

The Impact of Spectrum Set-Asides on 5G

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GSMA

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Executive summary

Part of the promise of the 5G era has been one of bespoke connectivity. Intelligent innovation and automation are becoming part of the workplace as Industry 4.0 delivers digital productivity to manufacturing processes, while government organisations and education campuses have local connectivity requirements. As hyper-automation connects factory robots to data networks, as education and business become reliant on connected technology, 5G has become a component of both industrial agility and economic competitiveness.

In order to be open to the challenges and opportunities of this new era of digitalisation, today's connected organisations may have their own set of connectivity requirements. Over the last few years, regulators increasingly have been requested to provide harmonised IMT spectrum for applications other than public mobile networks. These requests have tended to come from companies, industries, or public sector organisations (so-called 'verticals') for use in private networks.

Making spectrum available for industry users has to be balanced against demand from other users, including mobile operators who have increased

spectrum needs as mobile data traffic grows. As a result, the benefits that regulators expect from an assignment of IMT spectrum to private or local networks have to be carefully weighed against the cost resulting from potentially denying other users access to the same resources.

This report, prepared for the GSMA by Aetha Consulting Limited analyses the potential approaches available to regulators for providing spectrum to private networks. Through five country case studies it demonstrates the wider impact of these approaches, especially on mobile markets.

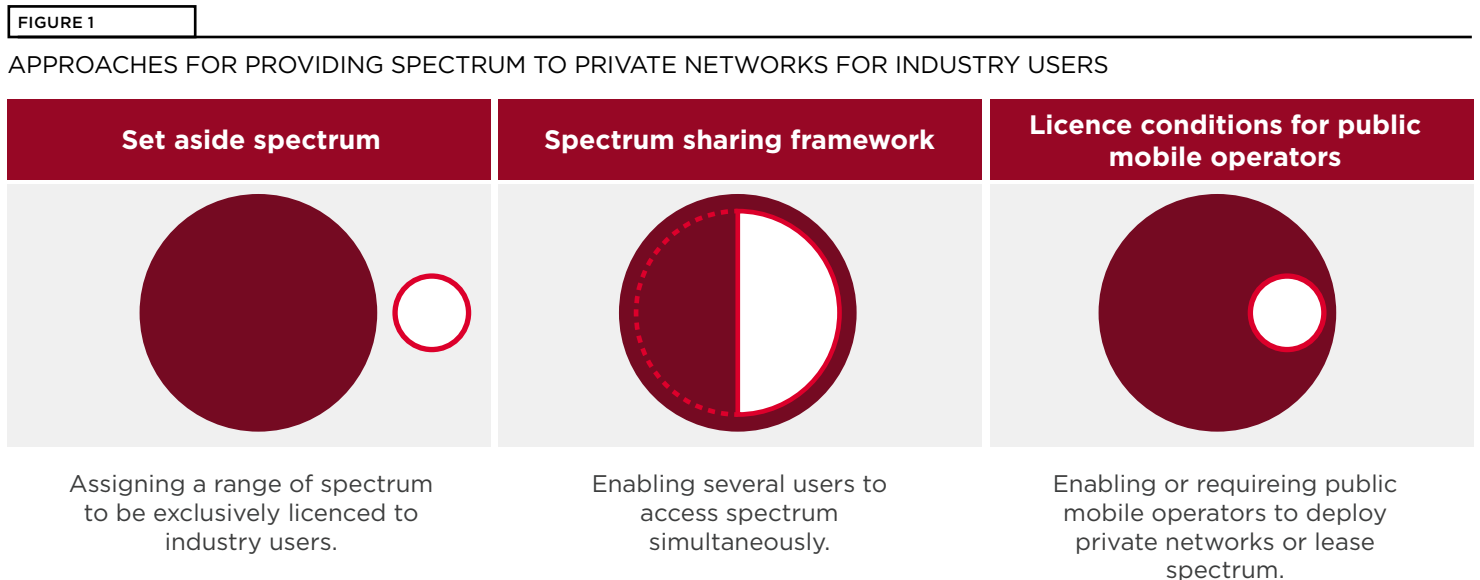
Main findings

Our analysis shows that caution has to be taken when making long-term decisions on spectrum assignments and highlights that market-driven approaches that foster cooperative solutions can bring the best outcome for spectrum users and consumers alike.

- **Set-asides carry significant risks to the economy**
 - Industry users will require spectrum to be made available within the relevant geographical area, with certainty of access and tenure, free from interference. Set-asides do not outperform alternative approaches, such as appropriately designed licence conditions. However, the economic cost for mobile operators created by set-asides can be enormous.
 - Set-asides prevent mobile operators from accessing potentially valuable spectrum assets, leading to poorer mobile network speeds and capacity. They can also create spectrum scarcity, which can raise prices in auctions.
- **Spectrum sharing frameworks are complex and carry risks on certainty of tenure and access**
 - Spectrum sharing frameworks have a lot of initial theoretical appeal but can be complex to design. Concerns around certainty of access and tenure as well as potential interference issues with other users limit the potential benefits from sharing for industry users.
 - Sharing frameworks can have a large negative impact on mobile operators. In the United States, we estimate that the restrictions to CBRS created an economic cost in excess of \$20 billion.
- **Well-designed licence conditions for mobile are least intrusive and stimulate cooperation**
 - Catering for private networks through licence conditions capitalises on a trend across all countries, that most networks are created in cooperation between mobile operators and industry users. This makes use of the knowledge and experience of mobile operators in deploying wireless networks.
 - Whilst these frameworks do not provide dedicated access to the spectrum for industry users, we observe no noticeable difference in industry interest compared to the more interventionist approaches to making spectrum available.
 - If designed well, it allows mobile operators to gain access to valuable spectrum assets whilst providing market-driven incentives for cooperation that are in the interest of all market parties.
- **Interest is mainly driven by properties of the spectrum band rather than the licensing mechanism**
 - Within the case studies, we observe no noticeable interest in demand for spectrum based on the licence approach chosen by the regulator.
 - Interest is highest in widely harmonised bands such as 3500 MHz, as industry users seek to benefit from existing ecosystems and standardisations above and beyond any assignment mechanism.

Approaches to licensing spectrum for verticals and private networks

Different approaches have been taken by regulators to meet the interest from industry verticals, which typically fall into one of the three categories that are outlined in Figure 1 below.



When determining the best approach for providing spectrum for private networks, regulators need to consider the needs of industry users who may be concerned with:

- access to spectrum in the right areas
- certainty of access and tenure
- protection from interference

At the same time, the impact of any potential licensing approaches on other spectrum users, such as mobile, has to be carefully assessed. Key concerns for regulators should include:

- the impact on the efficiency of spectrum use
- overall spectrum availability

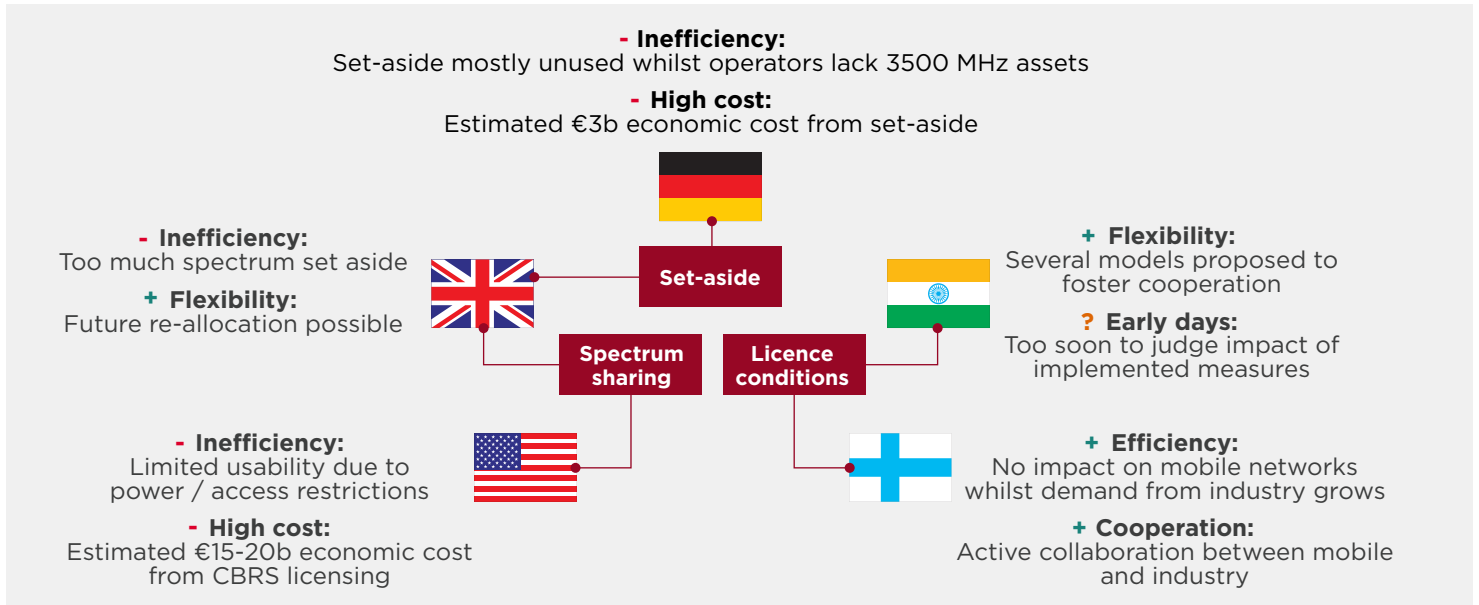
Spectrum allocated to private networks can, in most cases, not be used in parallel by other services unless careful sharing arrangements are put in place. Wrong assignment decisions can create large economic opportunity costs, potentially hurting the development of the private network sector as well as other spectrum users.

Insights from case studies

To analyse the impact of different licensing approaches, this study assesses five different countries that have assigned spectrum for private networks using at least one of the three above-mentioned licensing approaches, as highlighted in Figure 2 below.

FIGURE 2

COUNTRY-SPECIFIC INSIGHTS



Evidence from the case studies:

- We could not identify any significant benefits from the more heavy-handed approach of a set-aside.
- Spectrum sharing frameworks have proven difficult to implement without bringing obvious benefits to either industry or mobile users.
- Compared to the more market-driven approach of regulating licence conditions for mobile users, set-asides provide very similar benefits to industry users but carry large risks as they can lead to inefficient spectrum use, spectrum scarcity and large economic costs.

FIGURE 3

IMPACT OF LICENSING APPROACHES ON INDUSTRY AND MOBILE USERS

	Impact on industry users				Impact on mobile users		
	Geographic access	Certainty of access	Certainty of tenure	Interference management	Efficiency of spectrum use	Spectrum availability	Limited economic cost
Set aside spectrum	✓	✓	✓	?	✗	✗	✗
Spectrum sharing framework	✓	✗	✗	?	?	?	✗
Licence conditions	✓	✓	✓	✓	✓	✓	✓

1. The growing demand for private networks



Interest in IMT spectrum from industry users has particularly grown with the advent of 5G. This is because 5G supports ultra-reliable low-latency communications and massive machine-type communication which enable a variety of new use cases in industry and public services. Industry 4.0, is expected to make use of massive connectivity between sensors, devices, and components in manufacturing facilities and supply chains to increase efficiency and productivity. Hyper-connected smart factories may be complemented by smart cities in the long term, while public and emergency services are expected to benefit from highly resilient communications and low-latency applications. Globally, the total impact from 5G is expected to add \$134 billion to industrial manufacturing by 2030¹.

Take-up of private networks has been steadily growing over the last ten years. Private networks will primarily be driven by wireless infrastructure and will thus require access to spectrum for operating efficiently. Although unlicensed spectrum, using technologies such as Wi-Fi, will play an important role, licensed spectrum is likely to be equally important, especially for those organisations that operate mission-critical radio communications systems and need to have certainty of access to spectrum that is free from harmful interference.

There is particular interest from industry users for spectrum in the main mobile bands ('core bands') that are being used by the mobile operators for the deployment of 5G – for example the 3500 MHz band, from 3400 – 3800 MHz, and the 26 GHz band, from 24.25 – 27.5 GHz. The manufacturing sector has deployed the majority of private networks, with most networks relying on spectrum in the 3500 MHz range. Industry users expect that by gaining access to these bands, they can benefit from the IMT ecosystem (e.g., wide range of consumer handsets that already operate in this band) resulting in a lower cost of deployment.

Different regulatory approaches have been taken to address the needs of private networks and public mobile networks in the same harmonised bands. Regulators face a challenge in meeting the demand for IMT spectrum for private networks from industry users whilst at the same time ensuring that mobile operators have the spectrum required to support the development of 5G for the benefit of the wider public.

Despite the growing interest and significant potential outlined above, many private network business cases have yet to emerge while the nationwide deployment of public 5G networks (for both consumers and businesses users of their networks) has continued.

1. PricewaterhouseCoopers, 'The global economic impact of 5G', May 2021

2. Licensing approaches for private networks



The chosen approach to private IMT networks must ideally fulfil the needs of industry better than any alternatives. At the same time, spectrum use by private networks should also generate sufficient value to offset any economic or social cost caused if it prevents access to other potential spectrum users.

While determining the best approach for providing spectrum for private networks, regulators should consider the following needs of industry users:

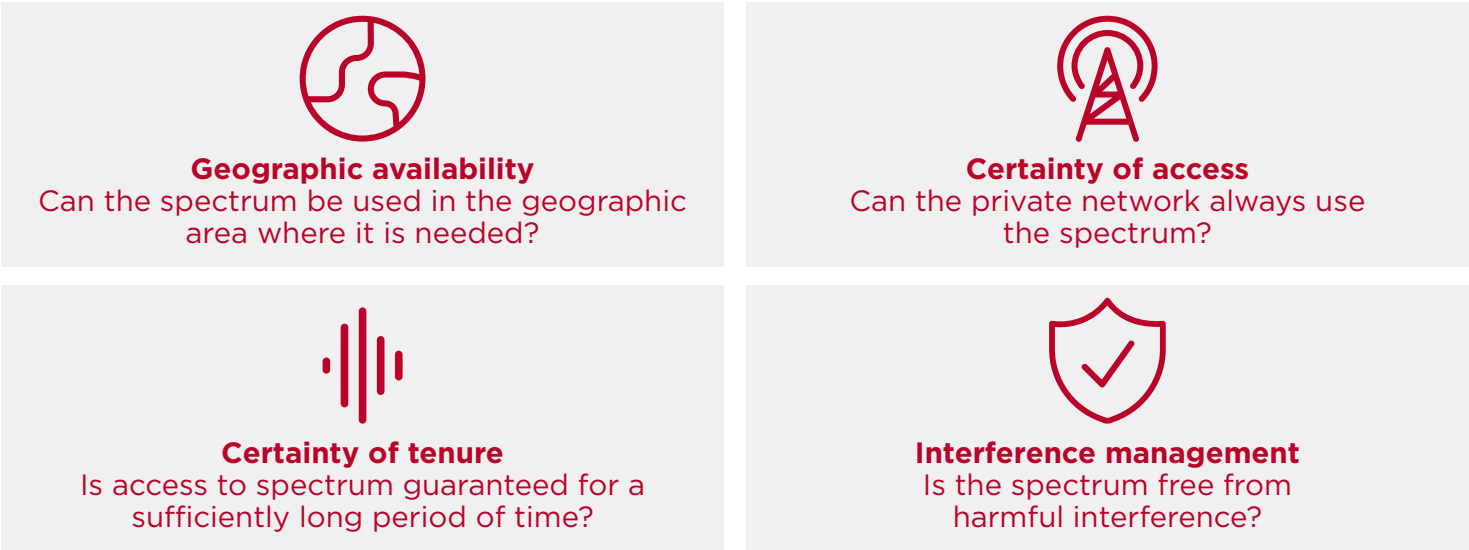
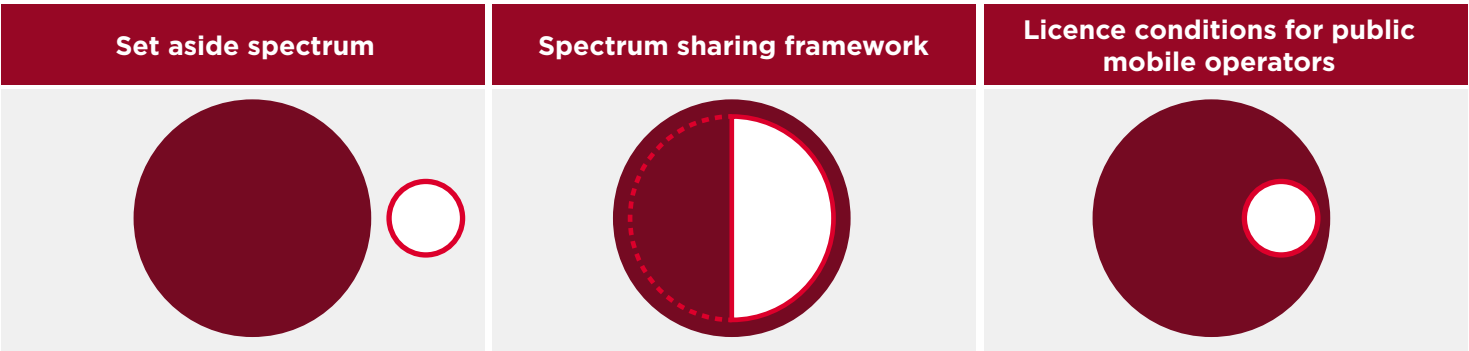


FIGURE 4

APPROACHES FOR PROVIDING SPECTRUM TO PRIVATE NETWORKS FOR INDUSTRY USERS



Assigning a range of spectrum to be exclusively licenced to industry users.

Enabling several users to access spectrum simultaneously.

Enabling or requiring public mobile operators to deploy private networks or lease spectrum.

Setting aside spectrum involves assigning spectrum for exclusive use by industry. Set-aside spectrum is often awarded locally while conditions and pricing often diverge widely from those of wide-area macro 5G licences. Licence conditions frequently include power restrictions and ‘use-it-or-lose-it’ terms – intended to minimise interference and incentivise use across a variety of sectors.

Spectrum sharing frameworks enable several users to access spectrum simultaneously. For example, public mobile network operators with frequencies which are unused in rural areas, or other existing (incumbent) users, such as government, military, or satellite operators, who only need access to a band for a proportion of time or proportion of geographic locations may be required to share the spectrum with other users including industry users deploying private IMT networks. These frameworks are typically designed on a case-by-case basis as national needs vary depending on population, geography, current spectrum holdings, and incumbent users.

Private networks through public mobile operators

- licence conditions can allow for a variety of approaches to deliver private networks through MNOs. Operators may be permitted or required to:

- deploy private networks using their existing network resources including spectrum, including using technologies like network slicing
- deploy private networks using separate spectrum assets
- lease spectrum to industry users wishing to deploy their own networks.

Introducing licence conditions enables flexibility for both operators and industry users.

Spectrum Leasing

- Verticals users can lease spectrum
- Vertical users can negotiate with an operator for a managed service

Network slicing

- Mobile operators can customise their networks to meet the industry user’s needs.

While the specific conditions vary between countries, in general operators are required to charge reasonable, non-discriminatory fees for the service they provide.

3. International case studies



Looking at existing practice shows that regulatory approaches to making available spectrum for private networks and industry users and their resulting impacts can differ widely. As 5G networks for verticals start to be used throughout the world, understanding their enabling regulatory mechanisms will provide value for businesses and consumers.

The case studies assessed in this report have been selected to illustrate how the different approaches to making available spectrum for private networks have been implemented in practice, as shown in Figure 5. The case studies have been grouped to align with the different regulatory approaches introduced in the section above.

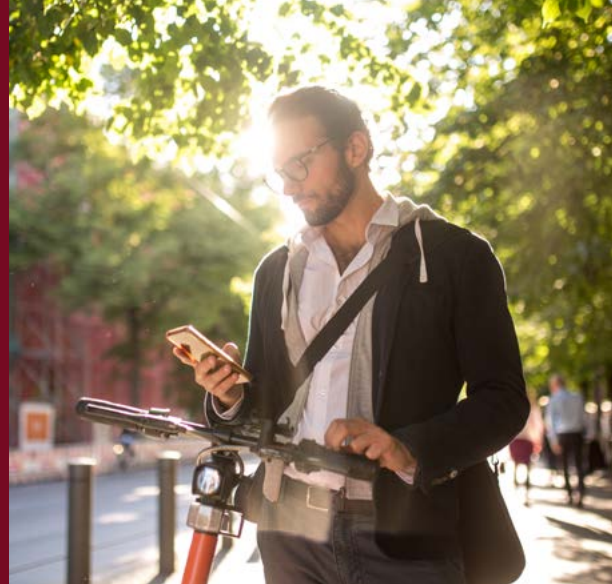
FIGURE 5

OVERVIEW OF THE SELECTED INTERNATIONAL CASE STUDIES

Country	Summary	Regulatory approach		
		Set aside spectrum	Spectrum sharing	Licence conditions
Germany	100 MHz set aside in the 3500 MHz band	✓		
United Kingdom	400 MHz set aside from 3800 – 4200 MHz and access to operators’ unused spectrum	✓	✓	
United States of America	Operators and industry users share access to 3550 – 3700 MHz		✓	
India	Operators may deploy networks or lease spectrum	?		✓
Finland	Obligation for MNOs to deploy networks or sublease spectrum	✓		✓

Germany

3500 MHz set-aside drives high auction prices and promotes inefficient spectrum use



Key lessons

- What:** Set aside of 100 MHz for industry users in 3500 MHz band
- Why:** Creation of incentives for local campus networks and Industry 4.0
- How:** Allocation of low-cost local licences based on application process with eligibility limited to owned/rented premises.
- Impact:** Inflated auction prices by c. €3 billion, whilst industry interest in the set-aside remains limited

Overview

- German regulator BNetzA set aside 100 MHz in 3500 MHz prior to the 2019 spectrum auction to create flexibility for new or developing 5G business cases and Industry 4.0.
- The immediate impact of the set-aside was to create scarcity in the mobile spectrum auction. This ultimately led to no German operator gaining access to 100 MHz in 3500 MHz, with total spectrum prices inflated by up to €3 billion.
- In contrast, interest from industry users remains low, with only 269 campus licences issued to date and mobile operators providing services to industry users using their own, artificially-limited spectrum.
- Furthermore, due to the 'real estate' licensing model chosen by BNetzA, set-aside applications are outside of urban areas, where the spectrum would be needed most by mobile operators, creating inefficiencies in spectrum use.

Background

With German industry contributing nearly 30% to GDP and amid growing interest in Industry 4.0, regulator BNetzA considered options for providing spectrum access for as-yet-unknown 5G use cases. Ahead of the 2019 spectrum auction, BNetzA decided to set aside 100 MHz in the 3500 MHz band for industry users to stimulate the creation of localised campus networks.

Licences for the set-aside spectrum are allocated based on an application process, where only the owner or leaseholder of the respective premise is entitled to apply. The German regulator had expected significant demand, but the expected rush for local licences did not materialise and, since the start of the licensing in November 2019, the number of users has grown slowly.

The (small) licence cost is calculated through a simple formula considering the applied-for bandwidth, licence duration and coverage area – with heavy-traffic or urban areas being priced higher than rural areas. For example, a 20-year 100 MHz licence covering 1km² of production plant premise in urban areas costs about €60.000. While it is not a direct comparison, the contrast to the cost of ~€150 million per 10MHz paid by mobile operators in the auction is significant.

The set-aside includes 'use-it-or-lose-it' and non-interference clauses, and low W_{transmit} powers are encouraged. In addition to the set-aside in 3500 MHz, BNetzA also made the 26 GHz band available under a 'first-come, first-served' approach, with both mobile operators and other users being able to apply for licences.

Main lessons

As of January 2023, about 269 campus licences were issued in the 3500 MHz and an additional 16 in the 26 GHz. Licensees include manufacturers, airports, and research campuses. Most of these licenses are actually not allocated to industry – as initially targeted – but to research institutes, universities or consulting companies. BNetzA does not publish further information on licence duration, area coverage, or bandwidths. However, with only 269 local licences, it is highly likely that the set-aside spectrum is going unused across large parts of Germany.

Furthermore, as the right to apply for the spectrum is limited to the owner / leaseholder / tenant of the area ('real estate licensing model') where the spectrum is meant to be deployed, the spectrum cannot be reasonably assigned in areas with fragmented ownership structures, i.e. it remains unused in city centre and residential areas – where it is most urgently needed by mobile operators. This has created significant inefficiencies in spectrum usage.

In parallel, partnerships between mobile operators and industry players are evolving, with Lufthansa and car manufacturer e.GO relying on Vodafone and Hamburg harbor, university hospital Bonn and machine factory Arburg working together with Telekom Deutschland. Notably, some of these networks utilise the operators' spectrum: innovative solutions are thus possible even without the set-aside.

At the same time, the estimated cost of the set-aside to the industry has been immense. With only 300 MHz of 3500 MHz spectrum auctioned, none of the four operators obtained 100 MHz, with two operators actually acquiring less than 80 MHz. The artificial scarcity induced by the set-aside drove prices to around 300% of those in neighbouring countries where sufficient spectrum was available – leaving German operators paying an excess of almost €3 billion and demonstrating the high financial cost of creating set asides in core bands.



**Dedicated 3.5GHz
set-aside**



**Large economic cost
(to mobile industry)**



**Low take-up to date
(inefficient spectrum use)**

Final impact

By creating the set-aside, BNetzA made up to 100 MHz of crucial 5G spectrum available for 'as-yet-unknown' use cases. In contrast, due to the scarcity induced by the set-aside, none of the mobile operators has access to 100 MHz for deployment today. This prevents the mobile operators from providing the standardised maximum possible performance of their 5G service to German customers.

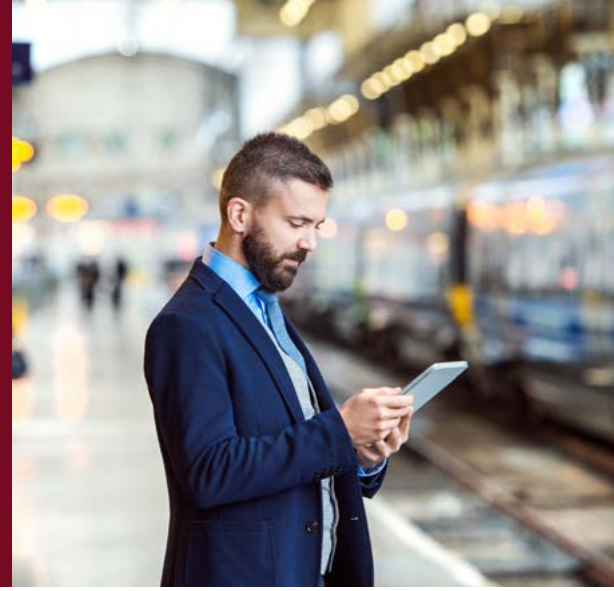
Concerns about the efficiency of spectrum use are exacerbated when considering that only 269 campus licences have been issued so far and industry players

continue to rely on the operators' spectrum assets for deploying campus networks. It appears that BNetzA's stated objectives for the set-aside could have been achieved more efficiently by placing the spectrum in the auction.

Finally, auction prices rose by up to €3 billion as a result of the set-aside. These funds could have been better invested into improving network coverage – a key topic currently pushed by both the German government and BNetzA ahead of the next spectrum auction.

United Kingdom

Unnecessarily large set-aside may require revisiting in future to ensure sufficient supply for mobile



Key lessons

- What:** What: Set aside of spectrum in bands adjacent to auctioned mobile bands to support local and industry users
- Why:** Support for a wide range of local wireless connectivity applications while utilising existing equipment ecosystems
- How:** Allocation of low-cost local licences on first-come-first-served basis
- Impact:** Grant of licences to less than 100 users nationwide, with full bandwidth of set aside spectrum not used anywhere in the country.

Overview

- To 'enable wireless innovation through local licensing', UK regulator Ofcom set aside spectrum for industry users via two different licensing mechanisms.
- Shared access licences offer local access to the 3.8 - 4.2 GHz band as well as frequencies not assigned to national mobile operators in the 1800 MHz, 2300 MHz, and 26 GHz bands. Unused operator-held frequencies in all bands can be temporarily licenced through local access licences.
- Whilst about 1500 shared access licences have been assigned to less than 100 licensees nationwide, actual demand suggests too much spectrum may have been set aside as most licences are only for 100-200 MHz of the 390 MHz available in the 3.8 - 4.2 GHz band. Take-up of local access licences remains limited, mainly due to the uncertainty of tenure for potential licensees.
- Importantly, Ofcom has retained the option of revoking shared access licences - which is critical as the 3.8-4.2GHz band may play an important role in providing additional long-term capacity for mobile use - especially if the band remains underutilised through the current sharing regime.

Background

In its 2019 statement on "enabling wireless innovation through local licencing", regulator Ofcom recognised growing interest in using private networks by sectors such as manufacturing, enterprise, and agriculture. To address this demand, Ofcom proposed two new licencing frameworks - shared access and local access licences.

Shared access licences grant indefinite access to spectrum not licensed for mobile in the 1800 MHz, 2300 MHz, or 26 GHz bands, as well the 3.8 - 4.2 GHz range. Adjacency to licenced mobile frequencies allows industry users to benefit from an existing equipment ecosystem.

Shared access licences are granted on a first-come-first-served basis, with licence fees at £80 / 10 MHz / year, including 'use-it-or-lose-it' terms. Licences allow for the deployment of multiple low-power base stations in a 50m radius, or a single medium-power base station in an outdoor non-urban area.

Local access licences grant access to licensed mobile spectrum in areas where operators have not deployed it and have no plans to do so within the 3-year licence

term. Licences cost £950 per band and cover a single location or area. Operators can ask Ofcom to refuse licences for reasonable objections – for example, interference to existing deployments – and their rights to deploy are unaffected, but they must coordinate with the licensee to mitigate disruption.

Main lessons

As of September 2022, Ofcom has issued around 1500 shared access licences, with 60% of these held by two licensees focused on telecommunication services. The rest are from just 76 licensees, showing limited take-up by users in other sectors.

- Most medium-power licences are for up to 200 MHz in the 3.8 – 4.2 GHz band. With 390 MHz in the band (part of which is assigned to incumbent users), this suggests that supply far exceeds demand.
- The low-power licence applications to date have primarily been for 2 x 3.3 MHz in the 1800 MHz band, where previously existing licences were converted to shared access licences, i.e. this is a continued use of legacy services under a new regime rather than demand for new innovative services.

Only 30 local access licences have been granted to ten different companies over the same period, mostly split between the 1800 MHz and 2600 MHz bands. The low take-up highlights the importance of certainty of tenure – with only a 3-year licence period, any investment carries a significant risk as spectrum may have to be handed back if mobile operators want to use the spectrum themselves.



Spectrum sharing approach



Focus on local licences



Wide range of spectrum bands available



Supply vastly exceeds demand

Final impact

Ofcom made available over 400 MHz for a variety of local use cases through shared access licences. Most licences to date are held by a limited set of users and are only for a fraction of the available bandwidth. While 5G use cases are still emerging, initial take-up thus suggests Ofcom set aside more of the 3.8 – 4.2 GHz band than necessary to support local users.

By moving local demand to the 3.8 – 4.2GHz range, Ofcom has ensured that UK operators have access to 390 MHz of spectrum in the 3500 MHz band, which has enabled 5G rollouts with good median downlink speeds compared to other European countries, according to Ookla.

At the same time, Ofcom has retained the option to revoke shared access licences in case it foresees a better use of the band. This flexibility is important to be able to react to situations where market demand and technology trends evolve, e.g. where there is increasing demand for further mobile capacity, e.g. in the 3.8 – 4.2 GHz band. At that point, it may be most economically efficient to return towards a more traditional model of exclusive nationwide licences for mobile operators – an approach that has served the UK well in the past.

United States of America

High economic cost resulting from tiered access to shared spectrum



Key lessons

- What:** Enabling dynamic spectrum sharing in the 3500 MHz band
- Why:** Protection of incumbent user whilst giving flexible access to other users
- How:** Automatic assignment of spectrum based on three-tiered dynamic sharing system, with strong restrictions on mobile use
- Impact:** Economic cost of \$15-20 billion due to imposed restrictions

Overview

- A 2012 US government report identified 3550 – 3650 MHz as spectrum suitable for spectrum sharing rather than reallocation to mobile use.
- This led to the creation of the CBRS band (3550 – 3700 MHz) using a complex three-tiered priority system aimed at ensuring continued access to incumbent users and allowing access to newly licenced priority users as well as unlicensed users.
- Whilst the CBRS spectrum was auctioned successfully, with more than 90% of available licences sold, the following auction for adjacent 3.7 – 4 GHz spectrum raised four times the price per MHz, suggesting an economic cost of the sharing approach in the range of potentially \$15 – 20 billion.
- With new unlicensed take-up being limited at present, this raises concerns about the success of the sharing approach applied for CBRS and points towards using traditional licencing models in future awards – an approach re-adopted by the FCC in subsequent auctions for similar spectrum bands.

Background

The US government's 2012 "PCAST" Report set out a suggested new direction for spectrum licensing. It suggested that the traditional method of reallocating spectrum from incumbent users to mobile services was outdated and spectrum must be shared. Instead, the report recommended dynamic sharing for certain bands, leading to the development of the Citizen's Broadcast Radio Service (CBRS).

- CBRS utilises three priority tiers, with higher-tier users protected from interference by lower-tier users.
- Incumbent military users occupy Tier 1, while Tier 2 (70 MHz in the 3550-3650 MHz range) is licenced to "Priority Access Licences" (PALs).
- In Tier 3, unlicensed users have access to the entire 3550-3700 when not in use by the incumbent or the priority PAL licence holders, with only an administrative fee charged for a licence.

70 MHz of PAL were auctioned in 2020, with a cap of 40 MHz per bidder at county level. Both priority and unlicensed users must adhere to strict power limits and are lower priority over the incumbent. Also, unlicensed users have no protection from interference, or expectation of exclusive use.

CBRS base stations for priority and unlicensed users are assigned frequencies by a dynamic automated spectrum access system. Environmental monitoring for incumbent users enables the automated system to reassign other users as necessary – including reallocating priority users and removing unlicensed users.

Main lessons

In the 2020 CBRS auction, 91% of the priority licences were sold for \$4.5 billion. The proceeds pale in comparison to the subsequent 2021 auction for 3.7 - 4 GHz spectrum, which raised about four times the price per MHz for spectrum in the same band. This price disparity illustrates the economic cost of placing usage restrictions on valuable mobile bands.

At the same time, there is no evidence of strong take-up by unlicensed users in the CBRS band. Whilst the FCC does not maintain data regarding applications for access to the band, users include public schools, smart

factories, and agriculture users. Furthermore, some mobile operators are utilising the unlicensed frequencies to supplement private network deployments. There are several factors contributing to the limited interest in unlicensed use. Interference between users is not managed, whilst different technologies such as Wi-Fi, WiMAX and other proprietary technologies are being deployed in parallel. Adding this to the lack of certainty regarding spectrum access and the severe power limitations means that the prospect of future widespread unlicensed use looks uncertain at best.



Tiered licensing model



Severe power restrictions



\$10bn+ foregone government revenue



Low take-up to date (inefficient spectrum use)

Final impact

By creating the CBRS, the FCC made available up to 150 MHz of spectrum for shared spectrum use between incumbent users, mobile operators, and industry users. However, the power restrictions, uncertainty of access, and complex deployment methods have contributed to inefficient spectrum use in a valuable mobile band.

This has created a significant economic cost. By looking at final prices in the 2020 CBRS and 2021 3.7 - 4 GHz auctions, it follows that the CBRS restrictions reduced the economic value for mobile operators by about 75%.

With the CBRS auction having raised about USD 4.5 billion, this implies an economic cost of about \$15 billion for the 100 MHz auctioned, rising to \$20 billion if the full 150 MHz available in the band is considered.

These foregone auction proceeds could have contributed to efforts to relocate incumbent users in an economically efficient manner and finding more suitable spectrum bands for shared low-power use, increasing the social value for consumers and spectrum users alike.

India

Dedicated set-aside risks spectrum fragmentation with potentially significant economic cost



Key lessons

- What:** Development of multiple approaches to private networks, including network slicing, spectrum leasing and consideration of dedicated set-aside
- Why:** Provision of different incentives to catalyse Industry 4.0
- How:** Encouragement of interested enterprises to engage with operators
- Impact:** Risk of potentially large economic cost by considering further dedicated set-aside for private networks

Overview

- India's Department of Telecommunications (DoT) aims to encourage the roll out of private networks through different approaches, including allowing cooperation on network deployments and spectrum leasing.
- As industry users and mobile operators are starting to cooperate on private networks, the initial indications are promising that the developed framework is setting sufficient market-driven incentives for cooperation and collaboration.
- Separately, open, non-discriminatory market-based processes may also allow for the acquisition of the required assets, as evidenced by industry user Adani Group acquiring 26 GHz spectrum in the 2022 auction.
- At the same time, the DoT is considering a set-aside in 3500 MHz, 4900 MHz and 28 GHz, proposed by the telecom regulator TRAI - but this appears to be a significant risk as it may take away spectrum from key mobile bands, risking multi-billion economic losses by further fragmenting already limited mobile spectrum holdings in India.

Background

The Indian Department of Telecommunications (DoT) wants to create 'a holistic approach towards emerging digital technologies...and catalyse Industry 4.0'. Private networks play an important role in this endeavour and India is pursuing a multi-pronged strategy to support their growth.

Prior to the recent spectrum auction, the DoT implemented three different approaches, based on TRAI's recommendation, by stating that:

- Private networks can be deployed through 5G network slicing of mobile operator's networks.
- Isolated private networks can be established by mobile operators.
- Mobile operators and enterprises can engage in spectrum leasing to enable private networks to be deployed autonomously.

There was no spectrum set-aside for private networks in the auction. However, one of the winning bidders was the Adani Group, an industry player focused on transport logistics and energy utility, which acquired 50 – 100 MHz in the 26 GHz band in six licence areas for INR 21.2 billion (US\$258 million) having plans to implement private network solutions, including enhanced cyber-security, for its own businesses.

In addition, TRAI has also recommended the set-aside of specific spectrum in the 3500 MHz, 4900 MHz, and 28 GHz bands subject to demand studies to understand market interest. DoT has undertaken a demand-assessment and it is understood that applications have been received from several companies. Based on further analysis of the demand received by DoT, spectrum could be awarded to enterprises directly or administratively at the price determined by TRAI and the DoT.

Main lessons

As of December 2022, seven private networks have been deployed in India. These successful launches illustrate strong future potential and include the first 5G private network deployed by Bharti Airtel for Bosch, and the recent '5G for Enterprise' solution at Mahindra's Chakan manufacturing facility, India's first 5G enabled Auto manufacturing unit.

In the 2022 auction, the Adani Group illustrated that the current policies allow for the deployment of private networks through acquiring spectrum in open, market-based, non-discriminatory processes. This was done in direct competition with mobile operators without preferential treatment for either party. As per the

company's statement, the company now plans to deploy private network solutions, including enhanced cyber-security, for its own businesses initially which can be further extended to other customers.

These market-based initiatives contrast with the final option considered by the DoT based on the recommendations of sector regulator TRAI – namely to set aside spectrum in the 3500 MHz, 4900 MHz, or 28 GHz bands. This interventionist measure carries a significant risk of further fragmenting spectrum bands in India – a market already marred with high spectrum costs and less amount of holdings by operators, holding back the evolution of the mobile market.



Flexible approach to private networks



Non-discriminatory market processes



Cooperation encouraged (between MNOs and verticals)



Risk of spectrum fragmentation

Final impact

With its current policies, the DoT has developed a policy framework that has created initial market interest, fostered cooperation between mobile operators and industry users, and incentivised participation of new players in the 2022 spectrum auction. Although it is too early to judge the success, the framework enabled private network solutions without the need for dedicated set-asides in key mobile bands.

The 2022 spectrum auction illustrated the significant interest in 3500 MHz and 26 GHz spectrum bands by mobile operators. All bands considered by the DoT for the set-aside are likely to play a vital role in providing

future capacity on Indian networks. With the mobile data ecosystem contributing an estimated \$136 billion to the Indian economy, the economic cost of further fragmentation could be in the billions.

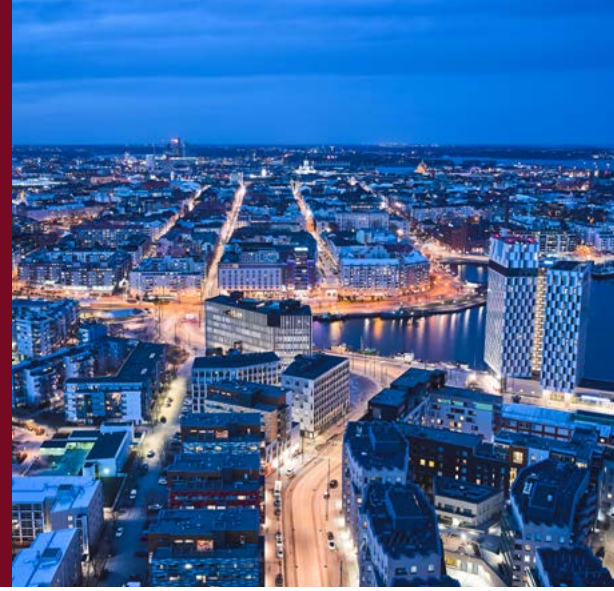
Only an open award process in these bands can now allow both mobile operators and industry users to compete on a non-discriminatory basis for the remaining spectrum. While providing a level playing field for operators and industry players alike, the DoT must ensure that licence conditions are not favouring any party, efficient spectrum use is guaranteed (e.g. through 'lease-it-or-lose-it' clauses) and any further fragmentation is avoided.

2. <https://www.airtel.in/press-release/07-2022/airtel-deploys-indias-first-private-5g-network-at-bosch-facility>

3. <https://www.airtel.in/press-release/12-2022/airtel-partners-tech-mahindra-to-deploy-captive-private-network-at-mahindras-chakan-facility>

Finland

Incentivising innovation without set-asides through licence conditions and cooperation



Key lessons

- What:** Obligation for 3500 MHz licence holders to negotiate private network contracts or sub-licence spectrum
- Why:** Deployment of innovative industry uses without affecting mobile usability
- How:** Requirement for operators to respond to tenders launched by industry users to negotiate access to 3500 MHz
- Impact:** Increased collaboration between operators and industry whilst providing strong investment incentives in 5G mobile networks

Overview

- The objective of the Finnish traffic and communication ministry and regulator has been to make Finland a 5G frontrunner in research and development, promoting innovative business solutions.
- To foster the deployment of local private networks in Finland, 3500 MHz licence holders were required to provide network services on request or to sub-licence the spectrum.
- This approach has positively contributed to an increasing number of innovative cooperations between industry users and mobile operators – even where the local services have not been actively requested as defined in the 3500 MHz licenses.
- At the same time, the absence of a set-aside in one of the key mobile bands has ensured Finnish operators were not inhibited and could quickly deploy 5G using up to 130 MHz.

Background

As part of a policy to promote Finland as a 5G innovator and testbed, licence conditions in the 3500 MHz mobile spectrum auction in 2018 fostered the provision of private network services without a dedicated set-aside.

The licence conditions stipulate that mobile operators must, where requested by tender, deploy a private network that meets the specified customer needs in a localised area, such as a hospital, port, or industrial facility. Operators can charge reasonable, non-discriminatory fees for these deployments. Alternatively, if they consider the tender requirements overly onerous, they must sub-licence 3500 MHz spectrum within the specified area instead.

Separately, enterprises as well as research and educational facilities (or the operators providing services for such users) can apply to Finnish regulator Traficom for local access to a dedicated set-aside of 20 MHz in the 2300 MHz band and 850 MHz in the 26 GHz band. In these bands, up to six-year licences are granted to applicants on a case-by-case basis. The fees are affordable by design and depend on the requested bandwidth and population coverage. Networks

operating outdoors in close-by geographic areas must subsequently synchronise to avoid interference, whilst some areas have significant restrictions in the 2300 MHz band due to incumbent usage by wireless cameras. Whilst the use of these bands is limited to private and minor public service in a local area, the applicant for the set-aside can also be a mobile operator, reflecting their role in providing tailored local services.

Main lessons

In February 2022, Telia became the first mobile operator globally to deploy a virtual private network based on slicing and edge computing. The installation was made at Swedish company Sandvik's Finnish test mine. Further private network deployments, with mobile operators as a partner, include projects for automated port operations, mission-critical networks for nuclear waste disposal, and for improving safety and operations in a gold mine.

Traficom does not publish details of the take-up of private networks or spectrum leasing. However, the test cases highlight the incentives for deploying innovative 5G networks inherent in the 3500 MHz licence conditions, fostering cooperation between operators and industry users.

According to Traficom, eleven licensees are using the 2300 MHz set-aside, and only four licensees are using the 26 GHz set-aside as of September 2022. Whilst the 2300 MHz band is not used for wide-area mobile services in Finland today, the band has been made available in neighbouring countries – therefore, this comparatively small set-aside may create a long-term economic cost by hindering a re-assignment of the band to public mobile networks if the clearance of other uses in the 2300 MHz band is possible in future. Such concerns are less prevalent for 26 GHz, where mobile operators today have access to 800 MHz each.



Obligations via licence conditions



Focus on cooperation (between MNOs and verticals)



Cutting-edge pilot projects emerging

Final impact

Finland met the spectrum needs of nationwide and private networks without a set-aside in any core bands. In doing so, the authorities created an efficient compromise that has preserved spectrum usability and created incentives to invest in mobile connectivity.

Finnish operators are among the world leaders in 5G deployment. Telia had infrastructure ready ahead of the auction in September 2018, allowing it to launch a pre-commercial network in November 2018. All three operators launched 5G services in 2019 and expanded network coverage throughout the coming years. Telia then launched 5G Standalone in November 2021, making it one of the first operators to do so in Europe.

Finland has seen successful and innovative cooperations between industry and mobile operators, whilst there has been relatively limited interest for licenses in the spectrum reserved for local mobile licenses in the 2300 MHz and 26 GHz bands. In a country where mobile data use per population is among highest in the world, future spectrum allocations should take these developments into account, relying on cooperations where possible rather than raising the risk of underutilised spectrum assets through dedicated set-asides.

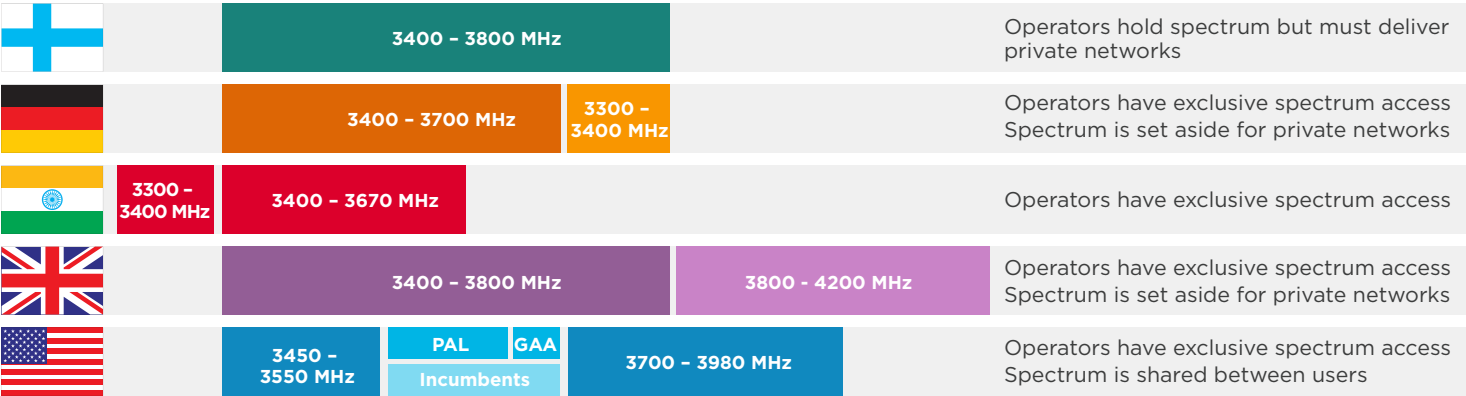
4. Learning from the case studies



The case studies show that approaches to making available spectrum for private networks and industry users and their resulting impacts can differ widely. They range from the cooperatively-minded, non-interventionist approach taken in Finland to the high economic cost created by set-asides in Germany or spectrum sharing in the United States. This is illustrated in Figure 6 below, showing how, across the case studies, a variety of approaches have been applied to the 3500 MHz band.

FIGURE 6

APPROACHES TO MAKING 3500 MHz SPECTRUM AVAILABLE FOR INDUSTRY USERS



In this section, we review the impacts that we have observed from the case studies and link these back to the characteristics inherent in the approaches chosen by regulators – a summary of our findings is provided in Figure 7 below.

FIGURE 7

IMPACT OF LICENSING APPROACHES ON INDUSTRY AND MOBILE USERS

	Impact on industry users				Impact on mobile users		
	Geographic access	Certainty of access	Certainty of tenure	Interference management	Efficiency of spectrum use	Spectrum availability	Limited economic cost
Set aside spectrum	✓	✓	✓	?	✗	✗	✗
Spectrum sharing framework	✓	✗	✗	?	?	?	✗
Licence conditions	✓	✓	✓	✓	✓	✓	✓

4.1 Impact on industry users

In Section 2, we highlighted the key requirements that private networks have for spectrum assets:

- Geographic availability: can the spectrum be used in the geographic area where it is needed?
- Certainty of access: can the private network always use the spectrum?
- Certainty of tenure: is access to spectrum guaranteed for a sufficiently long period of time?

- Interference management: is the spectrum free from harmful interference?

Based on the insights from the case studies, we have analysed whether the three different regulatory approaches identified in Section 2 can meet the needs of industry users.

FIGURE 8

CAN DIFFERENT ASSIGNMENT APPROACHES MEET THE REQUIREMENTS OF INDUSTRY USERS?

	Impact on industry users			
	Geographic access	Certainty of access	Certainty of tenure	Interference management
Set aside spectrum	✓	✓	✓	?
Spectrum sharing framework	✓	✗	✗	?
Licence conditions	✓	✓	✓	✓

4.1.1 Geographic access

The requirement for suitable geographic access can be met by all regulatory approaches. Across the case studies, we observe that spectrum is typically made available for localised areas rather than as nationwide licences. This reflects the needs of industry users - ubiquitous access is not needed for private networks and the higher costs associated with nationwide licences would negatively affect industry demand. The one exception in our case studies is the approach

chosen by the Adani Group, which acquired 26 GHz licences in several licence areas in India rather than in specific locations (which was simply not possible given the award mechanism). Buying spectrum regionally is understandable given the group's stated business ambition to serve a variety of users in currently unknown locations. As long as the long-term spectrum management framework in India is sufficiently flexible to allow for localised trading / sub-licensing, it should be possible for this spectrum to be used efficiently in the long term.



4.1.2 Certainty of access and tenure

Both set-asides as well as licence conditions for mobile operators provide sufficient certainty of access and tenure for industry users to deploy networks. The set-asides of 100 MHz of 3500 MHz in Germany and 20 MHz of 2300 MHz in Finland defined clear minimum licence periods and ensured that, ultimately, the industry users will be the primary spectrum user in the areas for which they seek access. This investment certainty can have an impact on take-up and provide the relevant security to make significant long-term investments into private networks.

In contrast, the situation is less clear in the case of spectrum sharing. The approach to shared access licences in the UK provides some certainty for private networks in the short- / medium-term and take-up has been stronger in this category. However, local access licences are only awarded for a period of three years.

The situation created by the CBRS system in the United States is even less certain, where unlicensed users may lose access to the spectrum at relatively short notice and for an undetermined period of time. The impact of this uncertainty is likely to reflect in the take-up of services and the willingness to commit to this band.

A company that wants to rely on private networks for the operation of its plants cannot have uncertainty over network availability. It thus follows that the shared spectrum approach will be unsuitable for users where a lack of spectrum access presents a business risk to the user.

4.1.3 Interference management

Within the case studies, there is a wide variation of how interference management is handled. For the set-asides, there are typically interference management licence conditions like those seen in mobile licences. Private networks will normally be subject to co-existence criteria for use of the spectrum.

Interference is most poorly managed in the case of the unlicensed CBRS spectrum. The same spectrum can be used for a variety of technologies, raising the risk of interference between users – whilst unlicensed users also must ensure that they do not cause interference to incumbent and priority users. For use cases involving mission-critical or military applications, interference-free access to spectrum will be particularly important and, again, shared spectrum access is unlikely to be workable for them.

Spectrum access granted via specific licence conditions is likely to give the best protection from interference. The mobile operators providing the access / spectrum will have clarity to manage co-existence either with their own or with other mobile networks. They can either set up the private network or integrate it into an existing public network and will be able to deliver clearly defined operational parameters to the private networks. This approach is likely to minimise the risk of any interference and provide the best interference management.

4.1.4 Additional observations

In addition to the above-mentioned aspects, other criteria such as the available bandwidth or the price of spectrum will be important aspects for private networks. However, there are no obvious reasons why any of the three analysed approaches should be particularly well-suited to provide certain bandwidths or raise higher fees. In all three approaches, we have seen more than 100MHz being made available for private networks – providing ample capacity – and we have also seen a focus on providing low-cost access to spectrum to incentivise take-up.

Interestingly, demand from spectrum users also does not appear to be driven by the approach that underlies the spectrum assignment. Interest in 3500 MHz in Finland seems comparable to that in Germany, despite Finland not using a dedicated set-aside.

From looking at the case studies, interest has certainly been higher in the harmonised mobile bands like the 3500 MHz band. When spectrum is made available within core bands, it enables private network users to benefit from existing equipment and technology ecosystems. The interest in spectrum is thus more driven by the available ecosystem rather than the prospect of exclusive licences.

One likely reason for the ambivalence to the licencing mechanism is that enterprises, even in countries which have applied a spectrum set-aside such as Germany, have ultimately still contracted mobile operators to deploy networks on their behalf – suggesting that the network expertise and economy of scale provided by the mobile operators can be more valuable than the freedom offered to industry users to independently deploy their own IMT networks.

4.2 Impact on mobile markets and mobile users

The case studies highlighted several key risks that will have to be considered as spectrum assignment decisions are made by regulators:

- Excluding mobile operators from spectrum bands can negatively impact efficiency of spectrum use.
- Too much bandwidth may be reserved for private networks.

- A large economic cost can be created by spectrum assignment decisions.

These risks do not apply equally to the different licensing approaches, as highlighted in Figure 9 below and further explained in the following.

FIGURE 8

IMPACT OF LICENSING APPROACHES ON INDUSTRY AND MOBILE USERS

	Impact on mobile users		
	Efficiency of spectrum use	Spectrum availability	Limited economic cost
Set aside spectrum	✘	✘	✘
Spectrum sharing framework	?	?	✘
Licence conditions	✓	✓	✓

4.2.1 Inefficiency of spectrum use

Within some of the case studies, spectrum has been reserved for exclusive use by private networks, which, by definition, precludes other users, such as mobile networks, from accessing the spectrum.

Such an approach is justified, if take-up of the band for private networks is high or if no take-up by other services is expected. However, it is unjustified if take-up by private networks is low and a significant use by mobile operators could be expected.

A prime example of inefficient spectrum use is the set-aside of 3500 MHz spectrum in Germany. As of end-2022, only c.270 licences have been awarded to industry users. In contrast, the band is a key asset for mobile operators looking to provide sufficient capacity to meet the growing capacity demand from 5G. Spectrum use would have been more efficient if this band had been made available primarily for mobile operators.

The German approach contrasts with the set-aside for a small amount of 2300 MHz in Finland. The set-aside of a small amount of spectrum in a band that currently cannot be used for nationwide mobile services in Finland, but has an international ecosystem, potentially increases the efficiency of spectrum use without harming other users.

4.2.2 Excessive bandwidth for private networks

In the United Kingdom, 400 MHz has been made available for shared access licences in the 3800 – 4200 MHz range. At the same time, current standards do not support such large bandwidths in this frequency range. Nor has there been any demand from licence holders for such large bandwidths.

Making large bandwidths available, beyond those usable by a single operator, makes intuitive sense if an exploitation of the spectrum assets by multiple users in the same geographic area is expected. However, in the case of private networks, it is highly unlikely that multiple users will simultaneously make use of the band in the same (limited) area, especially if power limits are set such that they encourage re-use in clearly-defined, small geographic areas. It follows that making a smaller amount of spectrum available (100 – 200MHz) likely would have been sufficient – by making this larger amount available, there is a risk that future assignments to other services, such as mobile, have become more costly as users may need to be migrated in the long term.

4.2.3 Large economic cost

The biggest risk from dedicated spectrum set asides is the economic cost resulting from spectrum assignments that impact other potential users, such as mobile operators. This becomes very clear when looking at the case of Germany, the United States and India:

- **Germany:** BNetzA set aside 100 MHz of immediately usable 5G spectrum for 'as-yet-unknown' use cases. This left just 300 MHz in the band for auction, with four interested bidders. As a result, no operator could acquire 100 MHz and the artificial scarcity drove prices up by almost EUR 3 billion compared to auctions without this scarcity. It is highly unlikely that the private networks which have since started using the spectrum could not have been served in a different way without creating this cost.
- **United States:** By sharing the CBRS spectrum between the incumbent users and other potential users and creating limitations on geographical availability, certainty of access and the amount of power to be used, the value of the spectrum to mobile operators was significantly reduced. Comparing the prices for spectrum in the CBRS auction to the subsequent auction for very similar spectrum in 3800 – 4000 MHz suggests an economic cost in excess of USD 20 billion.
- **India:** In India, spectrum in various key mobile bands is currently considered for a set-aside to private networks. With spectrum fragmentation in India already high and mobile usage growing, taking away spectrum from mobile operators could negatively impact the development of the market significantly. The mobile data ecosystem contributes an estimated \$136 billion to the Indian economy, meaning that the economic cost of further fragmentation could be in the billions.

As illustrated by the case of Finland, similar interest for private networks could have been created through alternative means – without the high economic cost. It should naturally be noted that making the CBRS spectrum available would have required the migration of an incumbent user. However, the additional economic value generated by making less-restricted spectrum available could have contributed to a migration without negatively affecting the current user.

5. Conclusions



Different approaches to making the spectrum available can be applied by regulators to meet demand for private networks. Conclusions can be drawn from the five international case studies.

Interest is mainly driven by properties of the spectrum band rather than the licensing mechanism

- Within the case studies, we observe no noticeable interest in demand for spectrum based on the licence approach chosen by the regulator.
- Interest is highest in widely harmonised bands such as 3500 MHz, which has an established ecosystem to support a variety of private network use cases.
- Industry users look to benefit from existing ecosystems and standardisations above and beyond any assignment mechanism.

Set-asides offer no strong advantages to operator-supplied private networks and can create large costs

- Industry users will require spectrum to be made available within the relevant geographical area, with certainty of access and tenure, free from interference with other users.
- Across the international case studies, set-asides are performing reasonably well for industry users across all these dimensions. However, they do not outperform alternative approaches, such as appropriately designed licence conditions, which have none of the negative impact to the mobile market.
- At the same time, the economic cost for mobile operators created by set-asides can be enormous, as indicated by the estimated EUR 3 billion cost generated by the set-aside in the 2019 auction in Germany.

Spectrum sharing frameworks are complex and carry risks on certainty of tenure and access

- Spectrum sharing frameworks have a lot of initial theoretical appeal. In principle, they should allow for the spectrum to be shared by different users in different areas and thereby enhance the efficiency of spectrum use.

- Frameworks can be complex to design, as illustrated by the long time taken to implement the CBRS in the United States.
- Sharing frameworks do not guarantee access to spectrum or long-term tenure, thereby reducing the investment certainty for industry users and curtailing demand. In the United States, access to CBRS spectrum can be revoked at short notice. In the United Kingdom, there are no guarantees for shared or local access licences to be extended in the long term.
- Sharing frameworks can have a large negative impact on mobile operators. In the United States, we estimate that the restrictions to CBRS created an economic cost in excess of USD 20 billion.

Appropriately designed licence conditions are least intrusive and stimulate cooperation

- In Finland and India, spectrum management frameworks have been put in place that enable discussions between mobile operators and industry users to jointly develop private networks.
- Whilst these frameworks do not provide dedicated access to the spectrum to industry users, we observe no noticeable difference in industry interest compared to the more interventionist approaches to making spectrum available.
- This approach capitalises on a trend across all countries, that most networks are created in cooperation between mobile operators and industry users anyway, to make use of the knowledge and experience of mobile operators in deploying wireless networks.

This report thus illustrates the caution that has to be taken when making long-term decisions on spectrum assignments and highlights that market-driven approaches that foster cooperative solutions can bring the best outcome for spectrum users and consumers alike.

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