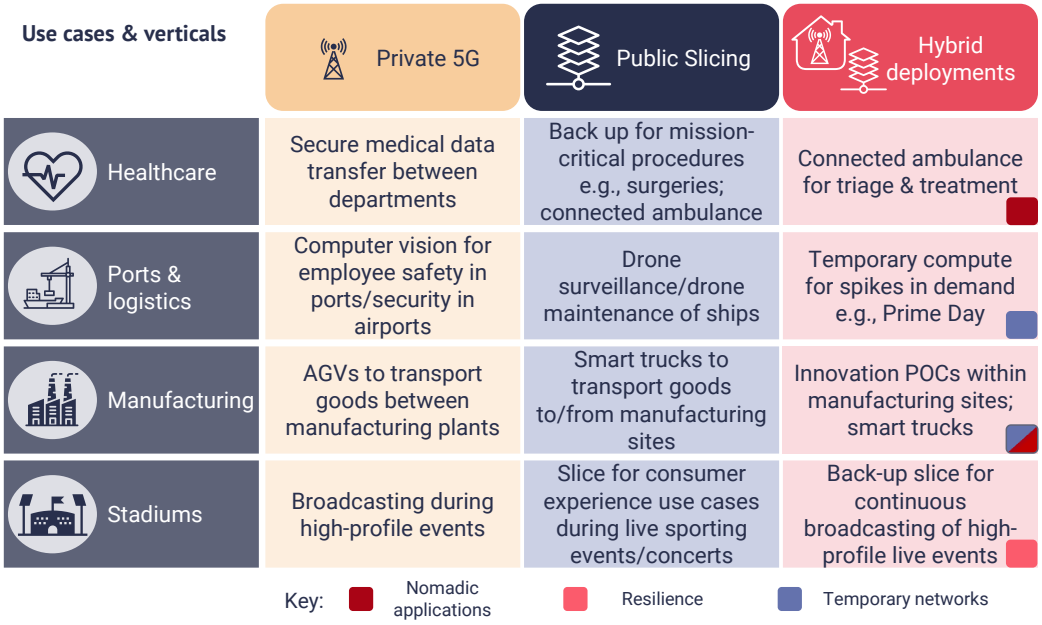
Temporary events drive demand for temporary network slices

Enterprises that experience significant strain on their network traffic over a temporary period may consider a slice of the public network to support their operations and enhance their productive potential. This could be the case in an online retail context, such as Amazon Prime Day, where significant discounting of retail products leads to enormous spikes in consumer demand and required output in warehouses and across the supply chain. In automated warehouses that already leverage connectivity from a private network, a warehouse operator may choose to additionally deploy a slice of the public network over the two- or three-day period to ensure minimal downtime in their network availability and coverage. During such short-term periods, the costs of network downtime and loss of productivity is far greater than at any other time of the year.

There may also be B2B2C drivers for temporary networks involving both private networks and public network slices. A large sporting, music or entertainment event may have a built-in private network at the stadium or venue for the connectivity needs specific to running the event. The enterprise in this instance may wish to deploy a slice of the 5G network for the audience of a single event, so that they can have an enhanced viewing experience, possibly enriched by augmented reality or virtual reality use cases.

To keep things as simple as possible for the enterprise, operators need to make it easy for them to recruit additional 5G connectivity resource via network slices. Being able to receive the request for connectivity, and automatically dedicate resources requires skills in orchestration and network management that operators currently do not have. As enterprises offer on-demand services, the role of automation is critical, especially in the context of increasingly complex connectivity scenarios like mixed deployments. We consider some additional examples of mixed deployment use cases in the context of key verticals. (see Figure 9).

Figure 9: Verticals and use cases for mixed deployments



Source: STL Partners

Mixed networks need a unified and automated operations environment

Whichever the business model, it will be crucial to get the operations right for any of these models to succeed in the market. Both private 5G networks and network slicing are highly complex offerings that traverse RAN, transport, 5G core and cloud domains.

Even if enterprises decide to own the equipment, many will turn to telcos or third parties for their private 5G network operations, as they lack expertise in operating 5G radio engineering, 5G core, edge cloud platforms and connectivity solutions. In return, they will want services that can be discovered, purchased and monitored on a marketplace platform. These services should be easy to order, fast to deploy and designed to accommodate specialised 3rd party MEC applications. Enterprises will also require solutions that will allow them to retain control and visibility over their services. Businesses can offer unused resources in marketplace platforms, with their own policies to control how the resources are used and by whom. Such an approach might provide alternatives to network slices for enterprises that want to deploy additional capacity through hybrid infrastructure backed by SLAs.

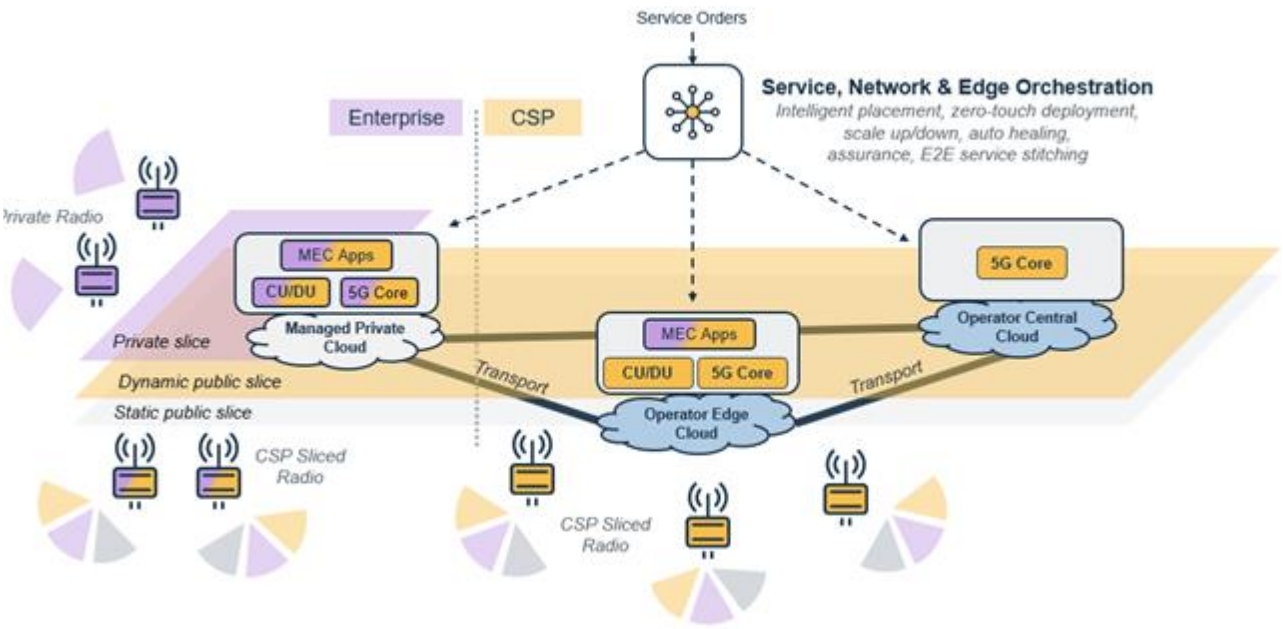
This requires a fundamental change in operations towards a highly automated environment. A combination of orchestration functions (across service, network and edge) and operational systems, such as configuration management, real-time inventory management and assurance will be needed to automate key processes, and will be needed at different points in time, including:

- Intelligent placement of resources onto the right on-premise, network edge or cloud platform (this is a current requirement/capability that operators are building)

- Zero touch deployment, provisioning and configuration of hybrid services and slices (this will become especially critical in the next one-two years as dynamic slicing matures)
- Continuous service and slice lifecycle management with scaling on demand, regular network updates with zero downtime and self-healing to maintain the SLA or optimise network performance (this capability will likely mature in the next 1-3 years, depending on the operator)
- Dynamic slicing across operator networks (national or international) with agreed slice models to maintain consistent SLAs (it will take about 3-4 years for operators to develop this capability, which will be essential for the success of network slicing)

Service orchestration plays a key role by providing a single pane of glass across all operational functions (see Figure 10). Numerous technologies and parameters must be negotiated to address the service (and slice) needs: radio access, cell radio resource usage, mobility, slice selection, MEC location selection, routing, failover and others. Service Orchestration then stitches services and slices together across different domains, both private and public, and ensures the SLA is maintained at all times.

Figure 10: A single pane view across network and service elements



Source: Netcracker

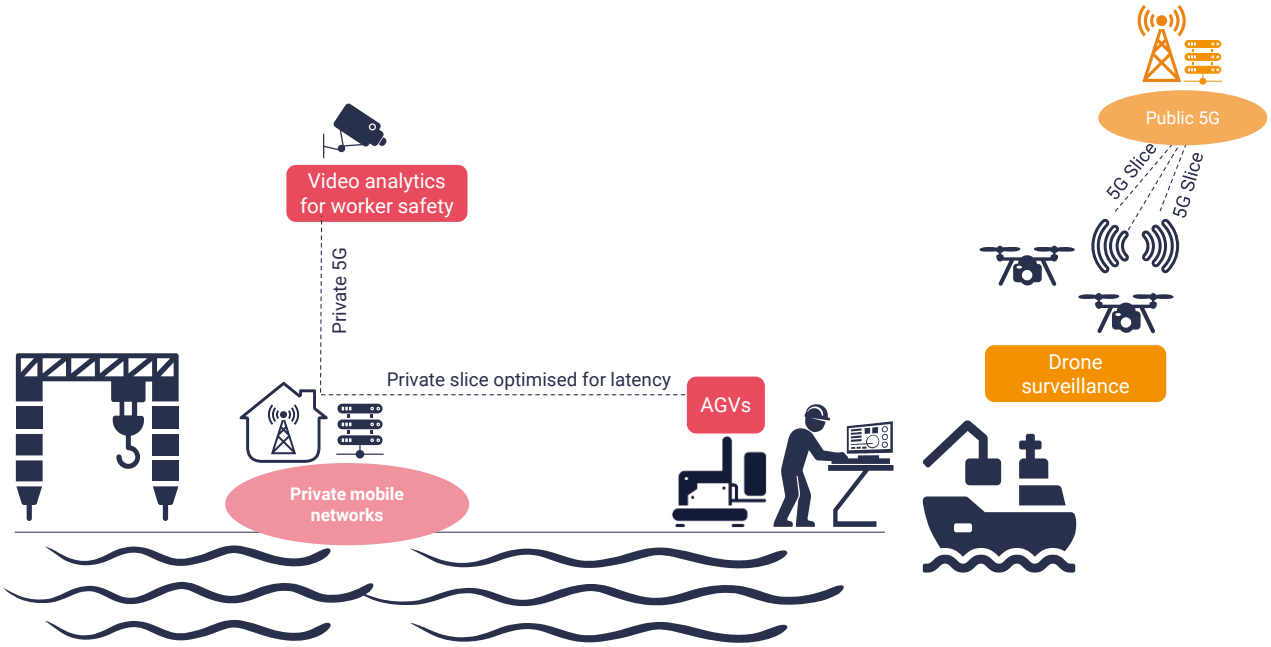
This unified and automated approach to operations will enable operators to scale the business, and incrementally add value, whilst providing targeted offers for the diverse verticals.

Vertical spotlight: mixed networks in ports

Ports will be an interesting area of focus for operators looking to offer slices of the public network to enterprises. Research in the European Transport Review[2] shows that the pace of digitalisation in ports is relatively slow, because of conservative attitudes to IoT, robotics and AI. However, it is clear that as port authorities look to their bottom line, innovative use cases, including those involving nomadic applications, will create an opportunity for operators to provide additional 5G connectivity through slicing of the public 5G network, including where private networks have already been deployed.

In the figure below, we set out a deployment scenario for a port of the future enabled by dynamic slicing with use cases supported by 5G connectivity from a slice and a private network (see Figure 11Error! Reference source not found.).

Figure 11: Using a private network and a network slice in a port environment



Source: STL Partners

AGVs moving around the port and transporting goods from one location to another are connected through a slice of the private network is optimised for latency. It is better suited for this use case to run on top of a private network due to its requirements around low latency and reliability. If the network fails to perform as intended, the AGVs might crash into each other or, worse, into humans, posing a significant risk to health and safety. Another use case running on top of the existing private network

[2] Brunila, OP., Kunnaala-Hyrkki, V. & Inkinen, T. Hindrances in port digitalization? Identifying problems in adoption and implementation. Eur. Transp. Res. Rev. 13, 62 (2021).

is using video analytics for worker safety. Computer vision is a bandwidth-intensive use case which makes private networks a more suitable connectivity option.

While operating these applications via a private network, the port might also want to leverage a network slice for drone inspection or surveillance. As the drones need to fly greater distances that are not covered by the private network, it makes sense to make use of the public coverage.

As ports succeed in their pursuit of digitalisation, incorporating hundreds or even thousands of devices in their operations, port authorities will need support in the management of these devices, and they will expect flawless delivery of 5G connectivity from the operator. To fulfil both obligations, operators must invest in orchestration capabilities either through partners or developed in house. In addition to network management, automation and facilitating seamless access to connectivity for the operator, orchestration includes important back-end capabilities for scaling deployments of private networks and public network slicing, as well as for measuring connectivity usage and charging for such services.

Network slicing and private networks should have common commercial models

As public network slicing matures, operators' offerings will become increasingly complex but at the same time more versatile. This means that enterprises will have greater optionality when it comes to buying and paying for telecoms operators services. While this is great news for both telcos and enterprises, it's also important to keep in mind that monetising 5G networks and the services that revolve around them won't be an easy task. CSPs need to be able to offer services and solutions that meet customers' technical and commercial needs.

Key principles for commercial models: simple, flexible, minimal capex, and going beyond connectivity

Given the fact that there will be an increasing number of mixed deployments of private networks and network slicing in the future, we explore the potential commercial models that operators could employ to make the most of these offerings. Based on discussions with enterprises on their preference for how they want to consume such network services, there are four key factors to consider:

1. **Simplicity**: whether deploying a dedicated on-prem network, a slice of the public network, or both, most enterprises want management, upgrades and automation of the network to be undertaken by the operator or a third party. Unless the enterprise has advanced network management capabilities, they would look for operators with simple approach to private networks.

2. **Flexibility**: enterprises' requirements vary from one another and change over time. Enterprises will look for flexible commercial models that allow them to switch on and off services or scale them up and down based on changing needs within their operations.

3. **Minimising upfront capex**: Especially given the fact that enterprises are looking for connectivity rather than infrastructure when pursuing 5G, they seek commercial models with minimum upfront cost required. This helps to make the internal business case for connectivity within the enterprise and means that costs are incorporated across the contract for connectivity.

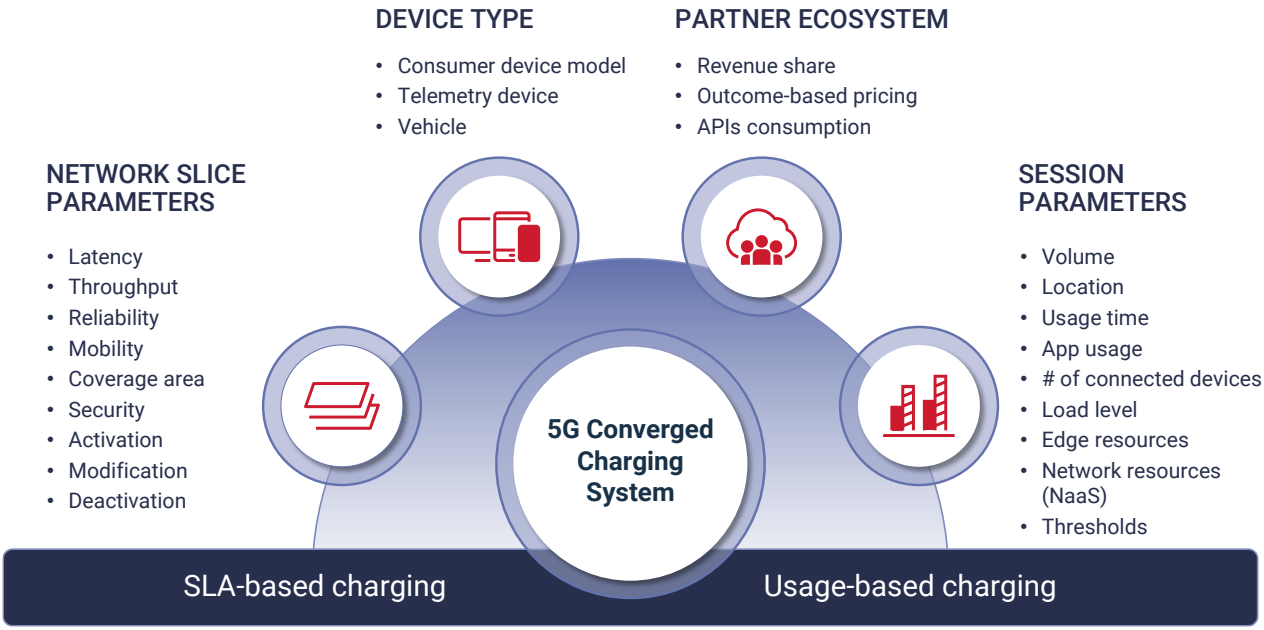
4. **Going *beyond connectivity*:** Enterprises are increasingly or exclusively interested in what cellular connectivity enables for their business, not merely the connectivity they consume. This means telecoms operators should pursue charging models where the costs for connectivity are built into costs for the application. This will likely mean charging for connectivity based on the number of connected devices or for bandwidth used.

The advent of dynamic network slicing, which brings with it on-demand network connectivity, creates the opportunity for operators to rethink the way that they charge for both public and private networks. Operators must find new ways to charge businesses and monetise the quality of service and experiences, not just connectivity. Breaking away from fixed charges for dedicated network resources,

enterprises will look to new usage based commercial models and these models need to be facilitated by new converged charging and billing systems.

Usage-based commercial models will require the ability to charge for **any attribute** of the private 5G network and network slicing offering. New 3GPP-based converged charging systems should be capable of charging beyond the traditional attributes including slice-specific charging (e.g. slice type, latency), type of device, session parameters, and SLA-based charging – as shown in the figure below (see Figure 12).

Figure 12: Emerging commercial models for telco offerings



Source: Netcracker

Network Slice-as-a-Service (NSaaS) and slice charging across multiple operator networks should also be supported to cover all customer segments including B2C and B2B, as well as partners form different industry verticals.

For operators who want to broaden their enterprise offer to include vertical applications and services, the converged charging should also extend to any service beyond telecoms including home security, health, industrial IoT, transportation and smart cities.

5 telco service models for slicing and private networks

We have summarised the various scenarios for deploying private 5G and network slicing, including the breadth of the offering, likely commercial models and example operators who currently offer a solution in each category (see Figure 13). These are not necessarily completely exhaustive. When it comes to usage-based models, the service may charge the customer on consumption of the network but also specific SLAs through APIs and other means.

Figure 13: Telco service models spanning across private networks and slicing

Service model		Commercial model	Breadth of offering	Example
Connectivity service	Similar to current model for providing 5G and private network services	Subscription (# devices or bandwidth) plus potential capex for equipment		DT 5G campus networks offering currently charges customers on a per-device basis
Wholesale for multi-tenancy	Network and infrastructure for wholesale customers with multiple tenants (e.g. business park)	Usage-based considering consumption from sub-tenants on aggregate		Crown castle provided a private network in multi-tenant office building using CBRS
5G & MEC-as-a-service	Network and infrastructure provided in a cloud-based model	Usage-based for network and infrastructure consumed		KPN provides 5G in a "coverage on demand" offering
Turnkey 5G solution	Productised E2E solution, without significant customisation and integration required	Connectivity bundled into solution (charged on usage basis)		Verizon 5G edge AGV (5G and edge) Etisalat private 5G slicing for industrial IOT
Custom solution	Bespoke offering for a customer to design, implement and manage an E2E solution	Project fees (for design, etc.) and managed services		AT&T's offering includes design, installation and support

Key: **Connectivity** **Compute** (Grey denotes this potentially being part of offering) **Application** Systems integration

Source: STL Partners

Connectivity service

The subscription-based commercial model is akin to a traditional connectivity model for a telecoms operator. In this scenario the operator manages the public 5G network slice and private network, charging a monthly or annual subscription for connectivity, usually based on bandwidth and/or number of devices. A small fee may be included for installation of any physical infrastructure, and cost for infrastructure is built into the subscription charge. Many telecoms operators, including Deutsche Telekom with its campus network offering, provide this as a managed service, ensuring it is easy for a general IT employee to manage the network through a portal. This requires the ability of the operator to orchestrate the network and compute infrastructure easily, for example so that customers can add devices quickly.

Premium subscription

Operators will have the option to offer a premium subscription for network slicing which offers a 'gold tier' slice with an SLA guarantee. This would be charged monthly or annually with a premium applied and would most likely be used for mission critical use cases or where security concerns are significant for the enterprise.

Wholesale for multi-tenancy

In a wholesale model the operator would sell infrastructure and network connectivity to a third party who subsequently re-sells the connectivity to its enterprise customers. For example, an operator might sell a private network and access to public network slices to a business park owner, with the office tenants as the customers. In the pursuit of enhancing their offer, the business park owner improves the attractiveness of their commercial, office or warehouse space by bundling in 5G connectivity from

a private network and/or network slices. To the enterprise customer, costs for connectivity would be bundled into their rental costs or added on top as a premium.

5G and MEC-as-a-service

> "Having an on-premise edge is important for extreme low latency cases, it is a functional need with a technical capability required to complement the 5G offering.
> ***KPN***

In this commercial model enterprises would simply pay for what they use, whether for connectivity or compute. When charging for a private network in this context, the operator would install edge infrastructure with limited or no upfront expense and charge the enterprise based on usage. For example, enterprises could be charged based on the device type (e.g. robot vs vehicle), session parameter (e.g. volume or usage time) or slice parameter (e.g. latency, bandwidth, security etc). Included in the physical infrastructure could be an on-premise edge, again charged based on usage for compute. In line with usage-based charging, the deployment of a public network slice would be charged accordingly, however this model is likely to need dynamic slicing to be able to scale use up and down for the customer. This is particularly interesting for enterprises who have variable connectivity and compute requirements, or those who want to try a new application and innovate. As well as KPN in Figure 13, start-ups such as Alef are developing an API platform to deliver mobile networking in a cloud-like way.

For operators looking to move up the value chain by operating at the application layer, there is a substantial challenge with offering turnkey solutions. Usually what is gained for operators in terms of scalability and standardisation is lost in terms of the opportunity to move further up the value chain precisely because they outsource value added activities and services to others in the ecosystem. For ambitious operators looking to win big with turnkey solutions, they would need to develop and manage an extensive and attractive vendor and application ecosystem.

Turnkey 5G solution

Many operators see their 5G monetisation strategy being tied to an end-to-end solution offering, which includes the application itself. The custom solution model provides this too, however most telecoms operators need to be able to scale go-to-market and delivery and to productise such offerings. For these types of solutions, operators need to ensure that they can charge not only for the connectivity part of the offering but also for the value that's created higher up the stack in the application layer, ideally without adding complexity for the customer. An example turnkey solution is Etisalat's cross-vertical managed 5G offering enabled by edge orchestration capabilities to offer new 5G and edge services through a marketplace environment.

There are a few models we have seen to create a turnkey 5G solution:

1. Productised vertical offering: e.g. Vodafone Business has combined its 5G, edge computing and IoT capabilities, coupled with specific applications to provide a digital manufacturing solution

2. Closed ecosystem platform: A connectivity and cloud platform that brings an ecosystem of ISVs and application partners to customers, already certified on the platform, minimising time to deploy and integrate

3. 5G-enabled application: e.g. Verizon Business offers an AGV management solution that can leverage (private) 5G networks

It is likely that there would still need to be some customisation when implementing for a customer, but the key aspect of turnkey is minimising the operational costs and times for both the service provider and enterprise customer.

Custom solution

In this model, the operator and ecosystem partners would work directly with an enterprise to understand its requirements and to design and implement a bespoke network solution which, depending on its requirements, could leverage a private network and/or a slice of the public network. The solution would usually incorporate on-premise edge which would add to physical infrastructure costs as well as the cost for designing the network (e.g. assessing number of radios and where they would go) and installing the physical network equipment. For an end-to-end solution, including end-applications, an enterprise customer would need the application to be integrated into its standard enterprise systems, be it the MES or SCADA system in an OT industrial environment, inventory management in retail or enterprise resource planning systems. This can be complemented by ongoing service fees if the telecoms operator helps the customer operate the network.

> "The end state for us is offering E2E solutions. Traditionally telcos wouldn't be good at the application layer, but this needs to change – and is changing.
>
> ***British Telecom***

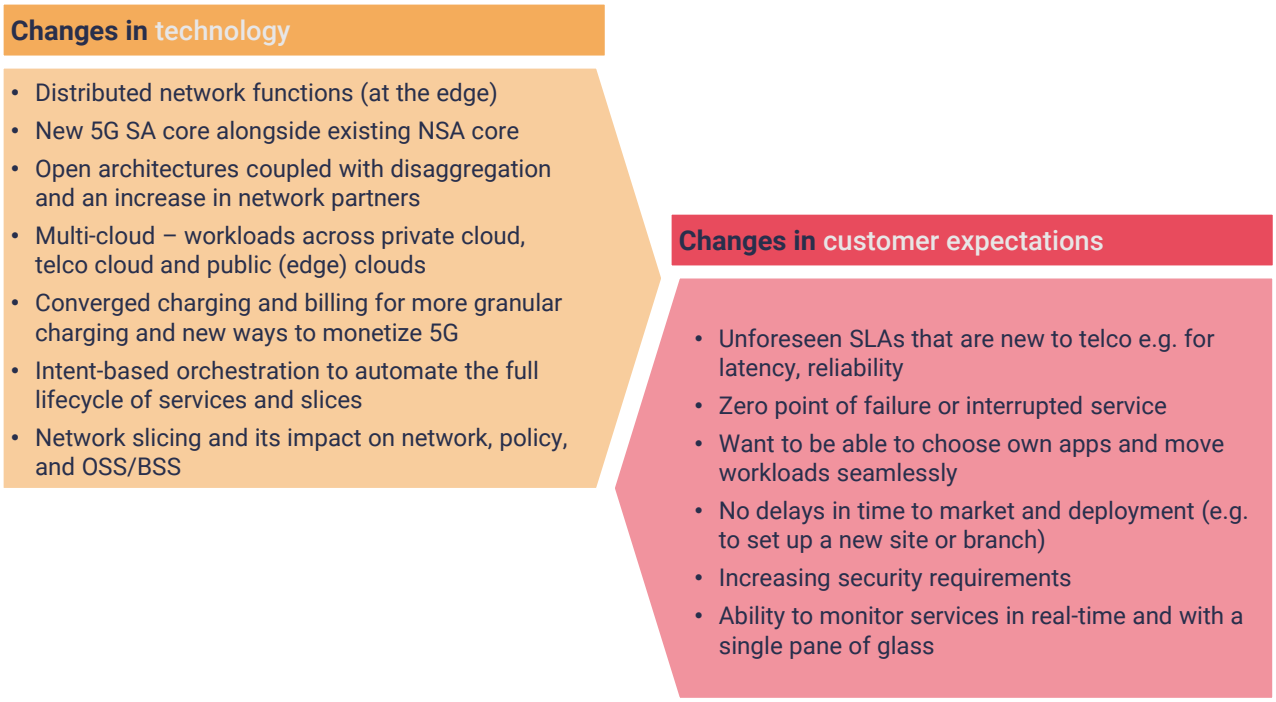
Many initial deployments of private network solutions are taking this approach and there are even custom slice-type wide area networks being explored by sectors such as automotive (to enable autonomous driving). However, most telecoms operators find this model unscalable in the long term, as margins can be lower and it is more suited to a systems integrator.

Mixed deployment models require a change in technology

Enterprise customers who invest in private networks and network slicing are investing in these technologies to achieve certain connectivity outcomes that enable specific use cases for them. Beyond merely being able to offer dynamic slicing, there are important challenges that operators face in ensuring that enterprise customers have a near seamless experience when using connectivity and compute to improve business processes.

The complexity is driven both by new technology and new customer expectations (see Figure 14Error! Reference source not found.).

Figure 14: Technology and customer expectations are changing in the world of slicing and private networks



Source: STL Partners

Automated orchestration and operations are essential to mitigating future complexities

The applications and use cases that drive enterprises toward 5G private networks and network slicing are often mission critical, meaning failure is not an option. Operators must be able to not only monitor their service but pre-empt and solve any foreseen problems that could interrupt their customers' workloads. In addition, as services and slices become more dynamic, with deployments across public, edge and private clouds, including diverse resources and applications, manual operations become

unfeasible. Automation of these processes is thus vital for keeping to the required QoS for enterprise customers and for achieving scale as operators work across additional enterprise customers, ecosystems, and verticals. For example, an edge compute platform may host a 5G core, security applications, MEC applications and SD-WAN transport. These resources will be mapped into an enterprise service that may also use a public network slice. Operators need to be able to provision the service with zero touch – from the cloud platform to the application and slice - and maintain the service and associated QoS in a fully automated way.

To resolve these technical challenges, operators need a new operational environment with orchestration and modern OSS capabilities that allow them to automate how services are designed, deployed, updated, optimised and assured across the network and across customer sites. Service orchestration is a critical component and would enable complete visibility across the operator's offerings, providing assurance that they can meet all network performance requirements and SLAs with a single pane of glass. Service orchestration would also ensure that private networks, slices, and edge infrastructure work seamlessly and securely together. As explored, where enterprises have both private networks and public network slices as 5G connectivity options, operators will pursue new commercial models. Behind each of these models, that make the most of usage-based charging and on-demand services, would be an orchestration platform or capability that captures usage at the enterprise site and automates backend processes such as billing, onboarding applications, undertaking lifecycle management, and managing workloads across the network to ensure hardware resource requirements are met.

> "What we need from orchestration is to be able to mix capabilities and functions, e.g. access and security. We want it fully automated. This is a capability a lot of telcos are building and expanding - to get to the full solution maturity will take time.
>
> ***British Telecom***

Conclusion and recommendations

5G connectivity has already made an impact for enterprises and operators alike as private 5G networks have been deployed across the world. While the advent of dynamic network slicing would not make private networks obsolete, it would shape and augment the 5G ecosystem towards a world of mixed deployments, enabling new use cases and accelerating enterprise transformation.

In order for telecoms operators to maintain a key role in this new ecosystem and ensure 5G delivers on its benefits, there are these four key lessons to take away from this report:

1. **There are going to be multiple ways to deliver mobile networks**, from using the public 5G network, to slicing and private networks. It is the role of the telecoms operator to understand each one of these, remove complexities around the technology and decision-making process for enterprises so they focus on their core business.

2. **We will start to see mixed deployments in production environments from 2023 onwards**, although these will be niche to start with and will be driven by a need for nomadic use cases, resilience or temporary networks.
3. **Telecoms operators should explore new business models that adopt cloud principles and conform to enterprise demands** with regards to flexibility, simplicity, and a move away from capex-heavy models and towards offerings that go beyond connectivity. Failing to do this will slow down market adoption.
4. **Enterprise networking will become more complex but orchestration solutions can reduce this** today and in the future. By making sure automation is inherent from the start, whether it be in managing network functions, customer deployments or monitoring, operational costs for the telecoms operator will be minimised.

STL Partners will continue supporting telecoms operators and other ecosystem players to accelerate enterprise adoption of private networks, slicing and edge computing. To learn more, read the following reports on similar topics:

- Telco Cloud Deployment Tracker: 5G core deep dive
- Telco edge platforms: Balancing speed vs value
- Private Networks: Lessons so far and what next

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