Private cellular networks: opportunities, challenges and the future

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Introduction

The advantages of private cellular networks are well rehearsed – from data usage savings and enhanced traffic flow, to better control and information security. However, if these private networks are to make a significant impact on delivering LTE and 5G value to verticals, new routes to market and business models are essential. In this paper we outline the drivers, barriers, technologies and players in this rapidly evolving market.

Market context and outlook for enterprise and private cellular networks

Most enterprises and industries have aspirations to use cellular connectivity to make processes more digital and efficient, but too few can access networks that are fully reliable, let alone optimised for particular requirements such as low latency. Fewer than half of enterprises say that mobile quality of service is adequate, especially inside buildings, and only about 20% would trust cellular networks with critical communications.

A survey of 120 enterprises showed that, on average, the ability of current cellular networks to deliver the most valued connectivity services was rated between 1.2 and 5.4 on a scale of 1 to 10.

This situation has led to Wi-Fi being the technology of choice for enterprise, indoor and private networks, but a rising number of use cases could benefit from using cellular connectivity too – particularly any requiring security, broad coverage, low latency, high mobility and guaranteed quality of service. Those range from the familiar, such as high-quality voice, to the futuristic, such as dynamic mobile robotics.

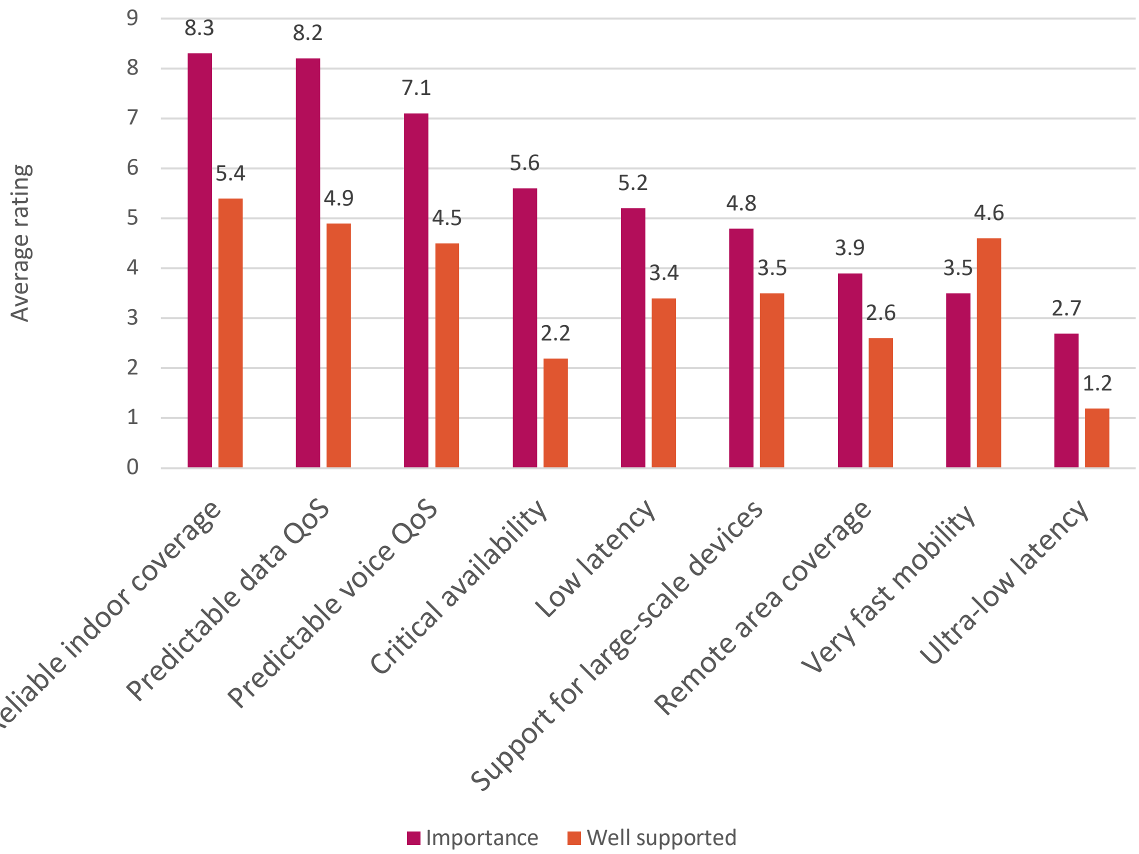

Figure 1

The most important cellular capabilities for the business, and the satisfaction with how they are supported by current cellular networks (Survey of 120 enterprises, average ratings out of 10)

The need is for networks that can support an enterprise's particular range of use cases, and connectivity that exactly matches a company's requirements. These demands are driving deployment of cellular networks by private network operators of various kinds. These operators understand individual vertical markets, and work closely with IT departments to ensure cellular is integrated with other technologies such as edge computing to support an enterprise's digital requirements.

The trend will see large numbers of mobile base stations deployed by enterprise operators. Between 2019 and 2026, the compound annual growth rate of new radio units deployed by MNOs will fall slightly, while those deployed by non-MNOs for enterprise use will rise by 13% (note, the non-MNO category does include dedicated private network business units set up by telcos and MNOs).

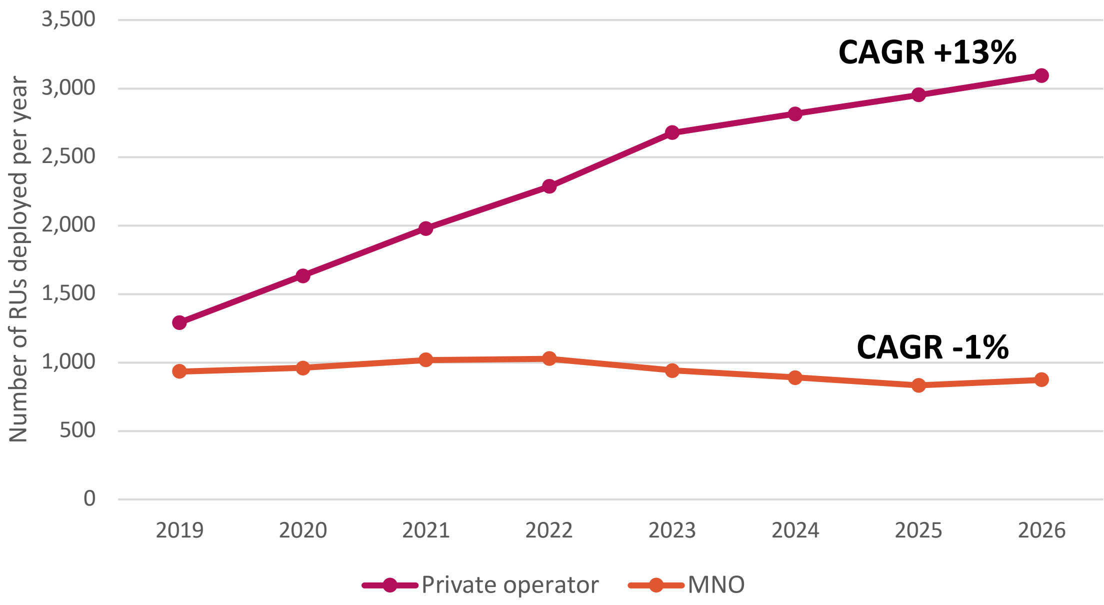

Figure 2

Annual new deployments of cellular radio units by MNOs and non-MNOs, with CAGR 2019-2026

The dilemma for conventional MNOs is that, while they may have an eye on the rising spend on cellular connectivity by enterprises, the diverse requirements of this market do not align well with their established business models. Their economics have depended on building very high capacity, very wide area data and signalling pipes, which can support huge numbers of users in a fairly generic way. Enterprises require more localised capabilities, with coverage reaching every corner, indoors and outdoors, and with the guaranteed QoS, latency and reliability they would expect from their own wireline networks.

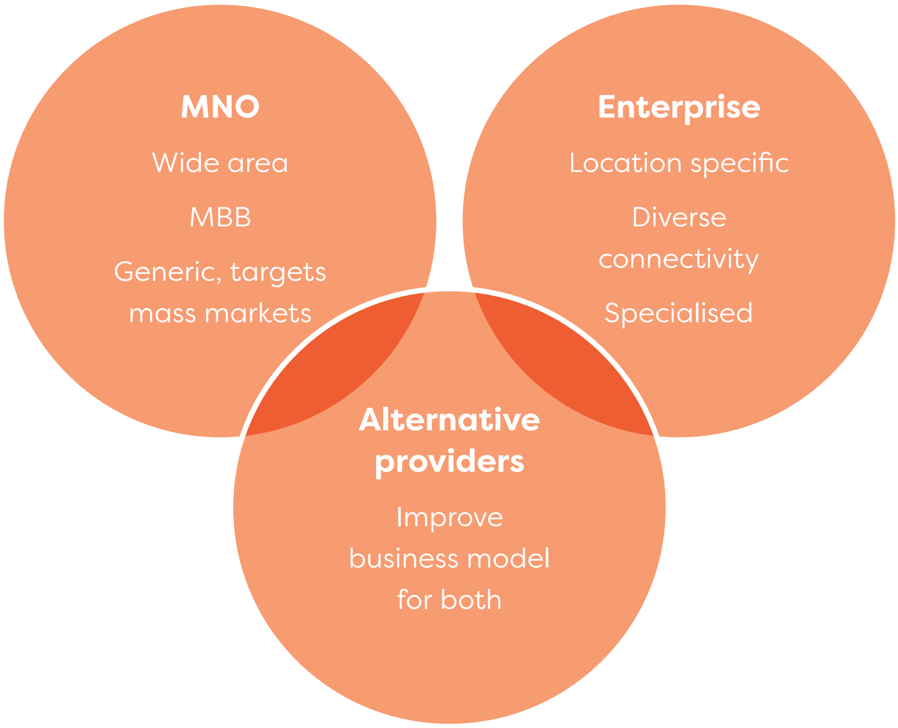

Figure 4
The rise of private cellular networks provides opportunities for new service providers

Some MNOs will adapt to the new requirements, either by setting up private network divisions, or dividing their 5G pipes into virtual slices tailored to particular industries. But our calculations make it clear that these MNO activities will not address even half of the level of enterprise and industrial demand. In particular, this will impact two categories of users:

- Organisations with very demanding connectivity requirements, such as automated factory or warehouse complexes which want to move to a more mobile, dynamic environment using 5G.
- Enterprises outside the top 100 – medium-sized organisations present a fragmented market. Each company has specific requirements, so the MNO's usual economies of scale are lost.

Private network operators will increasingly fill these gaps. Their business models will be formed to profit from a large number of relatively small build-outs, each one with specialised connectivity requirements. Their added value, and profit margin, will come from their knowledge of the particular vertical market and its commercial needs, and their ability to integrate cellular systems with IT, WiFi, cloud and other enterprise assets. Both these are capabilities which many MNOs have not needed to develop to a high degree.

There will be many types of organisation which offer deployment, integration, optimisation and management of private cellular networks. Many will be focused heavily on localised small cell networks, increasingly combined with edge computing and virtualised packet cores and RAN controllers. We have split our forecasts into five main categories, though there are variations within each one according to geography and vertical market. They are:

- **Private network operators** – these procure, deploy and often manage networks specifically for one enterprise. They may be dedicated PNOs, or private network business units within other organisations such as systems integrators, cable operators, WiFi providers and so on.

- **MNOs** – MNOs and telcos are increasingly setting up dedicated divisions to deploy private networks, leveraging their existing radio expertise and spectrum. These are only included in the forecast if they are separate business units and are deploying networks for enterprise use that are distinct from the main public cellular network.

- **Neutral hosts** – these build infrastructure to support shared networks specifically for enterprises, cities, railways etc. Their networks often include edge computing and other assets too. They can be used by multiple service providers to the enterprise, which may include MNOs. They may be specialist start-ups, cable or fibre operators, or tower operators. This category also includes cloud service providers such as AWS, which could host the local virtualized RAN controller and core in their clouds, and extend these resources locally via the small cells and edge nodes.

- **Heavy MVNOs** – these build out their own networks, often alongside localised packet cores and edge nodes, for specific enterprises, but provide national roaming and coverage via an MVNO agreement. Enterprise WiFi integrators, cable operators and some PNOs are extending their business in this way.

- **Enterprise IT departments** – especially in very large organisations, such as utilities and transport operators, which might also have some of their own spectrum.

Figure 5 shows how the balance of deployments of enterprise networks will shift, between 2019 and 2026, from MNOs to alternative operators. In the early years, the main work will be done by MNOs rolling out in-building solutions, in their own spectrum, as extensions to their macro networks. However, for the reasons outlined above, that will not be enough to satisfy the rising demand for enterprise cellular networks and increasingly, the other types of provider will step into the gap.

Service provider	Potential advantages	Challenges
Self build (Enterprise IT)	Greater control	Significant investment in spectrum, technology and skilled operatives
System integrator/ IT consultancy	Strong IT integration Established B2B relationships	Less cellular experience
Neutral host	Indoor cellular experience Upgrade to multi-operator support MNO trusted partner	Less focused on the bespoke network
Mobile operator (special division)	Extensive spectrum and cellular experience Hybrid private/public with national coverage	Legacy MNO culture is B2C and has struggled with B2B
System vendor (enterprise direct)	Tightly integrated technology solutions	Single vendor solution limited mix and match for best in class technology/lock in

Table 1
Pros and cons of different service provider options

Cumulatively over the period, PNOs will deploy or upgrade the largest number of enterprise cells, closely followed by the MNOs. But in 2026, the MNOs' share of the total deployments will have fallen to below 25%.

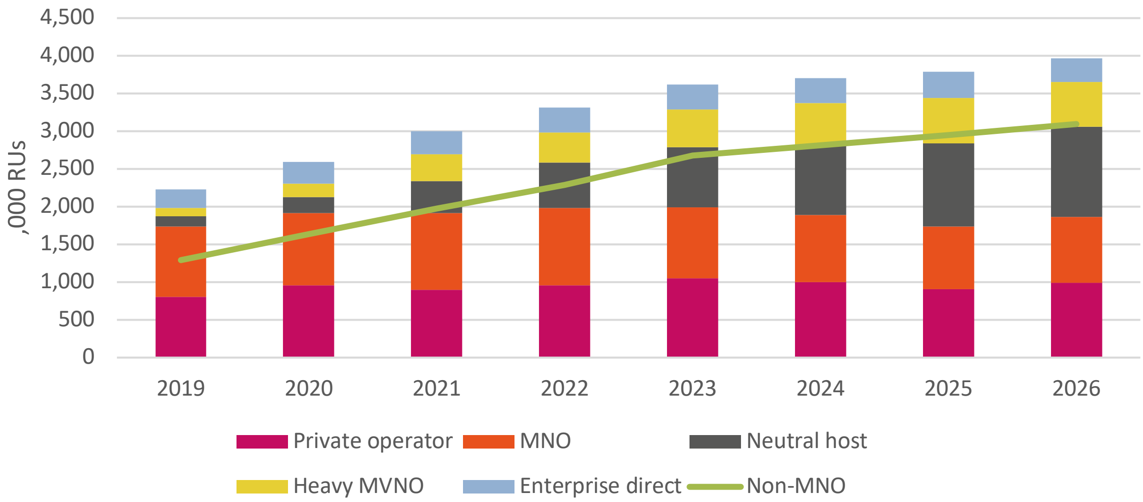

Figure 5

Deployments and upgrades of enterprise cellular networks by operator type 2019-2026

One of the most important enablers of private cellular networks is access to new sources of spectrum. The two key developments are cellular in shared spectrum; and 5G in millimeter wave bands (typically 26 GHz to 60 GHz).

Until 4G was standardised to run in unlicensed or shared spectrum, the only option for a non-MNO was to pay to use a mobile operator's airwaves, or for an enterprise or industry to acquire its own private spectrum. The latter was largely confined to vertical sectors with nationwide scope and very critical requirements, such as the energy utilities, emergency response agencies or railways, in many countries.

In recent years, 3GPP has standardised LTE specifications for unlicensed spectrum and the most recent release of 5G standards, Release 16, does the same for the 5G New Radio. Importantly, Release 16 includes a mode in which the unlicensed 5G network does not need an anchor network in licensed bands, and so it can be deployed without any involvement by the MNO if that is the most attractive approach.

Early activities in unlicensed 4G were mainly focused on the 5 GHz bands where WiFi is established. Of more interest to many enterprises is the emergence of new shared bands, which support different characteristics to those of WiFi. In particular, some regulators are supporting schemes, epitomised by the USA's CBRS general authorised access (GAA) tier. In such plans, networks can use spectrum without a licence, which reduces the cost of deployment and enables new providers, but there are stringent rules to avoid interference and congestion, enforced by an automated spectrum access system (SAS). This means that many of the enterprise requirements for high availability and quality of service can be met even in shared spectrum, though private or MNO bands will remain preferable for mission-critical or ultra-low latency requirements.

Availability of new shared spectrum will be a significant driver of build-out by non-MNOs – in the USA, we forecast that CBRS will drive deployments by alternative providers from 12% to 58% by 2024.

Regulators are increasingly considering schemes for millimeter wave spectrum, which will open up some of the huge capacity in those high frequency bands for enterprise networks, without significant licensing requirements. The UK, for example, will offer some very localised, affordable licences in mmWave, geared to supporting campus and industrial networks which are very geographically specific. Such policies will drive deployment in vertical markets which need high capacity in specific locations such as campuses, and they will encourage further diversification of the service providers.

Figures 6 and 7 show how the availability of mmWave will drive increased deployment in certain verticals. When all enterprise cellular networks are considered, the biggest cumulative adopters in 2019-2026 will be in retail/warehousing, government, transport and local government/smart cities. But in the millimeter wave bands, while government departments (including public safety) remain major deployers, many surveyed believe there will also be significant increase in roll-out by heavy industries such as manufacturing and utilities. These require high capacity and reliability in their campuses and in key locations such as factories and power plants, and mmWave promises affordable access to very large amounts of spectrum, and also to strong QoS, since the plentiful amount of bandwidth should mitigate against congestion. However, it's worth noting that trials in which we've been involved suggest that mmWave in the context of the metal infrastructure often used in manufacturing facilities can be challenging. Scattering degrades the radio performance and lower spectrum might be more appropriate for such use cases.

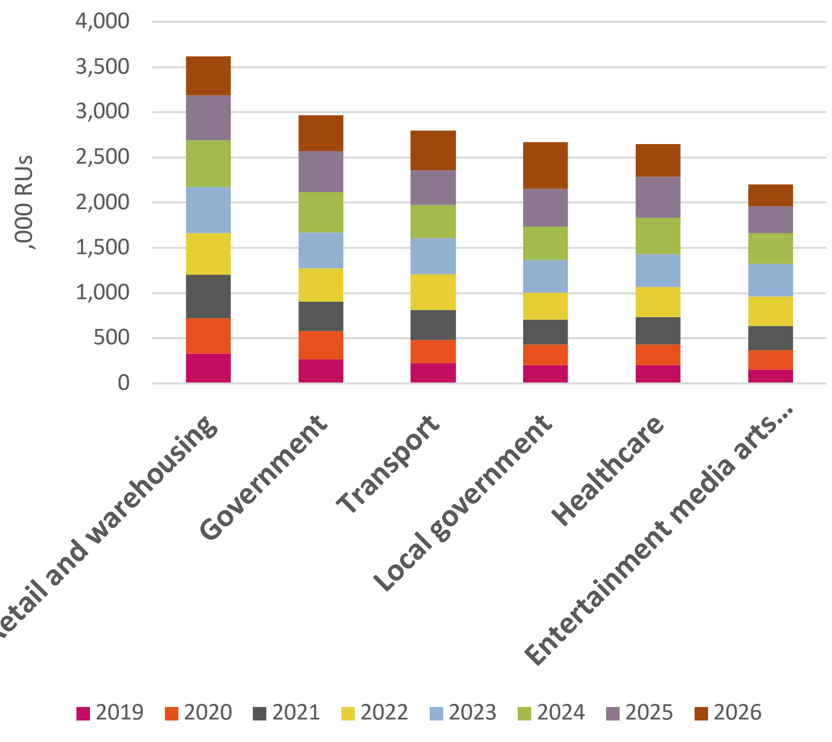

Figure 6

Deployment of enterprise cellular networks by the top 6 vertical markets 2019-2026, all networks

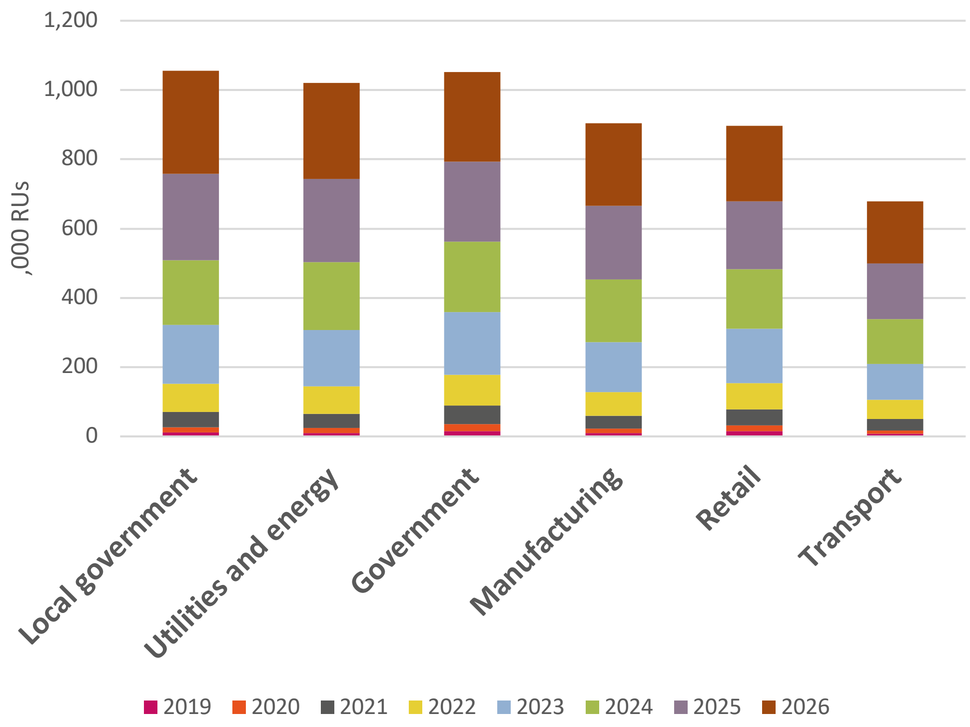

Figure 7

Deployment of enterprise cellular networks by the top 6 vertical markets 2019-2026, mmWave spectrum only

Private network deployments

In the context of maximising the LTE opportunity and taking 5G beyond the opportunities associated with eMBB, it's becoming clear that the growing complexity of the wireless ecosystem is throwing up new challenges to delivering the right services to meet a diversity of enterprise demand.

The engineers' answer to this is typically 'more technology'. For example, today techniques like network slicing are often presented as a practical solution to demanding or mission critical enterprise requirements even though, as we shall see, we believe commercial implementations are still three to five years away.

At Real Wireless, we recognise the potential of private networks for a range of verticals. However, the technology push can seem overwhelming and there are already signs that the wireless industry is organising around proprietary technologies and well-worn partnerships, rather than seizing this opportunity to finally get close to hard-to-reach sectors, really understand their requirements and deliver the right technology and service at a sustainable price point.

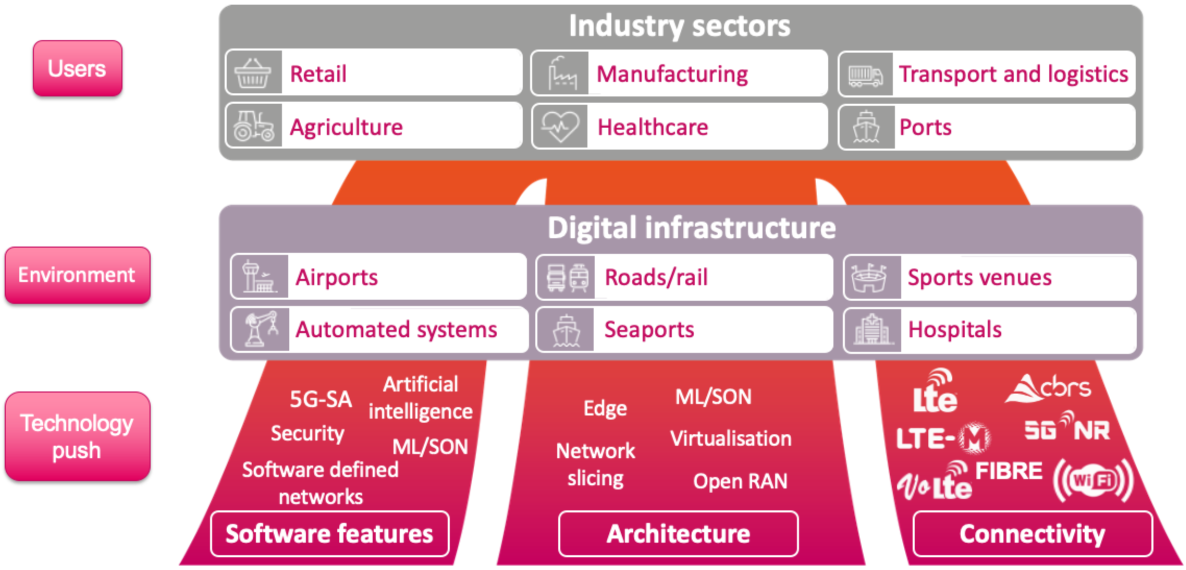

Figure 8

The technology push can seem overwhelming to enterprises, even though some 'solutions' are many years away from commercial reality

Understanding the client's needs, dimensioning a network that supports the required applications now and in future, selecting the best vendor and picking an appropriate procurement or delivery model is critical, and that's where Real Wireless' expertise comes in. This applies to all kinds of use cases and environments, from rural blackspot coverage to industrial, retail, transport, smart city and major venue applications.

casestudy Private networks for stadiums

Since 2006, Real Wireless has been engaged by major international venues – including Wembley Stadium – to advise on the technologies and design required to deliver the appropriate bespoke connectivity to such sites. This gives us in-depth understanding of the operational connectivity requirements for such venues, as well as the design and deployment strategies necessary to future proof against escalating and extremely variable visitor demand.

In 2013, Real Wireless was engaged by Tottenham Hotspur Football Club to help develop its strategy for wireless communications in the new stadium. The brief was to ensure that the stadium design included provision for all the wireless services necessary to deliver the best-connected experience for fans and operational staff in and around the stadium.

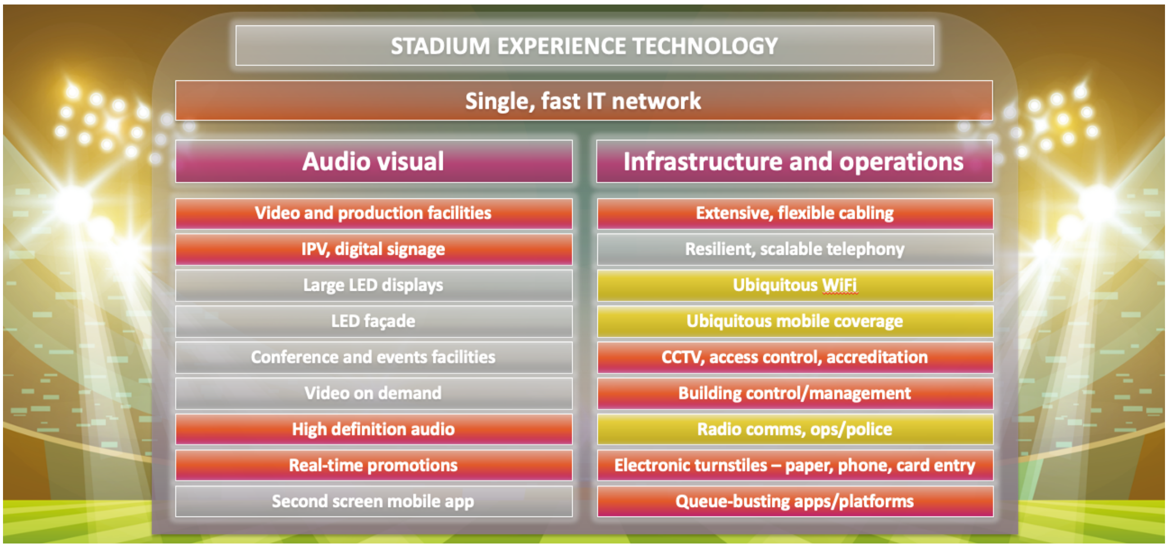

Figure 9

Stadium requirements that could be supported by private cellular networks

That meant all wireless technologies. Not just 2G, 3G and 4G mobile (and the ability to support 5G when it arrives), but PMR for support services, TETRA for emergency services and Wi-Fi – technically architected, supplied and deployed by the Club's official enterprise networking partner, Hewlett Packard Enterprise (HPE). In addition, there needed to be support for technologies such as satellite that may be required for broadcast and event use.

Multi-operator and multi-technology capability were not the only considerations. Sufficient space, power and air conditioning needed to be made available in the building design to accommodate the mobile operators' equipment and the various elements of equipment required for a distributed antenna system (DAS). In addition, as part of the stadium IT infrastructure build, containment and fibre for the mobile system needs were incorporated in the design package from the very beginning. This was seen as essential to guarantee an efficient mobile deployment.

The design of the new stadium incorporates key features with a fully-integrated technology infrastructure supported by an ecosystem of partners that have invested with the Club to build out the technologies created.

The seating bowl design for 62,062 fans gives an indication of how much careful planning has gone into this process. Mobile services to the bowl are provided by antenna located in discreet positions within the roof structure. Crowd movement and building layout are key factors in the sectorisation of the design. Similarly, the stadium will host a range of non-sporting events, including concerts, where pitch coverage is required.

Data capability is widely available where it is most needed. A high data rate service is available for the bowl, concourse, podiums, media areas, hospitality areas, conferencing suites and offices, as well as key operational areas such as event control and back of house. A medium data rate service covers the basement and parking areas, while a low data rate service is available for the stairwells and plant rooms.

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casestudy Providing high-quality private outdoor connectivity

Topping the list of private network benefits is the ability to customise your network to meet existing demand, while future-proofing to make the most of future opportunities. For example, a private 5G network, if procured correctly, will be able to support a public networking logical function, or you can overlay a public network, as long as you build the private network with the right architectural 'hooks' in it, from day one. In this way enterprise customers can enable a new business opportunity over time.

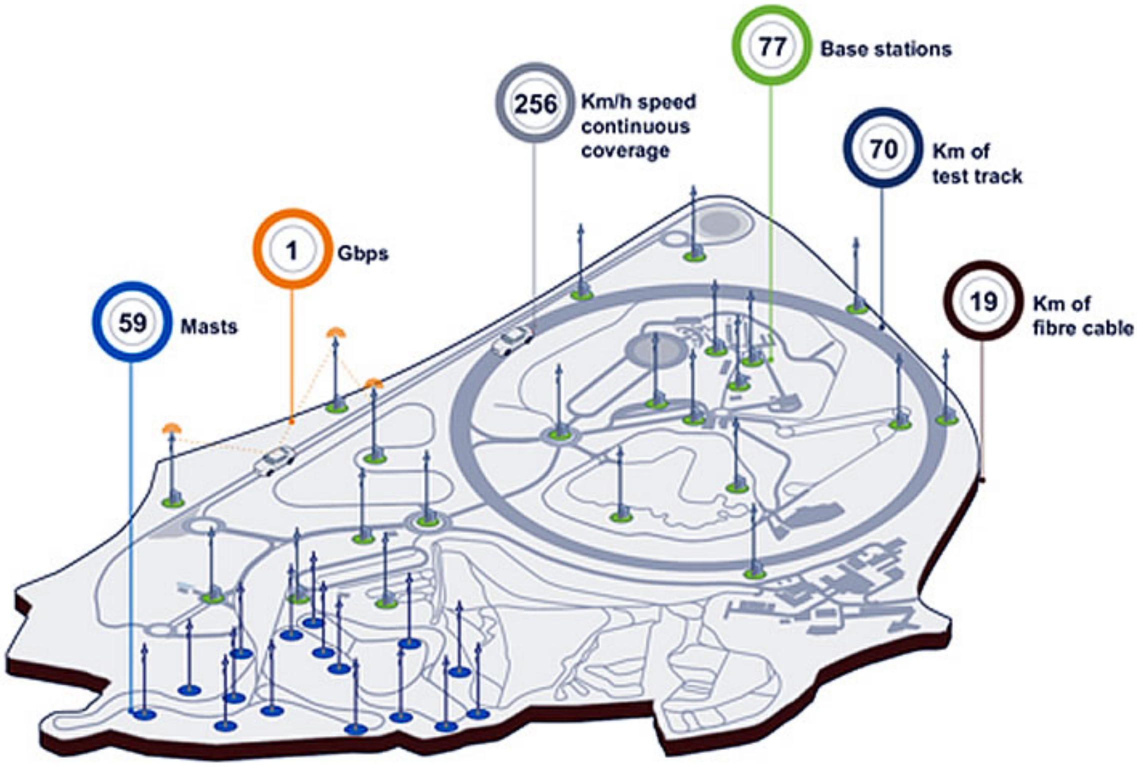

Figure 10

Millbrook 5G testbed designed to validate the connected and autonomous vehicles (CAVs) use case

This is the sort of network progression we have helped to evaluate within the AutoAir consortium: building a small cell network, providing good local private connectivity and then building a neutral host model on top of that, enabling to, for example, overlay a mobile operator or provide private connectivity.

We used our radio network dimensioning toolset to deliver radio planned site location recommendations for the Millbrook Proving Ground in Bedfordshire to assess the impact of real world 5G in the context of transport routes. Millbrook's newly built testbed has been designed specifically for connected and autonomous vehicle (CAV) development to ensure constant connectivity regardless of speed of travel.

The demonstrations used both the sub-6 GHz networks (2.3 and 3.7 GHz) and the 60 GHz mmWave network for Gigabit access to fast-moving vehicles. A small cell network was successfully employed to stream video from eight 4K video cameras mounted on moving vehicles to a moving coach.

The AutoAir project enabled developers to test CAVs in a secure environment using a private, tuneable mobile network

casestudy 5G network slicing trial in Hamburg

The focus of EU-funded seaport-based 5G-MoNArch project was to determine the extent to which 5G can deliver a flexible, adaptable, and programmable architecture.

Real Wireless dimensioned a private cellular network for some areas of the Port of Hamburg – focused on private and industrial/commercial consumers – but also considered the public access requirement to the same physical network. Other requirements were very much focused on IoT and automation, a private network operating in the heart of the port itself. We also dimensioned two virtual networks that were built upon the same physical infrastructure within that campus network environment.

Like our work for the AutoAir project, the environment in which we were operating was testbed rather than commercial deployment, but indicates the applications that might be associated with 5G private networks when the technologies mature three to five years down the line.

In the first of the MoNArch trials sensors were installed on three ships. These enabled the real-time monitoring and analysis of motion and environmental data from large parts of the port area.

The second example used network slicing to enable the port authority's operational management centre to control traffic flows via a traffic light connected to a private mobile network. This should help, for example, to guide trucks faster and safer through the port area.

The final example used slicing to create a private network to test high bandwidth availability to enable 3D information to be transmitted to an augmented reality application. This would enable maintenance teams on site – for example on a construction site – to call up additional information such as building data or receive remote interactive support from an expert.

Conclusion

If you run a business, which wireless system fits your operational needs? And when is the right time to invest in a private network? The risks are obvious: choose too soon and you may be locked into something that isn't right for you. Choose too late and you may find yourself playing catch-up with competitors in your sector.

Nevertheless, the opportunities they offer to enhance operational efficiency and increase engagement of staff, visitors and customers make private mobile networks hard to ignore. The challenge is making the right buying decision based on a clear understanding of your needs and the options available.

At the same time there are many different supply side players offering many different messages. This makes it harder to understand the choices regarding architectures, deployment, operations and maintenance – to name only a few.

We believe that without clarity across the industry, growth will be slow. And yet we also know that any private network offering has to be tuned to a variety of business cycles affecting a variety of industry sectors; one size will not fit all. It's not an easy balance to achieve.

We nevertheless believe that private mobile networks can and will be hugely valuable for both the wireless industry and for many key vertical sectors. This ecosystem will keep evolving – and new and exciting opportunities will arise as it does.

Private networks are here to stay. And through our deep understanding of the technologies employed and work at the cutting edge of their assessment and trial; through our long-term relationships with wireless users across a broad range of sectors, Real Wireless is uniquely placed to support the evolution of private networks into the mainstream.

Real Wireless is the world's leading independent wireless advisory firm. Its network of experts includes engineers, physicists, economists, security advisors, business strategists and deployment specialists. Real Wireless clients benefit from a comprehensive portfolio of specialists and custom tools that analyse radio network performance, techno-economic impact and the business model implications of wireless systems. With this unmatched resource Real Wireless is able to advise wireless users in any sector, as well as governments, mobile operators, regulators and technology companies.

Real Wireless has applied this unique range of technical and strategic expertise to some of the UK's biggest wireless infrastructure projects – from major stadium connectivity to shopping malls to transport systems.

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