Dense Air and the case for 'Neutral Host Networks' in the UK

Response to the Department of Digital, Culture, Media and Sport

Prepared by Dense Air Group

Paul Senior; CEO

Reference: Dense Air UK/DCMS/001

31 May 2018

(Confidential)

CONTENT PAGE

INTRODUCTION TO DENSE AIR

Dense Air is a new kind of wireless operator (www.denseair.net), focused on the delivery of wholesale services as a 'Carrier of Carriers'. Dense Air specialises in wireless-based solutions for both '**network densification'** and '**network extension**' by providing 'Small Cells as a Service'. Dense Air supports various technologies but is focused on solutions and services using 4G LTE networks and later on 5G NR (New Radio). For Mobile Network Operators (MNOs), Dense Air provides small cell based services to cost effectively infill coverage holes and capacity weak spots in their mobile networks. The solution offered improves the 'spectral efficiency' of existing macro cells and simultaneously provides better speed and quality of service to end users.

Dense Air also provides services to fixed and mobile operators who need to extend the footprint of either fibre or radio based networks. Dense Air provides solutions that can connect to end users with broadband in places where fixed or mobile infrastructure is uneconomic.

Our 'Small Cells as a Service' is suitable for urban, suburban or rural areas. Dense Air also supports private LTE and IoT networks for large enterprises and Government. In future, Dense Air will offer 5G solutions where the economics of nationwide 5G rollout prevent MNOs building a complete network themselves.

DENSE AIR
Mobile Networks Enhanced and Extended

Mobile Network Densification

Wireless Fibre Extension

5G as a Service

Today Dense Air operates in four countries, with its headquarters in the UK. Today Dense Air holds spectrum and has operations in Ireland, Belgium and Portugal. Dense Air is funded to obtain spectrum in other European countries and in the Americas, Asia, Africa and Middle East.

PURPOSE OF THIS WHITE PAPER

The purpose of this white paper is to explain the benefits associated with the deployment of a wholesale mobile network based on small cells that operate on a '**neutral host**' basis. Neutral Host operation allows any of the UK's MNO's and potentially also full MVNO's to access 'Small cells as a Service' (SCaaS) in locations where the macro cell or micro cell coverage is poor and/or locations where DAS or femto cells are not deployed because of issues with the economics and/or problems with the performance this infrastructure supports.

We will argue that there is a compelling case for spectrum policy to explicitly recognise the benefits of wholesale neutral host operators and why they deserve spectrum allocations that allow these types of businesses to thrive.

OUR BUSINESS PROPOSITION AND SOLUTION

In summary, Dense Air's business proposition is as follows:

- '**Network Densification** or **Network Extension**' as a service using small cells.
- Designed for 4G LTE networks and later for 5G NR.
- Filling-in coverage holes and capacity weak spots in mobile networks.
- Improving the '**spectral efficiency**' of existing macro cells.
- Objective: global wholesale provider for mobile and fixed network operators.
- We DO NOT compete with '**retail'** service providers.
- Solutions based strictly on operating small cells in licensed spectrum.
- Our services are suitable for urban, suburban and rural areas.
- We also support Private LTE and IoT Networks for large enterprises and Government.

The Dense Air small cell service is enabled using three distinct solution building blocks which come from our operational partner; SoftBank and our technology partner; Airspan Networks.

Small Cells operating in <u>licensed</u> spectrum:

- Small cells from Airspan Networks enable Dense Air to deliver indoor and outdoor coverage and capacity enhancement and economic network extension.
- These small cells are uniquely designed to allow shared 'neutral' wholesale operation.

Scalable cloud computing:

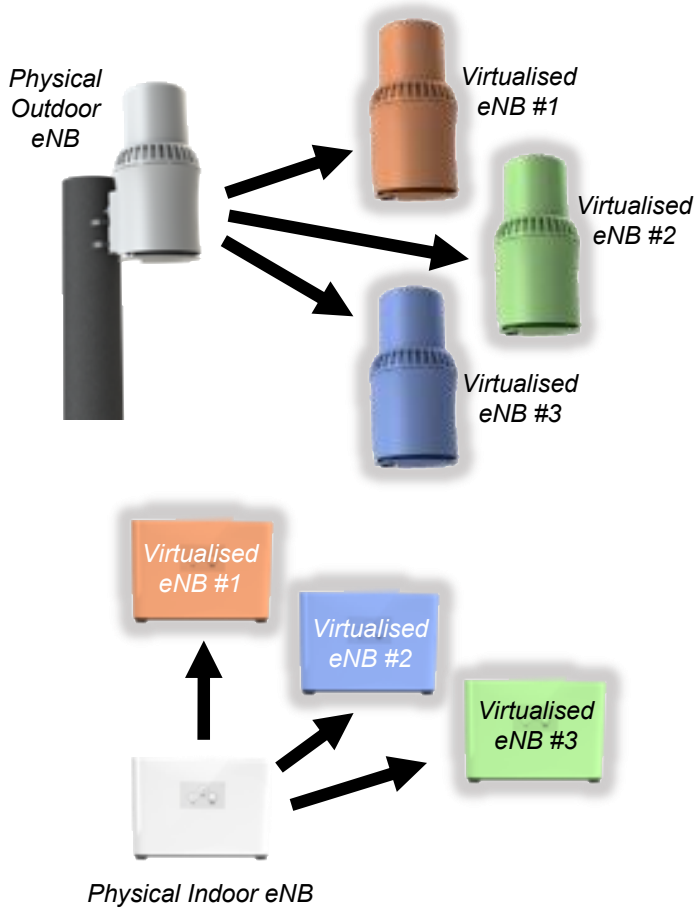
- Shared small cell infrastructure is provisioned, controlled and scaled using a cloud-centric 'Virtual RAN' COTS platform.
- The cloud solution enables support of many mobile or fixed operators from single physical cell.
- The platform allows Dense Air to scale its service to hundreds of millions of users and millions of small cells.

Big Data Analytics and AI

- Deployment of small cells into a network only works when they are placed in the right locations and at the right density. Dense Air has the ability to 'see' where LTE networks are performing poorly and has developed artificial intelligence that predicts how network performance can be improved in real-time. This is driven by the 'big data' collection of billions of anonymous logs from end user devices returning analytics on today's 4G networks.
- The targeted deployment of the small cell service into MNO weak spots dramatically increases the efficiency of the macro cell network which it supports.
- The delivery of small cells is supported by Dense Air partner portals and operations systems, known as DenseWare.

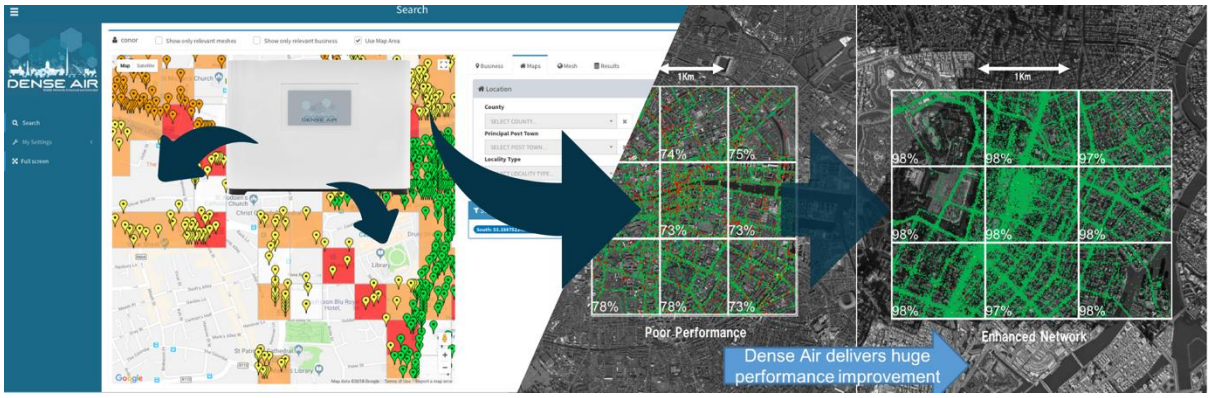
Dense Air 'virtualizes' its small cells and each physical eNodeB supports multiple 'virtual' instances. This allows a single set of active electronics to enable neutral host network sharing. Each virtual instance of an eNodeB is fully encapsulated and has separate address space, management and control interfaces. This ensures that there is no sharing of any data between virtual instances and individual Dense Air customer's data is secure and protected; it's not even accessible by Dense Air itself.

Each virtual eNodeB has its own PLMN ID and radio configurations and Dense Air implements advanced QoS/SLA solutions to ensure that each virtual small cell delivers the target capacity.



Virtualised Small Cells as a Service

The intelligent deployment of neutral host small cells is based on DenseWare. DenseWare is a toolkit of technologies that allows pinpoint deployment of small cells into locations that solve coverage holes or capacity weak spots. DenseWare allows customers of the Dense Air service to see where macro cell coverage is poor or cell edge capacity is weak. DenseWare collects millions of anonymous network logs from smartphones to create real-time performance knowledge on 4G LTE networks. Big data analysis techniques and artificial intelligence engines (AI) crunch this data on a weekly basis to ensure the investment in small cell deployment instantly improves the end user performance and service quality.



DenseWare bring AI to the deployment of Small Cells

Dense Air in the UK: Our planned investment (UK 2.3 and 3.4 GHz Auction)

Dense Air, via its spectrum acquisition vehicle, Airspan Spectrum Holdings, participated in the UK's 2.3 and 3.4 GHz Spectrum Award; conducted by OFCOM in Q1 2018.

Unfortunately, Dense Air failed to obtain any spectrum in the auction, as the price paid set a new industry benchmark for 2.3 GHz and 3.5 GHz TDD spectrum. Despite having a budget of $100m USD, the eventually price paid was $224m USD (£168m) for just 20 MHz of nationwide spectrum, which was the minimum amount of spectrum necessary to execute Dense Air's business model. This now means that Dense Air, despite being headquartered in the UK, cannot execute its business model in its home market.

In addition to the investment in spectrum, our business plan would have deployed over [redacted]. This mass deployment of 4G and later 5G small cells would have dramatically improved the service provided by the four UK Mobile Network Operators, without impacting the competitive framework or undermining their profitability or economic health.

Dense Air is a private venture, but its business model brings benefits to all existing mobile and fixed operators in a non-competitive fashion and it is a very sad day that this innovation, which was created in the UK, cannot at this point move forward.

UK MOBILE INDUSTRY AND SPECTRUM

The model of spectrum allocation and licensing has not changed significantly, in most major mobile markets, since the 2G era. Operator investment and major auctions have focused heavily on national exclusive licences to support a deployment pattern driven by macro, outside-in networks in sub-2 GHz spectrum bands.

This has addressed some, but by no means all the demands of mobile broadband connectivity. Significant challenges in the 4G era have included poor indoor coverage and networks which are optimized primarily for consumer mobile broadband requirements but are not ideal for more specialized industry uses. A good example, highlighted by a report for the National Infrastructure Commission, is poor connectivity along the UK's roads and railways to support passenger and vehicular services.

If 5G is to fulfil its many objectives and deliver the socio-economic results the UK has targeted, these gaps will need to be filled. In Rethink's opinion, the neutral host model will be critical to this. It will reduce the cost and time-to-deploy for connectivity that is optimised for industrial and IoT requirements and so will contribute to the social and economic objectives of the UK's Digital Strategy. It will improve the economics of addressing new use cases for existing MNOs and lower the barrier to new providers targeting specific industries.

This will require changes in spectrum policy to flourish; with the spectrum from 3.4 GHz to 4.2 GHz providing the most immediate opportunities. Dense Air is a new company which is acquiring spectrum to support neutral host small cell networks based on equipment from its parent; Airspan. It has spectrum in the 3.5 GHz band (Bands 42 and 43) in three European countries already. We want to set out the case for facilitating this neutral host model in the UK and the impact that the Dense Air model could have on the country's 5G future.

5G NEEDS TO BE DIFFERENT

The introduction of 5G has the potential to make a huge impact on UK society and economy because it is the most radical upgrade to the mobile network since 2G. Not in radio network technology terms, since in most respects 5G is building on 4G concepts, but in terms of how it will be deployed and the use cases it will support.

UK and international R&D programmes have focused on making 5G a wireless network that would not just enhance the conventional mobile operator business model by increasing the data rates of mobile broadband (MBB) connections. It would also be able to support a wide variety of network capabilities, from very low latency to very high reliability and very high security, in order to support the widely diverse connectivity requirements of different industries and use cases.

Many industries see 5G as an important enabler of digital transformation strategies – but only if the networks address their particular requirements; extreme security for healthcare management for instance. If that is achieved, they will be able to harness 5G for more than MBB and help to change the way they work and support their customers. This, in turn, would have profound effects on UK productivity and competitiveness and deliver significant social and economic benefits.

In a study by IHS Markit, sponsored by Qualcomm, it was calculated that 5G could enable $12.3 trillion in goods and services worldwide by 2035, when its full effects will be realised. Also, companies offering 5G products and services could generate $3.5 trillion in revenue and 22 million jobs. Whether or not the precise projections prove credible, it is notable that such bullish forecasts can only come true if 5G supports a wide variety of use cases and network behaviours, as Figure 1 below shows.

Many of these will rely on connectivity that is optimised for ultra-dense device populations (especially in the Internet of Things); very low latency response; or critical availability and security. Indeed, the IHS study considers massive IoT support to be the aspect of 5G that will generate the most value.

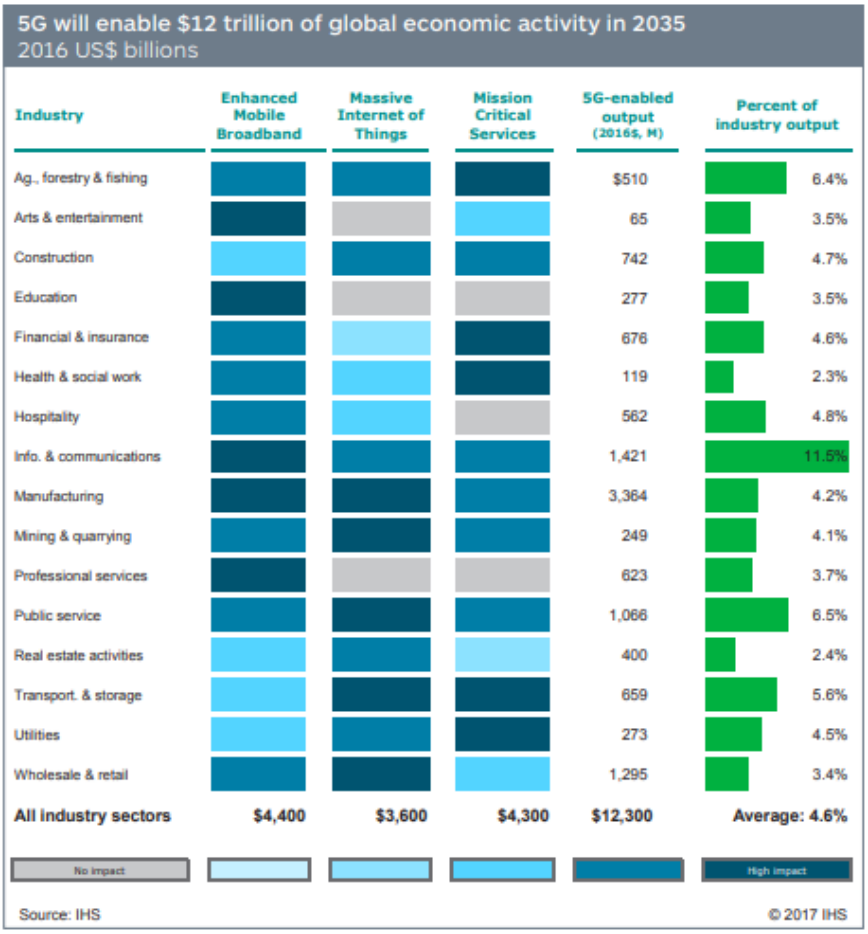


Figure 1. 5G-enabled global economic activity by 2035

This represents a significant change from 3G and 4G, which were entirely built around the MBB category. The kind of results this study envisages will only be enabled if the regulatory environment and operator business case, makes it feasible to invest in a new kind of network and platform.

The technology enablers of this new multi-functional, high capacity 5G platform are coming into place rapidly. Important enablers of the new services include:

- Higher spectrum bands will be used for 5G than previous mobile standards, from 3.5 GHz to millimetre wave bands like 26 GHz or 67 GHz. These offer high capacity though limited range and so are ideal for building dense networks of small cells which can enable new classes of service in selected areas (e.g. very fast video streaming to large numbers of users in a stadium).
- High levels of automation in planning and running the network, to reduce cost and improve quality of service.
- Virtualised and programmable networks in which many network functions are implemented in software on off-the-shelf boxes rather than on specialised hardware. This supports flexible allocation of network resources to different users or services and will eventually enable network slicing, allowing an industry, enterprise or MVNO (mobile virtual network operator) to have a virtual slice of capacity optimised for their requirements and charged on a pay-as-you-go basis.

These changes promise to make 5G very different from its predecessors and to enable specialised connectivity for many industries and communities. However, this will only become a reality if the MNOs can see a strong business model, because they control all the licensed spectrum. If they continue to prioritise their core MBB model and to build their networks to suit that alone, the potential of 5G in the UK could be wasted.

THE UK'S 5G PICTURE

UK government and private industry have been active participants in 5G R&D and policy making, both nationally and as part of international initiatives. Public and private organisations have supported activities such as the 5G Innovation Centre at the University of Surrey and full-scale tests of autonomous vehicles in partnership with Jaguar Land Rover near Warwick.

The IHS Markit study predicts that the UK will be the fifth largest investor in 5G R&D and capital spending in the world, between 2020 and 2035 (behind the USA, China, Japan and Germany), contributing over 3% of the global total.

The socio-economic goals for 5G were set out in the government's Digital and 5G Strategy, announced at the Spring Budget in 2017. These are to:

- Accelerate the deployment of 5G networks and ensure that the UK can take early advantage of the applications those networks can enable.
- Maximise the productivity and efficiency benefits to the UK from 5G.

- Create new opportunities for UK businesses at home and abroad and encourage inward investment[1].

This is clearly looking well beyond an extension of current commercial MBB models, towards investing in a network which is capable of supporting a far wider variety of behaviours and business models.

The MNOs' position

However, the early signs in the UK are that the MNOs and the regulator are in 'business as usual' mode. As far as the major operators have detailed their 5G plans, their first priorities are to enhance the core mobile broadband (MBB) model, with some interest in fixed wireless access (FWA).

Roll-out is likely to focus first on densifying heavily used locations, such as city centres, using 3.5 GHz spectrum, which was recently auctioned and retaining the 4G core (5G New Radio Non-Standalone). A second phase, after sub-1 GHz spectrum is auctioned and cleared for use (around 2020), would focus on a more wide area, macro level upgrade and a 5G core.

In relation to the three key enablers outlined in Section 2, the UK MNOs have not published timelines to implement mmWave spectrum, though Ofcom has identified 26 GHz as a 'pioneer' 5G band and BT has been involved in extensive tests and trials, as have the parent companies of O2 and Vodafone. These three groups also have major programmes to virtualise and automate their networks to improve current economics and support 5G (e.g. Vodafone's global Project Ocean), but have not made commercial announcements around network slicing.

BT Chief Executive Gavin Patterson told a shareholders' meeting in May that the company would launch 5G services by the end of 2019 and his CTO; Howard Watson said he was 'confident' that the first application would be enhanced MBB. Patterson has previously spoken of the difficulty of making a business case for new 5G services, especially in the Internet of Things (IoT), while Vodafone's CTO, Johan Wibergh, has said that 5G needs to be justified initially by its efficiencies in delivering MBB more cost-effectively.

These are all sensible approaches from established MNOs which have based their business model around MBB, largely to consumers. It has been difficult for national mobile operators round the world to make the economics work, to address a wide range of vertical markets, especially indoors. Such a change, on a large scale, would require:

- Specialised channels and teams with expertise in many very different industries.
- A new approach to sharing cost and revenues, often involving many stakeholders, such as enterprises, property owners and local authorities.

---

1 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/677598/Next_Generation_Mobile_Technologies__An_Update_to_the_5G_Strategy_for_the_UK_Final_Version_with_Citation.pdf

- The considerable cost of supporting challenging 5G attributes, such as very high reliability and very low latency, across a national network.
- The risk of taking on liability for mission critical or even life critical services.

Most MNOs are focusing on a few vertical sectors in which they believe they can secure a strong position in the value chain, such as connected cars. Some, like Vodafone, are investing in higher level cloud-based services such as device management. And there are examples of MNOs building specialised networks, such as EE's Emergency Services Network (ESN).

However, these limited activities leave many of the goals of the 5G programme unaddressed. For the UK telecoms industry as a whole, it will be tough to justify 5G investment without new revenue streams, as consumer ARPUs fall and the market saturates. But for now, national MNOs are focused on different ways to address their commercial challenges – increasing their bundling of services in quad play offerings; reducing costs drastically; investing in content and other non-connectivity assets; and consolidating to achieve economies of scale.

Therefore, if these are the only companies implementing 5G, it raises the risk that the UK will be slow to see new services materialise, even though they have been placed at the heart of the 5G Strategy by government and that will, in turn, hamper industries' attempts at digital transformation.

NEUTRAL HOST PLATFORMS DELIVER 5G GOALS

If new 5G services are not delivered by MNOs, there must be alternative ways to introduce them to UK businesses and consumers, without hurting the MNOs' core business. In particular, there is rising interest in neutral host platforms that support specialist service providers, which have greater expertise and routes to market, in emerging enterprise and machine-to-machine use cases.

These neutral host operators do not need to build national wide area networks; those will remain controlled by the MNOs. Their role is to deploy 'sub-nets' – localised or specialised networks, usually based on small cells, which can fill coverage or capability gaps in the MNO networks. This leads to extension and densification of the country's total connectivity footprint and the new resources are offered to MNOs or alternative service providers on a wholesale, 'as-a-service' basis.

Such neutral host operators do not eat into the MNOs' core business model because they are non-retail. Their platforms are open to the MNOs to use, if they wish to reduce their cost of addressing enterprise and vertical markets, especially those requiring dense local capacity. If the MNOs do not find these cases attractive, third party service providers are also able to harness the neutral host system to address specific customer bases with a different economic approach.

To some extent, such models are starting to emerge by harnessing shared spectrum, which enables specialist providers to establish networks that are optimised for particular industries without buying licences. Some smart city networks, like the WND/Arqiva city IoT system in the UK, based on Sigfox technology in unlicensed spectrum, are good examples.

Such projects introduce three important elements of the new telecoms landscape that will be essential to deliver 5G's full potential:

- The networks are neutral host, supporting third party service providers with specialist expertise, in a more flexible way than the traditional MVNO agreement.
- The base stations are rolled out where demand is identified, rather than on a national scale. This points to the creation of localised or vertical-specific deployments with the superior economics of targeted build-out.
- Cloud-based services to support back end systems and even the packet core, can reduce the capital and operating cost of a new network and support service providers on a 'pay-as-you-grow' basis. Nokia's Cloud Packet Core is an example.

NEUTRAL HOSTS NEED LICENSED SPECTRUM TOO

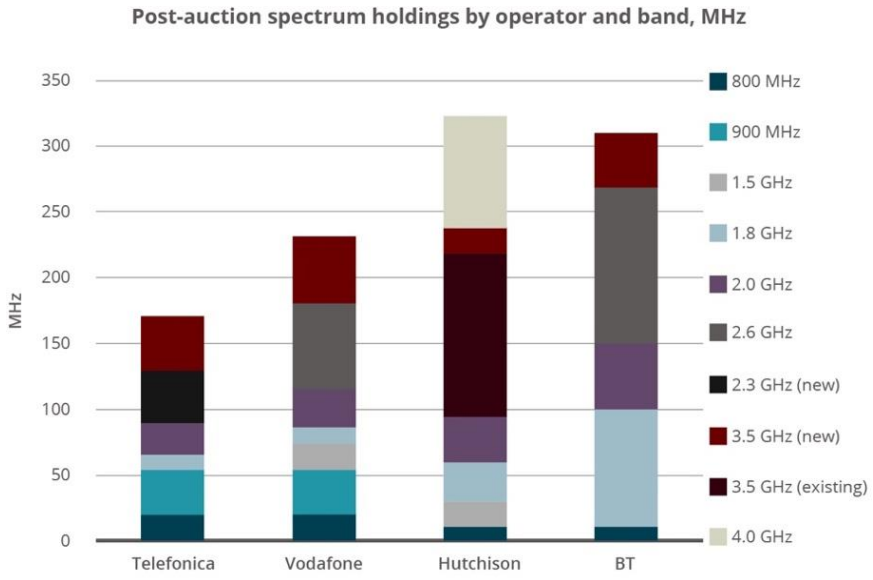
However, there is a significant downside to these early examples of non-MNO industrial networks; they are reliant on shared spectrum. There are two issues with this:

- In the UK, as in most countries, policy on dynamic spectrum is in its infancy. Unlicensed bands such as 5 GHz, which supports both Wi-Fi and LTE-LAA, carry risks of interference and unpredictable performance, which are unacceptable for critical applications. More controlled systems of shared spectrum are emerging. Examples include the TV white spaces in the UK and USA and the USA's new CBRS band in 3.5 GHz, which includes a shared access tier.
- For truly business or life critical applications and for those requiring very high speed or quality of service (such as railway connectivity), licensed spectrum remains essential to enable a single operator to have full control over how the network behaves and is optimised.

Some European regulators have recognized the need for licensed spectrum to be available to support new operators, which will harness neutral host models to accelerate availability of specialist 5G services for different industries. Dense Air, which is seeking to buy spectrum to build neutral host networks, has secured licences in the 3.5 GHz band in Ireland, Portugal and Belgium, for instance. The French regulator; ARCEP, is planning to earmark some spectrum in the band for rural use and for private enterprise providers.

But the UK's recently concluded auction of 3.4-3.6 GHz spectrum was a major disappointment in this respect. There were no special provisions for newcomers and although Dense Air was a bidder, the prices quickly rose higher than expected, favouring the established MNOs. In the event, O2, BT/EE and Vodafone got 40 MHz in the 3.4 GHz band, while Three got 20 MHz (though it already has assets in this band thanks to its acquisition of UK Broadband).

The current spectrum holdings in the UK are summarised in Figure 2.



Telefonica O2 still has the smallest spectrum portfolio.
Hutchison has large high frequency holdings but less at lower frequencies.

Source: New Street Research estimates

The UK has the chance to introduce a different approach when the next auctions are held. These are likely to be in 700 MHz and 3.6-3.8 GHz. The latter, because of its plentiful capacity (which could be extended to 4.2 GHz in future) is the most interesting for supporting an additional, neutral host operator.

While emerging sources of 5G spectrum, such as the millimetre wave bands, still have considerable uncertainties in terms of device availability and real-world performance, the spectrum between 3.4 GHz and 4.2 GHz is well understood and a commercial ecosystem is evolving rapidly, partly because of early deployments in these bands in key Asian economies like Japan and China. This means that there is no reason, in technology or device terms, to delay allocation of these airwaves for new models.

Philip Marnick, Ofcom's group director of spectrum, told the Dynamic Spectrum Alliance's annual Summit in London in May that Ofcom was aiming to release spectrum in 3.6-3.8 GHz in 2019 and is exploring ways for MNOs to coexist with incumbent satellite operators in the 3.8-4.2 GHz band in future.

Marnick said MNOs and government agencies needed to "figure out a way" to make spectrum available to more players, including start-ups and enterprise disruptors, acknowledging that no operator could support all the use cases envisaged for 5G. "5G is a range of things" he said. "I believe it is a mobile technology that can be used to facilitate development – and not just by the mobile operators. The 5G world is not the traditional mobile of the last 30 years".

He added: "Our objective is to ensure that spectrum does not inhibit the roll-out of 5G…. This includes exploring options for greater sharing of spectrum amongst different users and looking at new ways to ensure all industries can access the airwaves they need to unlock the full potential of future technology."

It is critical that government and regulatory policy builds on these statements of intent. So, what can the UK government do to facilitate this new model, based on neutral host infrastructure and a combination of shared and affordable licensed, spectrum?

Key policy decisions could include:

- Earmarking spectrum in 3.6-3.8 GHz and future higher bands including millimetre wave, for enterprise and neutral host use (at least partly). Since the specialist sub-nets will be based on small cells, 40 MHz would be sufficient as a minimum, rather than the 100 MHz required to support full 5G functionality on a macro level.
- Making interim allocations in some locations to support Phase 2 DCMS projects, in order to demonstrate the benefits of neutral host economics in areas that are challenging to the MNO business case, such as roads, railways and rural areas.
- Working with stakeholders such as cities, rail operators and property developers to simplify access to sites and fibre to enable the new 'sub-nets'.
- Mandating neutral host for selected economically significant initiatives where the single operator model is clearly challenged, including Connected Communities and the Trans Pennine railway.

Railway connectivity was highlighted in the National Infrastructure Commission's Connected Future report[2] as an area where dramatic improvement was required and the government has launched a consultation on the topic, with the objective of brining 5G gigabit connectivity to passengers by 2025. The policy accepts that a dedicated trackside network will be required, rather than relying on the operator's existing macro cells, which do not supply the required coverage or high speed hand-off.

The first pilot project, which will explore the best connectivity options as well as using Network Rail fibre and site assets, is on the Trans-Pennine route connecting Manchester to York. This would be an ideal project in which to test the technological and commercial implications of a neutral host model to improve the business case for operators of railway services.

THE POTENTIAL IMPACT OF NEUTRAL HOST SPECTRUM

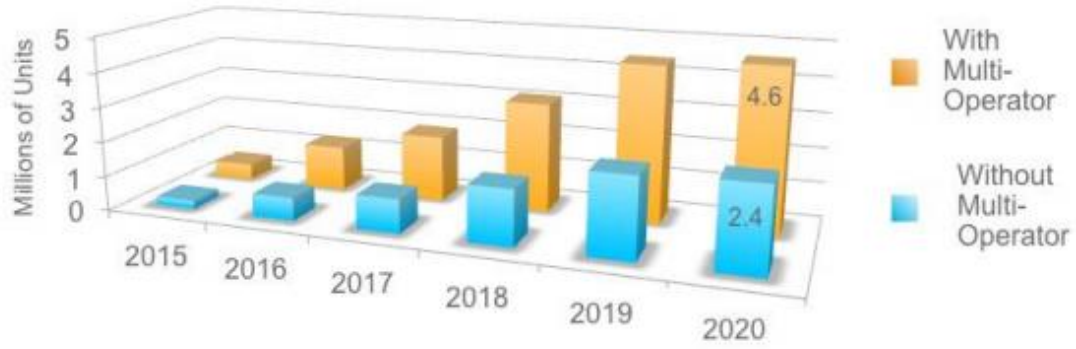
What would be the potential impact of a policy that enabled neutral host, business-to-business networks to be built in a combination of shared and affordable licensed spectrum?

Study results

Studies in the UK and round the world are making the case for neutral host sub-nets as a way to deliver a wider range of 5G benefits, more quickly and contribute to operator business cases, government socio-economic objectives and consumer or industry choice.

2 https://www.nic.org.uk/wp-content/uploads/Connected-Future-Report.pdf

- Consultancy Wireless 20/20 created a business case tool to assess various neutral host models and, after engaging with over 100 operators, concluded that: 'venue owners, mobile network operators and neutral-host service providers all can take advantage of the cost savings and efficiency of resources that come from sharing infrastructure in venues. This creates a lasting advantage for all industry players. As such, the trend toward neutral host deployments in desirable venues is one of the most important trends in the mobile industry.'[3]
- Mobile Experts, in a 2016 report, found that indoor cellular deployment had been "held back by products which require cooperation of mobile operators and complex projects with multiple stakeholders." The report concludes that only simplifying the deployment process would address the issue.[4]
- A report for the Small Cell Forum, on multi-operator and neutral host models, assessed that enterprise and industrial deployments will only happen if they are affordable for the service providers and offer multi-operator access for the enterprise. Without multi-operator support, the global deployment of small cells for enterprise and IoT usage will be just over half the potential growth, with neutral host and multi-operator models included (Figure 3). That means many locations and industries would remain underserved by high quality mobile coverage.
- In a study by Rethink Technology Research, it was found that if regulatory barriers to shared infrastructure and neutral host spectrum are removed, the pattern of deployment of small cells would change significantly (Figure 4). The forecast looked at the rise of private or neutral host service providers to support the increasing diversity of use cases for mobility. It predicted that, by 2023, 79% of small cells would be deployed and managed by non-MNOs; in many cases via neutral host mechanisms. The MNOs would remain almost entirely responsible for wide area macro networks, deployed in exclusive licensed spectrum and would monetize the connectivity between these services and the more localized, vertically specific sub-nets.



[3] http://www.wireless2020.com/media/white-papers/NeutralHostWhitePaper01192016.pdf

[4] 'Enterprise Mobile Infrastructure', April 2016, Mobile Experts

Figure 3. Estimated deployment of non-residential small cells, with/without multi-operator/ neutral host support

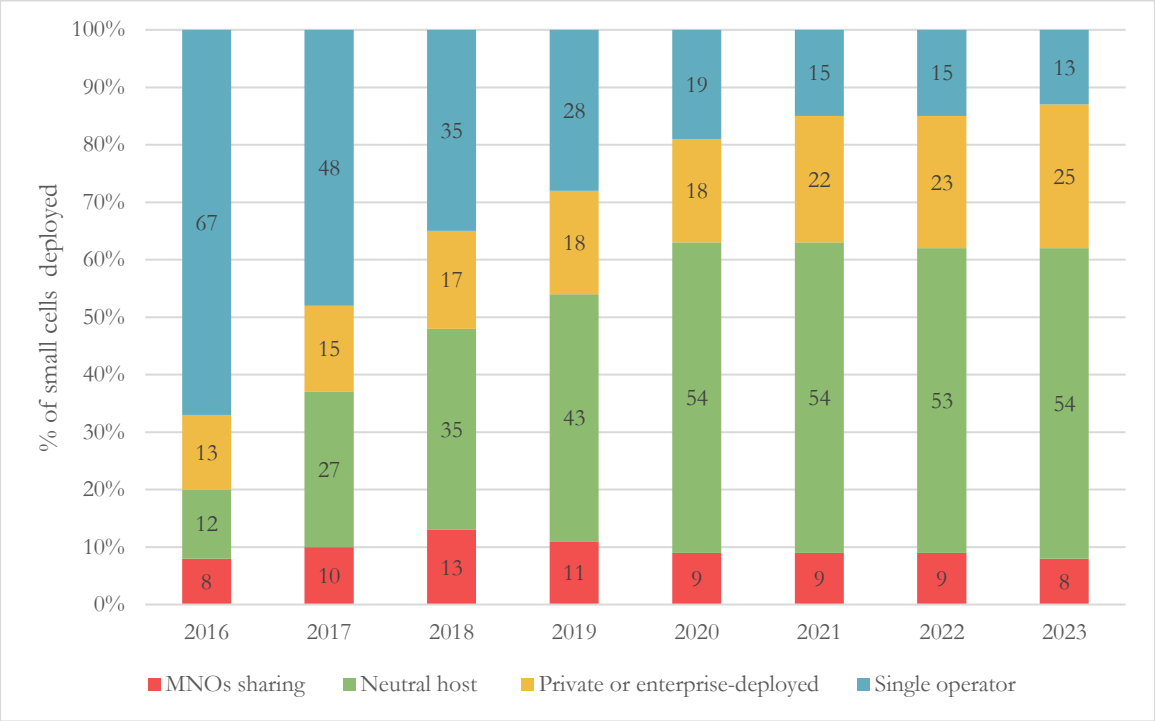


Figure 4. Percentage of small cells deployed and managed by various service provider types 2016-2023[5]

That indicates the general trend away from the 'one MNO one network' model which worked well for 3G and 4G – because they were effectively single application platforms, supporting human use of mobile voice and data. Once the networks must support machines and a wide range of vertical sectors, not just the telco one, it will be important to have new ownership and management structures and important that the UK creates the environment to allow these to flourish.

Neutral Host Examples

There are examples round the world of neutral host wireless networks in operation:

- DAS (distributed antenna system) is a technology for extending coverage over large and often densely populated locations such as stadiums. The multi-operator and neutral host approach is well established because of the significant expense of deploying a DAS. However, despite advances in more flexible digital DAS platforms, it remains a solution whose deployment cost makes it suitable only for very large enterprises.
- Wi-Fi networks have become increasingly capable of supporting many business and industrial applications, especially indoors. The difficulty for MNOs to make the case to deploy cellular networks inside buildings has made Wi-Fi the default enterprise wireless system and in many cases it works on a neutral host basis, supporting multiple connectivity and service providers.

[5] Rethink Technology Research, 'Enterprise Small Cells 2016-2023' January 2018 www.rethinkresearch.biz

- In the 5G era, there is likely to be greater technical and commercial convergence between cellular and Wi-Fi and both technologies will operate in some bands in common, notably 5 GHz. However, Wi-Fi (and any unlicensed spectrum solution) has limitations as outlined above. Solutions like railway connectivity will rely on seamless integration of Wi-Fi access with high reliability, high mobility cellular solutions.
- Tower operators already operate a neutral host model for passive infrastructure such as masts and fibre. Some are expanding into supporting neutral host networks with active infrastructure (base stations). A UK example is Arqiva with its deployments of 5G fixed wireless, city small cells and Sigfox systems.
- Cable operators, particularly the USA's Comcast and Charter Communications, have outlined plans to deploy small cell sub-nets in licensed or shared spectrum to support their own wireless services, but also to enable third party enterprise providers.
- Some specialist neutral host providers, targeting enterprise use cases, are emerging, including Dense Air, Clearsky and Cloudberry Mobile. Many of these providers have been confined to working in shared spectrum, or in partnership with MNOs in order to use their spectrum for indoor or specialist networks. However, if neutral hosts secure their own spectrum, as Dense Air is doing, they will have greater flexibility to work with a wide range of partners and plan their networks around the needs of emerging enterprise use cases.

Benefits of Neutral Host Models

The studies cited above point to the key benefits of a neutral host model enabled by shared infrastructure and flexible spectrum policies. Overall, neutral host addresses two key challenges simultaneously – the cost of deploying a 5G network which will be far denser than previous ones; and the ability to support a diversity of specialist operators for demanding industrial use cases.

Cost Sharing

The cost issue is significant for established MNOs and for new entrants. In an analysis of one European country, where all three operators followed a conservative approach to 5G investment, consultancy McKinsey predicted that total cost of ownership for RAN would rise by 60% in 2020-2025, to support 25% annual data growth.[6]

The densification associated with 5G makes the issue more challenging. Very few operators have sufficient spectrum to enable them to fulfil 5G potential, so reuse via small cell networks is important. This means 5G will be small cell centric but it is only possible to get enough users per gNB to make the economics and the deployment practicalities work, in a neutral host model.

[6] https://www.mckinsey.com/industries/telecommunications/our-insights/the-road-to-5g-the-inevitable-growth-of-infrastructure-cost

Figure 5 indicates the many aspects of 5G which would drive deployment cost and TCO upwards, according to McKinsey.

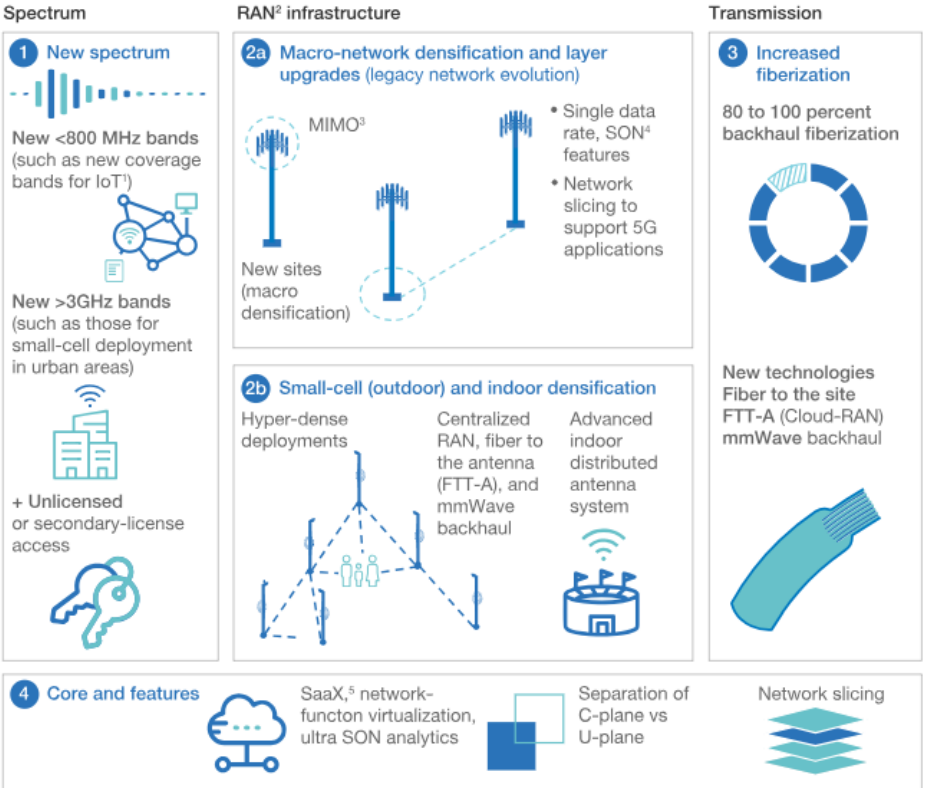


Figure 5. Areas of increased investment requirement in 5G. Source: McKinsey

This becomes even clearer with sectors that require large-scale and very high performance networks, such as railways or utilities. A single, neutral host infrastructure, with sufficient capacity and flexibility to be shared by many service providers, is the best answer. This can be used by MNOs which want a more cost-effective way to extend their model into IoT or industrial applications and by new entrants or specialists.

Other Important Benefits

There are many other benefits:

- It becomes more cost-effective to achieve very broad coverage and high quality of service, even for challenging network behaviours such as ultra-low latency. That will enhance the MNOs model because they will be able to access the neutral host network to fill gaps in their own coverage and capacity and so improve the quality of their core services at relatively low cost.
- The MNOs will also be able to test the commercial waters of specialist URLLC (ultra-reliable low latency communications) networks without having to implement those capabilities across their footprint. This could accelerate the diversification of their models and improve their overall competitiveness and viability.

- Where the MNOs choose to stay focused on their traditional services and footprints, the barriers will be lowered for specialist providers to use the neutral host network to deliver enterprise, IoT and critical communications services. They will be able to do this without significant investment in infrastructure or in the skills to plan and manage a cellular network; and they will be able to align their cost to their revenues with a pay-as-you-go system.
- For these enterprise MVNOs, there is a greater opportunity to influence the neutral host to support their particular connectivity requirements in terms of coverage, capacity and performance, to be optimal for their use cases. In conventional MVNO arrangements, they have to make the most of a macro network which has been planned around the MNOs' core business priorities.
- Neutral host platforms are the only practical or affordable way to deliver very challenging mobile networks, such as those on the Tube or major railways, within the timescales set by the UK government (before 2025). Such networks require the participation of all the MNOs so they are usable by all passengers. Neutral host saves the MNOs from making all the investment required for these specialized systems – at a time when their capex budgets may be stretched by 5G MBB upgrades. It also works around the political and competitive barriers that often hinder projects in which the MNOs themselves share the deployment, or one MNO leads it and hosts the others (the multi-operator model).
- The same issues apply to smart cities, a centrepiece of government digital and 5G policy. No city can make a deal with a single MNO, since all citizens need to access the networks and services, but a multi-operator model is often unattractive to the operators.

The Economic Impact

The most important aspect of the neutral host model, as supported by targeted small cells and a mixture of licensed and shared spectrum, is that it must be a win-win for existing MNOs and for the industries which wish to harness 5G to enhance their own business cases. It must support a platform that enables all the contributors to the UK economy, not just the telco sector, to use 5G to drive new efficiencies, services and growth. And it must also address the cost and time implications of social objectives such as reducing the digital divide, improving the cost and quality of healthcare and education and extending rural broadband.

In a study of a major European market, Rethink projected the impact of 5G deployment by 2024, with and without a new neutral host operator enabled by licensed spectrum allocation and friendly regulation (e.g. no barriers to sharing active infrastructure).

Figure 6 shows that, in the neutral host scenario, total investment in 5G would be 28% higher than the base case (existing MNOs deploying from 2020, no neutral host or new entrant). That, in turn, would support a wider variety of services, in a shorter timescale (3.6 times higher, with many of the additional use cases being those demanded by vertical industries and by government digital strategies).

It was clear that the new deployments did not come at the expense of the MNOs' commercial viability. In this model, the existing MNOs' collective profits would be 40% higher than in the base case, because they could access shared networks to reduce the cost of addressing enterprise, indoor and IoT services. And the total revenues of all operators would be 60% higher because of the larger number of providers and the ability to offer more high value services.

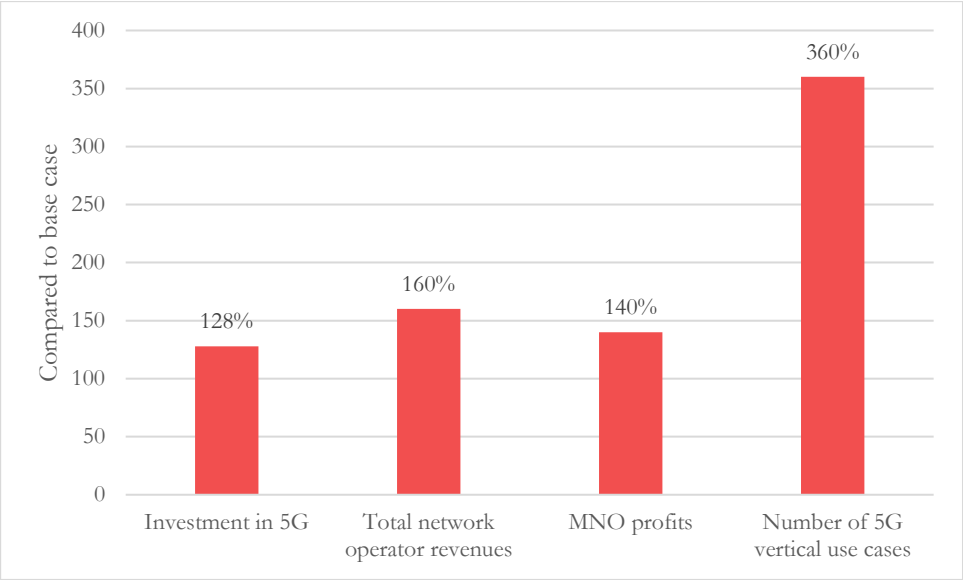


Figure 6. Top line summary of projected impact of a neutral host small cell operator on 5G, by 2024 (compared to base case where there are no new operators and no operator M&A).

Source: Rethink case study, major Europe market.

There are several critical success factors to enable this kind of scenario to evolve in the UK in the early 2020s. They are summarized in Table 1:

Critical success factor	UK status
Availability of handsets and IoT devices	3.4-3.8 GHz band is on the near term (2020) roadmaps of most major device makers, in shared and licensed bands
Licensed spectrum allocated for neutral host to ensure affordability	Did not happen in 3.4 GHz auction, opportunity to change the policy for the 3.6-3.8 GHz auction and to consult on shared access in mid-band and mmWave
Lowering of administrative barriers to deploying small cells e.g. access to sites, backhaul and power, equipment approvals	EU is formulating policy on streamlined site and equipment approvals. Issues being addressed by some city and government projects. More coordination needed to achieve consistent, highly automated approvals, as well as cooperation with major infrastructure holders like Network Rail.

Framework for vertical industries to participate in neutral host model and potentially co-invest in networks	Higher level of consultation and coordination with UK industries. This is strong in some sectors, e.g. automotive, but less so in others e.g. agriculture, manufacturing. Examine co-investment models around the world e.g. China Unicom, Japan's Rakuten.
Securing the support of MNOs	Clear regulations required to protect existing MNO interests. Ideas might be that neutral host must be B2B-only, MNOs have first right of refusal to networks.

HOW CAN DENSE AIR HELP?

Dense Air has licences in Ireland, Portugal and Belgium and is targeting spectrum in 10 countries by the end of 2018. In all cases this will support deployment of neutral host networks, which will help support new service providers and business models that complement the MNOs' retail mobile broadband services, rather than challenging them.

Dense Air is targeting three main markets for its neutral host platform:

- Mobile network densification, based on its 'Magic Box' small cell technology and providing dense neutral host zones where they are required, to complement MNOs' macro networks and support new entrants.
- Wireless fibre extension, supporting wireless last metre deployments for fixed line operators, or fixed wireless access (FWA) systems which can be leveraged by multiple providers. This provides an alternative to the common macro cell approach to FWA, which suffers from high contention rates. The small cells, combined with millimetre wave relay to extend range, provide a far lower cost option (mmWave is about 25% less costly than overhead fibre).
- A fully hosted 5G-as-a-service offering.

Dense Air is confident that, once at least one of these models is proven to work in its initial markets, access to spectrum will become easier because investors and regulators will have the proof points they need that a neutral host model will enhance the socio-economic impact of 5G as well as promoting new competition without hurting the established MNOs' core business.

Unlike some neutral host solutions, Dense Air, via its parent company Airspan Networks and operational partner (SoftBank) has extensive experience of deploying small cell networks at scale, thanks to its parent Airspan. Airspan has been deploying very large-scale small cell networks, indoors and outdoors, from its work with Softbank in Japan and Sprint in the USA to the mass deployment of small cells at Jio in India. Dense Air brings this knowledge to bear on its neutral host deployments. This will be especially valuable in terms of understanding the most efficient, streamlined processes for deploying cells at scale.

The economics of deploying large numbers of small cells have proved very challenging, but Airspan believes it has addressed many of these barriers with Magic Box. A cluster of Magic Boxes can be managed by a virtualized controller with a single interface to the macro network, to reduce cost and complexity. At Mobile World Congress 2018, Airspan showed a vRAN with FDD spectrum as the anchor and LAA/CBRS, with just the PHY running on the small cells and the MAC virtualized. But as long as vRAN requires fibre, it will have limited applicability in Europe, an issue which could be solved by getting mmWave right. In addition, Airspan's small cell technology has been recognised by the mobile industry and won the MWC 2018 coveted GLOMO award for Best Mobile Technology Breakthrough and the Small Cell Forum award for Excellence in Commercial Deployment (residential).

A key feature of the boxes that Airspan provides to Dense Air is that they support a wide range of network capabilities, which can be activated or deactivated in different combinations, as required by individual operators (e.g. one provider might support Voice over LTE, another fall-back to circuit switched voice, but both are enabled by the same box).

Another technology which Airspan has been able to harness, thanks to its work with Softbank to improve small cell economics, is big data analytics. Using data from smartphones, the system can understand and predict traffic patterns and cells can be placed in just the right place to use spectrum efficiently and support high quality of service.

These tools can help a neutral host to assess coverage for individual customers, for instance, fixing coverage issues for a local supermarket. MNOs can select the locations they want to activate within their network to address their particular traffic patterns and identify locations with sufficient user density to make it economic to deploy a small cell. This targeted approach has helped Sprint to increase its average downlink speed by between 45% and 80% in the 200 towns and cities where it has installed Magic Boxes so far.

Case study: AutoAir

AutoAir is one of five one-year projects awarded funding by DCMS in the first quarter of 2018, all of which aim to contribute to the UK's 5G programme through technological and business case demonstrations. AutoAir is focused on 5G applications related to connected and eventually autonomous, vehicles. It will deliver and test real 5G New Radio (NR) prototypes for use in this scenario and some of its work on high speed mobility is also expected to be directly relevant to connected trains. This is significant because the UK National Infrastructure Commission (NIC), in a report published in late 2017, identified that rail was one of the areas where mobile coverage most needed to be improved.

AutoAir is a consortium consisting of 5GIC at Surrey University, Dense Air, McLaren Applied Technologies, Blu Wireless Technology, Quortus, Millbrook, Real Wireless, ARM, Cobham Wireless and Celestia Technologies. Testing of 5G prototypes and applications will take place at Millbrook, the UK's leading test centre for vehicles. The R&D underpinning the radios will come from Airspan, leveraging research done by the 5G Innovation Centre (5GIC) and 100 MHz of test spectrum.

Dense Air will build and operate the network at Millbrook on behalf of the consortium. The result will be a permanent 5G test network which will remain at Millbrook for use by UK operators and auto makers.

This network will consist of 40-50 small cells supporting a variety of access and backhaul/relay technologies in different parts of the Millbrook campus - 4G and 5G NR in sub-6 GHz spectrum and a mesh technology based on 802.11 standards and running in millimetre wave spectrum. Airspan's 'Magic Box' cells will be deployed on the campus's existing 23 Wi-Fi sites and coverage extended using mesh nodes, fed by 10G fibre.

The number of cells planned will deliver a hyper-dense neutral host network within Millbrook, which will deliver valuable lessons about network behaviour when large numbers of cells are deployed in close proximity – an important element of many mobile operators' 5G plans (e.g. Sprint USA).

The combination of connectivity options reflects the real world situation of most early 5G deployments, in which different radios and spectrum bands will need to work closely together and 5G will often be deployed initially to support dense or high quality zones beneath a wide 4G coverage layer.

The test network is designed to reflect the kind of topology that many operators will deploy on day one; not end-to-end 5G. Selective 5G NR installations will be confined to the user plane, combined with the existing LTE core and control plane and enhanced by localized capabilities, including edge compute nodes and virtualized local packet cores. This approach means a wide variety of services can be deployed on an optimized sub-net, without having to wait for 'pure 5G' to be ready across the network.

The Millbrook facility also allows a wide range of use cases to be tested, from dense indoor connectivity in its conference centres and offices, to high speed (up to 180 miles per hour) on its driving track. Importantly, many of the results will be applicable to railways too, potentially with small cells installed on the trains and millimetre wave (mmWave) mesh along the tracks.

An important result of the Millbrook project will be to demonstrate the potential of the neutral host model this paper has described. Having constructed the network, Dense Air will make the Magic Box cells neutral host, by encapsulating the PLMN ID for each operator in its own dedicated interface. Those operators could be existing MNOs or new entrants with specialized activities in the road or rail market, including systems integrators, MVNOs or transport operators, for instance. Each would have their own private PLMN ID and traffic would pass to the wide area MNO network where required, by roaming or tightly integrated handover. The platform also supports local break-out for enterprise applications, giving specialist service providers control over their own traffic, security and services.

The economics work better if the neutral host network does not have to make use of the MNOs' spectrum and had Dense Air succeeded in the 2018 3.5 GHz spectrum auction, it would have contributed that to the AutoAir project.

CONCLUSION

This paper argues that the neutral host model and new entrants wholesale Neutral Host operators will be critical to the UK because:

- To fulfil its objectives, 5G must support a wide variety of industries, not just the telecoms vertical.
- That means networks being optimised for the specific needs of other vertical sectors, including human-based and machine-to-machine applications.
- MNOs have generally struggled to define a strong business case for enterprise and indoor connectivity. Despite interest in vertical and IoT opportunities, most acknowledge that they are best placed to support use cases which are heavily driven by broadband data and are national and mobile in scope.
- That presents the risk that investment will be limited or delayed in anything beyond the evolution of the current national mobile broadband business model.
- A wider variety of network behaviours is required, including indoor or indoor-out networks; very dense hot-zones; localized and edge-oriented networks; low latency networks. Most of these are hard to justify on a one-network-per-operator basis.

A solution is to deliver these services on a common wholesale small cell platform which can be harnessed by multiple service providers from MNOs to MVNOs to private network operators, improving return on investment on the infrastructure.

While some neutral host networks have been deployed in unlicensed spectrum, this has limitations when it comes to very high reliability, security and predictability. To fulfil all the potential of 5G, a combination of licensed, shared and unlicensed spectrum is likely to be required.

Regulators (OFCOM) should consider the benefits of assigning licensed spectrum for neutral host networks or adopting structures which enable neutral host operators to enter the market. Mid-band spectrum such as 3.4-4.2 GHz is well suited to dense small cell deployments and has sufficient capacity to support a new entrant without weakening the established MNOs ability to enhance their wide area MBB networks and their businesses.