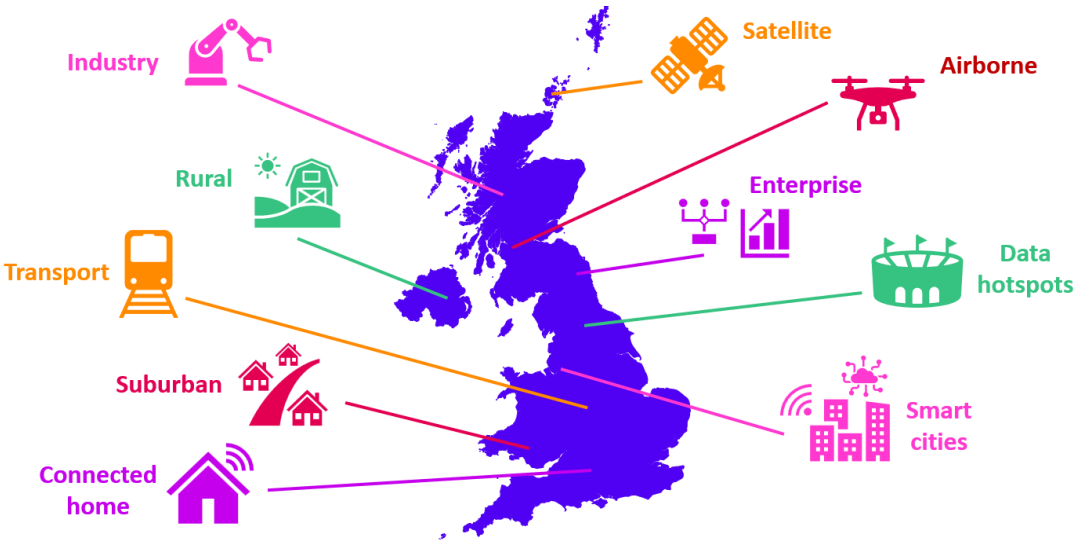
Spectrum Management for Next Generation Wireless Broadband

Flexible access and spectrum sharing



Discussion Paper

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Summary

Ofcom's mission is to make communications work for everyone in the UK. Ultimately this means people having access to affordable, high quality wireless connectivity that meets their growing needs, wherever they are in the country. As part of this mission Ofcom is responsible for managing the radio spectrum in the UK and we have a duty to ensure its efficient use to the benefit of all.

Today the majority of people in the UK connect their wireless devices using Wi-Fi and the national mobile networks. The availability and quality of these networks has improved dramatically since the millennium when 3G mobile and first-generation Wi-Fi became widely available. As we look forward to the end of this decade, we expect to see the introduction of new versions of Wi-Fi (beyond Wi-Fi 7) and 6G mobile as well as a range of new wireless technologies and deployment models such as connectivity from the sky and space (non-terrestrial networks or NTNs). Together these networks have the potential to bring significant improvements in availability, reliability, performance and choice of wireless connectivity across the UK. Collectively we term these networks and technologies 'Next Generation Wireless Broadband' (NGWB).

This paper explains why we expect the diversity of NGWB network options, uncertainty in how and where they will be used, and the need to continue to support the benefits of incumbent spectrum uses, will require an approach to managing spectrum in which there is a greater emphasis on sharing of spectrum and more flexible access. This approach is consistent with our 2021 Spectrum Management Strategy[1].

This approach to spectrum management may require changes along the whole spectrum 'pipeline' – from technical studies and allocations made at the ITU, through to equipment standards that incorporate flexible access and sharing 'by design' and thereby enabling more options for domestic spectrum authorisations. To achieve the full benefits of NGWB we will need to work closely with spectrum regulators and industry from around the world to ensure the international spectrum management framework remains fit for purpose and reflects the changes in both the demand and supply of NGWB.

We look forward to discussing the case for change we've outlined in this paper with other spectrum regulators and industry at upcoming international and domestic discussions. We are also interested in continuing to hear from stakeholders that are developing NGWB technologies or are deploying or considering deploying networks and offering services in the UK.

What will drive demand for NGWB?

Demand for NGWB will come from the evolution and growth of existing services and, potentially, the introduction and adoption of new services.

We have seen significant growth in traffic on both mobile broadband and Wi-Fi networks over the last decade, a trend we expect to continue. Between 2013 and 2022, licensed mobile traffic grew on average by approximately 40% year on year, a similar growth rate to fixed broadband. Although our latest annual Connected Nations report[2] showed growth slowed between 2021 and 2022 we expect that demand will continue to grow, but that the rate of that growth is highly uncertain. There is also uncertainty in how that growth will be served. For instance, significant growth today in Fixed

[1] See https://www.ofcom.org.uk/__data/assets/pdf_file/0017/222173/spectrum-strategy-statement.pdf
[2] p.41 - 42 https://www.ofcom.org.uk/__data/assets/pdf_file/0034/249289/connected-nations-uk-report.pdf

Wireless Access (FWA) may be displaced by the deployment of fibre networks or may continue to grow as an alternative means to cost effectively access broadband services.

In addition to growth relating to increased adoption and evolution of today's applications, new growth may be stimulated by the development of new devices and services that rely more heavily on technologies such as machine learning, edge computing and advanced sensing and positioning.

Changes in the transport sector could be a driver of NGWB demand. In addition to greater demand from train passengers, connectivity requirements for cars and commercial vehicles may increase as people seek to do more on their journeys and better-connected vehicles can improve road safety and improve traffic flows. In the sky, air corridors established for drone delivery services, and perhaps even air taxis, will require high quality connectivity.

Wireless services for enterprise and industry that have begun to emerge with the advent of 5G and Wi-Fi 6 could be fully realised as NGWB networks are expected to deliver extremely reliable and low-latency connections across the required coverage area.

Where Critical National Infrastructure (CNI) relies on wireless broadband networks, resilience and security capabilities are crucial. The networks must be able to provide service when parts of the infrastructure are disabled due to faults, natural disasters, or deliberate malicious attacks.

The innovation and full benefits of these services may require a combination of different technologies and networks to complement the national mobile networks and Wi-Fi – a 'network of networks' approach.

An increasing range of technologies and networks could play a part in meeting NGWB demand

Today, wireless broadband is primarily delivered to end users through the national mobile networks and Wi-Fi. By the end of the decade a number of other NGWB technologies are likely to play a role in complementing mobile and Wi-Fi to meet consumers and businesses evolving needs of capacity, coverage and resilience. In some cases, these new technologies may have the potential to increase competition and choice.

National mobile networks are expected to be the mainstay of outdoor NGWB. We expect the mobile network operators to migrate more spectrum from legacy 2G, 3G and 4G technologies to 5G and, beyond 2030, to 6G**.** Densification will start to contribute more significantly to dealing with the growth in demand across the network together with the use of large amounts of spectrum available in the mmWave bands (particularly in urban areas). As set out in our work on forecasting future demand for mobile spectrum, there is still expected to be a need for more spectrum for mobile capacity, particularly in the mid-bands, that emerges in the 2028-2030[3] timeframe. Providing mobile coverage to the most remote parts of the UK is likely to remain challenging due to the costs of building and operating terrestrial mobile masts.

Wi-Fi already carries the majority of consumer wireless broadband traffic[4], primarily indoors. As the UK migrates to fibre to the premise fixed broadband, we can expect ISPs to migrate their customers to the latest generations of Wi-Fi to avoid the final wireless link in the home becoming a connectivity

[3] https://www.ofcom.org.uk/__data/assets/pdf_file/0036/248769/conclusions-mobile-spectrum-demand-and-markets.pdf

[4] Ofcom Communications Report 2023 reported average monthly data use on residential fixed broadband was 482 GB in 2002, compared to 8.1 GB for mobile data users.

bottleneck. The latest Wi-Fi standards (Wi-Fi 6 &7) use more radio spectrum and more advanced protocols to improve in-home and enterprise coverage, performance and reliability and to meet the growth in data use.

In addition to Wi-Fi, 'small cell' 5G solutions are becoming more popular for improving **indoor coverage and quality** of the national mobile networks and for deploying private networks. Given the large majority of wireless broadband data is associated with 'indoor' use, whether at home, at work or in transit we see significant advantages in terms of performance and efficient use of spectrum when the wireless routers / wireless base stations are placed in the same space as the users. Additionally, lower power deployments, whether indoor or outdoor, support significant spectrum reuse, thus, delivering the required capacities that users expect where and when they expect them. Whilst 'outside in' coverage solutions are degraded by the signal loss of the building's walls, 'indoor in' solutions can deliver better coverage and capacity and potentially allow sharing of spectrum between indoor and outdoor networks. This is particularly relevant for higher frequencies bands. Ofcom is currently exploring various approaches including 'indoor - outdoor' and 'geographic' sharing in the upper 6GHz bands (6425-7125 MHz).[5]

The market for **local networks** to serve enterprise and industrial customers is growing. Optimal solutions will depend on the exact requirements – some may be well served by the functionality offered by Wi-Fi, or by 5G and future 6G technology depending on their specific needs.

A range of airborne and space based **'non terrestrial network' (NTN)** technologies have the potential to play significant complementary roles in delivering NGWB. The performance and price of satellite broadband has improved in recent years with the deployment of large constellations of low earth orbit satellites such as OneWeb and Starlink. These platforms have increased the geographic availability of high-speed broadband across the UK. Several companies have plans to launch constellations in the coming years, bringing innovation and competition. We also expect a wider range of devices to be served with smaller, lower cost terminals for connecting to buildings and vehicles as well as direct to handset services (albeit at lower speeds).

As well as satellite-based NTN, there is the potential for NGWB to be delivered from **airborne platforms** ranging from a few hundred metres to c. 20 Km. Advances in lightweight materials, electric propulsion and autonomous flight are making these platforms commercially viable.

NTNs could complement terrestrial networks by providing back-up in the event of local outages – increasing overall **resilience**. NTN platforms may also provide cost effective backhaul for remote terrestrial base stations where fibre and wireless backhaul aren't viable.

The demand for NTNs may not be as great in the UK as they are in countries with lower mobile coverage. [6] However, we recognise that these new platforms could lead to new, unforeseen innovations and could also provide efficient solutions for improving overall network coverage, resilience and performance across the UK.

NGWB will not be limited to communications. Radio based sensors are likely to play an increasing role in the operation of wireless networks and offer new functionality for applications that run over them – such as positioning and sensing for autonomous robots and data collection for digital twin applications. These sensing capabilities maybe particularly valuable when deployed within local networks in industrial sites such as factories and warehouses. With advances in signal processing and

[5] https://www.ofcom.org.uk/consultations-and-statements/category-1/hybrid-sharing-to-access-the-upper-6-ghz-band

[6] Ofcom Connected Nations Report Summer 2023 Update reported 4G coverage from at least one network of 93%. The Shared Rural Network programme aims to increase coverage to 95%.

antenna design, combined sensing and comms technologies could become a core feature of NGWB networks.

Flexibility and spectrum sharing will be required to support NGWB network demand and deployment

As outlined above, there is considerable uncertainty on the demand side in terms of new applications and services, and an increased set of options for the delivery of NGWB.

On the demand side, there is uncertainty on the rate of traffic growth and how this will vary in different parts of the UK, outdoor vs. indoor, local vs. national and with the introduction of new use cases. On the supply side, there will be a wider range of networks than there is today and each will have different characteristics in terms of performance, cost and spectrum use.

Given this uncertainty and the range of potential outcomes, we will need to retain flexibility in how we make spectrum available to ensure access to spectrum is not a barrier to network deployment. Additionally, in some areas, we anticipate that there could be competing demand for the same spectrum and so optimal use will require spectrum to be shared.

There is very little unused, 'green field' spectrum, particularly below 15 GHz, and this is where demand for new spectrum is concentrated. Spectrum sharing could enable new NGWB networks to be introduced into bands where there are important incumbent services. For example, the introduction of NGWB technologies that operate co-channel with existing defence use. Sharing may also be relevant in situations where it is impractical to clear users from a band, such as when there are already a large number of licence exempt devices deployed that are delivering significant benefits for consumers.

There is also the potential to introduce NGWB technologies that complement and operate co-channel with existing wireless broadband networks. For example, NTN platforms complementing existing terrestrial mobile networks and serving the same installed base of user devices on existing mobile frequencies.

To achieve the goals of more flexible access and sharing we need to consider each stage in the spectrum management 'pipeline' – from the current model for international allocations and coexistence rules, through to domestic authorisation and mechanisms to ensure long term efficient and optimal use.

Technical developments offer the potential to move beyond simple sharing arrangements based on geographic separation, signal to interference thresholds and conservative coverage /propagation models. A toolkit of technologies can be used to improve service quality and spectrum efficiency. These include spectrum sensing and machine learning to characterise spectrum use and autonomous and cooperative algorithms to dynamically assign spectrum resources. Developing radios with wider tuning ranges could provide more flexibility in which bands are used in different countries whilst still securing the economies of scale associated with common standards and global supply chains. Spectrum sharing and flexible spectrum use will need to be a key design goal for new technical standards rather than a 'bolt on' afterthought.

Analysis of the coexistence potential of different services and technologies needs to become more sophisticated and be front and centre in any technical studies, as demand for finite spectrum resources continues to grow. Going forward, technical studies may need to consider the wider range of technologies and architectures that might be deployed in a band, ensuring that technical parameters do not inadvertently prevent future uses. Studies that assume the introduction of a

single technology and architecture, such as 'high tower, high power mobile', omnidirectional antennas, poor receiver quality, unlicensed access to spectrum without geographical constraints or the clearance of a band to enable NGWB might not lead to long term optimal use of spectrum. By considering and accommodating a wider range of solutions in technical studies (such as lower power, NTN, database controlled and indoor-only deployment) national spectrum regulators would be better equipped with a toolbox of solutions from which they can select the optimal mix for their country's needs.

Ofcom is starting to use flexible access and spectrum sharing approaches

This more flexible approach to spectrum management is consistent with our Spectrum Management Strategy and the conclusions of our review of future Mobile Spectrum Demand.

We are already implementing these strategies in the way we are making spectrum available:

- We have enabled spectrum sharing in the 3.8 – 4.2 GHz band which has allowed multiple local 5G networks to be deployed and coordinated around existing satellite earth stations and fixed links.
- For mmWave spectrum suitable for 5G, we're progressing an approach that reflects the expected variation in demand between urban and rural areas and the differing needs of the national mobile network operators and those seeking to deploy local networks.
- We are promoting development of proposals for the upper 6 GHz band in Europe which would allow Wi-Fi and mobile services to share the band.
- Through our Spectrum Sandboxes programme, we will provide spectrum users with the opportunity to experiment and demonstrate spectrum sharing methods to us, to optimise our license allocation processes.

Our strategy will continue to guide our approach to assessing any proposals for new spectrum for NGWB.

International spectrum allocations

For the reasons set out in this paper, to maximise the benefits of NGWB networks changes may be necessary at each step in the spectrum management 'pipeline' – including the allocations and studies agreed at ITU-R World Radiocommunications Conferences and in other fora.

An international spectrum identification process which reflects the need for national flexibility could deliver benefits for countries around the world. For countries like the UK, with widely deployed fixed broadband and mobile networks, then there is an opportunity to complement and enhance these networks. For countries with less developed networks and for whom the economics of fibre and terrestrial mobile roll out are challenging, NTN networks could, for instance play a more important role in connecting users.

We believe that such a flexible approach will enable individual countries to meet their own national spectrum needs while also benefitting from common equipment standards which will deliver cost reductions in network deployment and lower device costs. However, it will require international allocations which promote spectrum sharing, based on co-existence studies which use real world data and realistic assumptions to promote efficient use of spectrum. Moreover, spectrum regulators

will need to better understand the optionality available and have the necessary resources and stakeholder support to be able to effectively apply the outcomes of such international discussions in line with their national requirements.

We look forward to considering these ideas further with regulators and industry in upcoming international discussions. We would be keen to explore how to enable us all to be best equipped to meet changing needs and ensure that consumers around the world can derive greatest benefit from future wireless services.

Understanding NGWB spectrum demand in the UK

We recognise that establishing more flexible access to spectrum can require more technical studies and, potentially, more complex equipment and authorisation systems. We need to be proportionate in our approach and balance incremental costs and time against the potential benefits. With better information on the likely future demand for spectrum we will be better able to strike the right balance and prioritise our work accordingly.

We are interested in continuing to hear from stakeholders that are developing NGWB technologies and those that are or are considering deploying networks and offering services in the UK. We would welcome views on where they see a market opportunity and the nature of the NGWB network they would look to deploy.

As we develop our thinking we will continue our engagement with incumbent spectrum users, including public sector users, to explore opportunities for spectrum sharing.