Why has spectrum sharing been so hard to accomplish?

Martin Cave and William Webb[1]
October 2017

1. Introduction

About 5 years ago we wrote an article bearing on spectrum sharing entitled 'the Unfinished History of Usage Rights in Spectrum'.[2] This is an attempt to bring the story up to date. As the reader will infer from our current title, one feature which does fully survive in the present update is use of the word 'unfinished.' Five years on, although our understanding of the problem has changed, the project of increasing the effectiveness of our use of spectrum by sharing is still not so much in the foothills, but with the foothills still in fairly distant view.

So what has changed? One background feature is that the momentum of spectrum user rights (SURs) (defined as a limit on the interference that can be expected from others in the same and neighbouring bands) as the primary way of controlling interference appears to have faltered. Conceptually, SURs are a much more satisfying and unified means of defining the (increasingly interlocking) entitlements of a spectrum users. However, the traditional method of apparatus licensing has survived from the era of, predominantly, exclusive access to licensed spectrum, is well-understood by incumbents, and is likely to form a backdrop to the development of sharing.

The other lesson we derive from the past five years is that legacy spectrum users, unsurprisingly, continue to bring forward objections to sharing. And why should they not? At best, sharing subjects both public sector and commercial users of spectrum to greater risks of interference, if the technical processes of sharing falls down. It may, in addition, subject incumbent commercial users to more competition in downstream markets, which reduces the rents which they earn from access to spectrum. And incumbents may pick up some of the costs of sharing which they might otherwise avoid.

The situation is different when access to spectrum is competitively tendered in a primary or renewal auction, in which bids can take account of the above factors, and bring down spectrum prices. But this has not prevented mobile operators in particular from arguing strenuously for the familiar model of exclusive licensing.

The general theme of this paper is that, for reasons which include those given above, spectrum sharing, at least in its early stages when legacy rights seem to be threatened and apprehension is at its height, requires significant leadership and incubation by the spectrum regulator. This arises because, as well as dealing with the divergent incentives affecting different players, there is a huge problem of technical and commercial co-ordination. At this early stage, the best approach may not be to seek to draw up general or universal rules concerning sharing but to fix up commercially viable sharing outcomes in selected cases. This approach allows a variety of

[1] Imperial College Business School & Director, Webb Search, respectively. Contact address: Martin.e.cave@btinternet.com
[2] Martin Cave and William Webb) 'The unfinished history of usage rights for spectrum', *Telecommunications Policy*, 36 (2012) pp.293-300.

approaches to be trialled in controlled experiments in bands with different characteristics. If put into effects in different jurisdictions, there is significant scope for international learning.

However, we start by examining some general principles relating to the modalities of defining access rights, and how incentives to share on a voluntary basis can be harnessed: these can help to define possible solutions in different bands. We also look at the lessons of illustrations of sharing – some (such as TV white spaces) already in place, others (such as the trial with the CBRS band in the US) in the early stages of design and implementation.

Accordingly, section 2 looks at the definition of access rights in a sharing regime and how they can be assigned, and examines incentives to share, affecting public sector and commercial users; section 3 examines how the differing characteristics of frequency bands from 700MHz to 60GHz such as the propagation range and incumbent users influence the approach to sharing; section 4 covers lessons learnt from the TV white space, predominantly in terms of process and database management; section 5 discusses the CBRS approach and how it might transpire; section 6 looks at sharing in the so-called mmWave bands which have become a topic of interest with the advent of 5G. Section 7 contains our conclusions.

2. Access rights in a sharing regime

Currently, in most instances, a spectrum licensee's rights have been defined by giving them a maximum transmit power up to which they could operate specified apparatus at a specified location for a specified purpose; they also received an undertaking that they would not suffer harmful interference - a term that was generally ill-defined. The licensing system easily accommodated temporal sharing by time of day, day of week, etc., and geographical sharing was built into the system via the specifics of the transmission limits placed on the equipment.

This regime co-existed side-by-side with unlicensed spectrum, to which users had access without the need for permission, provided that they complied with restrictions on the characteristics, notably the power, of the apparatus which they used. But access to most spectrum bands in any given geographical area was confined to a single user.

Did this mean that the licences were exclusive? De facto, in the vast majority of cases, they were. But in several spectrum management jurisdictions, including the UK[3], the regulator retained the power to insert additional licensees into the relevant space, provided such insertion did not degrade the incumbent's licensed access to the band. But this did not give other users the automatic right to enter that space and exploit unused spectrum. Where this has occurred (notably with respect to TV white spaces – see section 5 below) it has been accomplished by the regulator intervening to make special arrangements. This particular disposition of spectrum access rights could, of course, be changed; in principle the licence to any band could allow any secondary user to utilise unused spectrum capacity within it.

This type of licensing is often termed "apparatus licensing". It is inflexible, as any change of technology, let alone a change of use, requires a new modelling exercise to control interference. In some jurisdictions an attempt has made in recent years to define the rights of licence holders in terms of the maximum level of interference they can inflict on out-of-band or out-of area users. But so far this new approach has gained limited traction[4], and apparatus licensing is the dominant mode of spectrum management.

[3] Thus Ofcom writes: "..no Wireless Telegraphy Act licence is exclusive, and we have discretion to authorise multiple uses of licensed frequencies, for any purpose, in line with our statutory duties." *A Framework for Spectrum Sharing*, April 2016, page 2.

[4] This approach is often called spectrum usage rights (SURs). It has gained limited traction largely because it is complex, and because incumbents view any change in licensing approaches as risky.

Spectrum shortages have focussed attention on mobilising and sharing unused spectrum in licensed bands, particularly below 6GHz. Much impetus was given to this by an influential report delivered to the US Government in 2014.[5] The key innovation in the new approach is that the identity of the operator with access to the spectrum at any moment is not determined in advance, but can emerge from a real-time process in which different users, arranged in a hierarchy, take precedence over one another in accordance with that hierarchy. This can be accompanied by an arrangement in which operators can be on the same level in the hierarchy, with access being determined either on a 'first-come, first-served' basis, or randomly, or by rotation. An example of a regime of this kind is described in section 5 below.

The considerations noted above have been founded on widely used current arrangements for assigning spectrum licenses, which are broadly characterised by two parallel regimes:

- Spectrum licences which are auctioned, or otherwise assigned competitively, for a specified period, which may be tradable across operators in the course of that period; this category of licences is normally used for commercial purposes[6]
- Spectrum licences or authorisations which are assigned on an administrative 'command and control' basis, either to private sector bodies or to public sector organisations (notably in the defence field).

Spectrum can be interchanged between these two groups. This may occur to a licence formerly assigned by command and control, either when a licence formerly assigned administratively is auctioned and/or when spectrum previously used in the public sector is re-allocated for commercial purpose.

With the advent of widespread sharing, it is natural to revisit the efficiency of these arrangements, not least because the regime acquires a major new and variable component: the choice in the case of each band of the relevant shares and sharers. This leads to a reconsideration of the costs and benefits of the alternative assignment methods. We do this in two stages. First, we speculate about what a developed system of this kind might look like. Then we consider the obstacles which may exist to getting there, and how they might be overcome.

Market approaches to the design of sharing arrangements

It is thus useful to ask whether there is a solution to this problem which leaves more power to the market place. At least two solutions can be identified – differing in the manner, noted above, in which 'exclusivity' is defined.

In the first version, a single licensee is allocated full rights of access to all of the spectrum within given geographical and band limits, subject to restrictions on emissions at the boundaries. In this scenario, the regulator's involvement can be limited to authorising the trading of 'sliced and diced' access rights within the specified licence, and collecting information from participants in sharing contracts sufficient to enforce the rights of adjacent users outside the sharing arrangement. (In the limit in which the licensee itself makes no use of the spectrum, its role would default to that of a 'band manager'). In this minimally regulated scheme, disputes between sharers would be resolved by the courts under the law of contract, and the original licensee could be held responsible for any illegitimate interference imposed by any of the sharers on an external party.

PCAST, *Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth*, available at: https://obamawhitehouse.archives.gov/blog/2012/07/20/making-most-wireless-spectrum.

[6] For a proposed auction regime for selling lower tier rights in a leased spectrum access (LSA) framework, see

By way of illustration, it has been widely noted that there is no necessary reason to prevent licensed spectrum access (LSA), a form of sharing developed in Europe[7], from being largely replicated contractually by the primary licensee, at least in some jurisdictions. Interestingly, the reason cited for making it a product of public regulation, rather than of private contracting, has on some occasions been the greater certainty of enforcement that public law can bring to bear.

It will be clear from this formulation that unlicensed operators (apart from low power ones which interfere with no other transmitter) can only be added to the mix in this regime to the extent that they are known either to the licensee or to the regulator. Thus, the only unlicensed use compatible with the arrangement for enforcement described above seems to be the 'traditional' unidentified unlicensed users subject to power restrictions on their equipment.

In the second version, the licensee is assigned an apparatus licence, which does not fully exhaust the potential of the spectrum concerned – for example, not all the spectrum potentially available may be required by the licensee; or it may not be used continuously; or it may not be used in the full geographical area for which it is assigned.

In these circumstances, an overlay licence can be issued, which entitles the new licensee to use any spectrum not exploited by the incumbent[8]. As Thomas W Hazlett, an eloquent supporter of such an approach, notes:

> "Incumbent interests are untouched. But the new rights enable bargains tapping fresh collaborative energies. Entrants and incumbents are able to explore options for rooting out existing rigidities, unleashing higher valued services. If they can spy such opportunities, and then craft an agreeable split of the gains from trade, they walk away happy. Contentiousness over shifting spectrum use becomes a game to create lucrative innovations."[9]

By way of precedent for such Coasian bargaining, geographically contiguous licenses have been known to agree to small changes in the configuration of their transmission apparatus to their mutual benefit, whether by barter or monetary payments. With overlays the gains from trade are multiplied. Given that both the incumbent and the overlay entrant are licensed, it would be natural for the regulator to enforce interference obligations imposed on both licensees, with respect to one another and with respect to other spectrum users.

It is worth pointing out that sharing both creates opportunities for, and imposes additional burdens on, a spectrum market place. In a world of exclusive licences, a single trade can transfer the right of access to spectrum to a more efficient user. But the more idiosyncratic structure of a shared right limits the universe of potential purchasers, which might have to contract not only with the seller of the right but with those sharing the band with the seller.

How can greater flexibility be delivered? In the first version discussed above, the primary licensee might seek to draw up a more elaborate or complete contract which takes account of various contingencies; or it can reserve for itself the ability to vary the rights it grants to its contracting party – possibly subject to an obligation to compensate that party for loss of access. In the second version with multiple licensees, the regulator is involved. In principle it might seek to introduce flexibility into the licences it grants, by giving itself codified rights to vary

[7] Under LSA a small number of licenses are issued to secondary users who must not interfere with the primary user. By restricting the number of secondary licensees some understanding of the future interference environment can be provided.

[8] For example, a rural community might self-deploy a cellular solution in a geographical area where mobile operators have not rolled out their network.

[9] Thomas W Hazlett, *The Political Spectrum*, Yale University Press, 2017, pp 278-9.

some of its parameters. This would increase flexibility but the equal and opposite loss of certainty would reduce the willingness to pay for licences.

Incentives to share in the commercial sector

These two mechanisms may offer beguiling prospects, and, according to Hazlett, the latter has undergone 'proof of concept' in the United States.[10] But are they realistic? We begin by considering whether incentives are in place to achieve them in either case.

The first variant requires an initiative on behalf of (effectively) an exclusive licensee. We separate the discussion between the cases of a private sector licensee, driven by the profit motive, and a public sector spectrum user, whose motives are sometimes harder to penetrate.

A commercial licensee with access to more spectrum than it needs at first sight faces a simple test in deciding whether to share: does the profit from sharing exceed its costs? The maximum revenue for the licensee as rentier is based on the joint or several willingness to pay of potential sharers in the licensed band, some of which may have other options for access to spectrum. The costs comprise two elements; the cost of doing the transaction (to which we revert below), and the loss of profit resulting from downstream competition from the sharer. Unless expressly prohibited from refusing to supply downstream competitors, a licensee which is not dominant in the relevant spectrum or downstream anti-trust market would normally have the right to exclude downstream competitors if it were profitable to do so.

In the second case of overlay licenses, a commercial incumbent only has a choice as to whether to contract further with the new licensee, not whether to acquiesce with sharing its spectrum. In this case, the spotlight turns on incentives for both the entrant and the incumbent. What can each do with and without the other's co-operation? What will it have to pay to get it? Over what time horizon might it be available? What probabilities attach to the various possible outcomes? In this respect calculation is akin to that of a firm buying land which can only be developed in conjunction with land of its neighbours. In both cases the price of the asset (land for development or overlay licence) is determined on the basis of the answers to the above questions.

The other 'cost of entry' for all participants is the cost of implementing the sharing arrangement. At this stage of the development of sharing, this is likely to be high. This point came out in Ofcom's 2016 consultation on spectrum sharing:[11]

> "Stakeholders ... argued that transaction costs can be prohibitive, particularly where the value to an individual potential user is small, and said that licence holders may be unwilling to devote management time to developing spectrum sharing arrangements at the expense of focussing on their core business. [One] noted that market barriers may be particularly significant where there is little or no experience of sharing spectrum, given the initial effort required."

In other words, this is an area where there is a lot of scope for learning by doing, with the result that no-one wants to lead, but prefers to be a 'fast follower.' This may support an argument for either subsidising innovative sharing experiments (possibly by conducting a tournament to compete for available funds), or for the regulator to get involved directly as a 'broker' of the sharing arrangement.

Sharing with the public sector.

[10] *Ibid*. page 278
[11] Ofcom, *A Framework for Spectrum Sharing*, April 2016, page 19.

Public sector spectrum holders have rather more complex objectives than private sector ones, often resulting from their softer budget constraints and complex or even incalculable objectives. In many jurisdictions they occupy about half of the spectrum, spread across all bands, so it is vital to pay attention to their sharing potential.

Attempts to encourage economy by public sector spectrum users fall into two categories, which can be combined:

- a) use of economic incentives in the form both of 'sticks,' (such as annual spectrum access charges, or facing a requirement to buy spectrum in an integrated public/private spectrum market when they want more of it), and of 'carrots' in the form of rewards for releasing spectrum (for example keeping some of the proceeds from auctioning the released spectrum, requirement to buy spectrum in an integrated public/private spectrum market when they want more of it, or being (over) compensated to move to another band, or:
- b) administrative instructions from government to release for refarming a target quantity of spectrum.

Because these mechanisms are often used in tandem, unravelling their individual impacts is difficult.

Spectrum sharing has introduced another dimension into the transfer from the public to the private sector of access rights to spectrum. On one hand the public body loses fewer rights, and probably ones of little value to it; on the other, the transactions costs of sharing have to be borne, and the risks adequately mitigated. In consequence, the degree of resistance may not be much reduced. As in the case of a complete transfer, offering the loser some rewards may cause things to go more smoothly. We discuss an ongoing public sector sharing exercise in Section 5 below.

The problem of getting started

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This section has shown that there are various ways in which spontaneous or regulated sharing might impinge on the existing dichotomy of spectrum management, between (effectively) exclusive licences and unlicensed commons, with the middle largely excluded. The introduction of sharing on a large scale will take some time, and will permit competition or complementarity among different sharing modes.

But at present the situation is becalmed. The reason is the imbalance between the very high 'first copy costs' of a sharing arrangements and the incentives for commercial or public sector spectrum users to get involved. In short, the returns are low and the risk is high. Some interim form of top-down initiative, whether regulator-driven or decentrally implemented but subsidised, seems necessary.

What form might this take? Other regulated sectors have thrown up cases in which it is both feasible and desirable to reduce barriers to entry, but because 'learning by doing' is required, no-one wants to lead, but prefers to be a 'fast follower'. In some of these sectors, a case has been recognised for subsiding, not basic R & D, which has already been funded, but first commercial implementation.

As an example, in the UK energy sector, where there is both substantial regulation (which may slow down innovation) and an urgent need for innovation to achieve a low carbon energy sector,

the regulator has for several years subsidised innovation. The latest version includes three schemes:

- a network innovation allowance to fund small projects;
- a network innovation competition (or tournament) to fund larger flagship projects, and
- an innovation roll-out mechanism, to spread proven innovations.[12]

This may support an argument for either subsidising innovative sharing experiments, possibly by conducting a competition for available funds, open to both commercial sector and public-sector spectrum users – the regulator choosing those projects appearing to offer the greatest total benefits, both directly to the sharers and spill-over benefits for other sharers. It is worth noting that since the regulator is inevitably a major member of the *dramatis personae* of a sharing exercise, it too has to sink resources into the process, and be prepared to learn from the experience.

3. Characteristics of different bands

Sharing has become widespread in some bands, such as the 2.4GHz band, but hardly used in others such as the 1.8-1.9GHz cellular bands. The reasons for this difference are partly physical and partly historical.

From a physical standpoint the key issue is propagation. Higher frequencies tend to travel less far, making sharing simpler since the probability of interference between users is reduced. This is why most sharing takes place in the higher frequency bands above 1GHz. There is a specific issue at 2.4GHz which has contributed to it becoming the primary shared band worldwide – 2.45GHz is the resonant frequency of water molecules making it the choice for microwave ovens. These ovens can leak small amounts of power which can cause interference. This persuaded regulators that the band could not be licensed and so it was made available for best-effort shared usage.

Generally of much greater importance is history – specifically the current usage of the band. If these users cannot readily be moved out of the band, or if their usage is sparse, then this tends to bias regulators towards sharing. However, if the band has international designation for a usage that generally favours exclusive access, such as cellular, then regulators will tend towards clearance and auctioning, making use of extended time-periods where there are stubborn incumbents. Government incumbents can be particularly difficult to clear and here sharing is often seen as a more palatable way ahead. Table 1 summarises the key factors biasing a band towards exclusive or shared access.

More likely to be exclusively licensed if:	**More likely to be shared if:**
• Below 2GHz • Internationally harmonised • Easy to clear • Viable for cellular usage	• Above 2GHz • Complicated usage with multiple incumbents • Governmental, especially military, use • Best usage unclear

Table 1 : Summary of band characteristics influencing spectrum management approach

In subsequent sections we examine two specific bands – TV white space at 400-800MHz and CBRS and 3.5-3.7GHz to illustrate how these factors can influence choices and outcomes.

[12] Ofgem, *Version 3.0 of the Network Innovation Allowance (NIA) Governance Documents, July 2017*, available at: https://www.ofgem.gov.uk/publications-and-updates/version-30-network-innovation-allowance-governance-documents

4. TV white space

The TV bands are typically considered to extend from 470-790MHz, although in some countries such as the US, they are less extensive, with the upper limit being around 700MHz (and progressively moving downwards as will be discussed). These bands have often been used for more than 50 years for terrestrial TV broadcast with transmissions from high mast sites made at high powers and received by millions of households using external rooftop antennas. Typically, transmissions were made using multiple-frequency networks[13] where the same frequencies were not used by neighbouring masts to avoid interference. Instead, there was a reuse pattern of around four, with a quarter of the available frequencies being used on any given mast. For this reason, the TV bands often appeared sparsely populated when observed on spectrum monitoring equipment – there were a lot of "white spaces" between the monitored transmissions.

These spaces appeared suitable for sharing. This was because clearance of the band seemed unlikely given the high levels of TV viewing in many countries so changing to a different exclusive usage was problematic. However, the static nature of the TV transmitters and the stable and unchanging TV transmissions made it possible to clearly define the sharing opportunity. These relatively low frequencies were also considered valuable for many applications including Internet of Things (IoT) and rural broadband. This led to high-profile initiatives commencing in the US in 2008 and the UK in 2010.

Nearly a decade later there has been very little shared use of the bands and TVWS is broadly seen as a failure. What went wrong? There were two major factors: uncertainty and delay. These are discussed below.

By about 2010 the idea was gaining currency that although the TV bands could not be completely cleared and refarmed, they could be partially cleared. In the US the 700MHz band had already been cleared and re-purposed for mobile usage and there was discussion of doing the same with the 600MHz band under the heading of the "incentive auction"[14]. In Europe there was discussion of clearing the 700MHz band. While still leaving enough spectrum for TV transmission, these initiatives would reduce the TV white space significantly. There was also uncertainty around the future demands of existing shared user of the band, the so-called programme making and special equipment (PMSE), broadly wireless microphones and cameras widely used for broadcasting, shows and many other applications. Regulators were inclined to be conservative in their rules for transmission powers for users sharing the spectrum further restricting the amount and value of the shared use. Many felt that with uncertainty over the long-term availability of TVWS it was too risky to invest in deploying networks or developing custom chipsets.

The second problem was delay. TVWS became initially available in the US in 2012 after four years of study, and in 2016 in the UK, after six years. These timescales were overly long for the start-up companies formed to innovate in the bands, many of who ran out of funding. They were also too long for the IoT industry which sought alternative spectrum solutions. This was exacerbated by a lack of interest in other countries, preventing a global market. The net result was that trials were not followed by deployment and the interest of the telecoms industry turned elsewhere.

TVWS did leave one important legacy – the development and validation of the concept of using a dynamic database to provide spectrum access. In this approach, often termed dynamic

[13] In principle, single-frequency transmission is possible with digital technology, but this is rarely used in practice as it complicates regional variations in programming and in any case cannot be used across national borders.

[14] This subsequently went ahead in 2016/17.

spectrum access (DSA), sharing devices first contact an approved database which provides them with details of the access restrictions in their location. Both the FCC and Ofcom developed processes for formulating the rules for these databases, testing and certifying commercial implementations and ensuring an appropriate legal underpinning. The industry looked into business cases and technological issues and while not all were solved, much was learnt. This legacy means that, in principle, the introduction of similar sharing approaches in other bands should happen more quickly.

In summary, TVWS was an innovative approach but the regulatory environment failed to provide sufficient certainty or move with sufficient speed. This predominantly appeared to be because regulators were predisposed towards the existing broadcasting uses and new mobile deployments, seeing sharing as a last resort and one that could be dispensed with once the "classic" spectrum management options became available.

5. CBRS

The Citizens Broadband Radio Service (CBRS) is a US initiative. Like TVWS, it grew from the observation of a frequency band – in this case around 3.6GHz (3550-3700MHz) - where there was little apparent usage. In the US this band is assigned to defence, predominantly ship-born radars which are only active in coastal regions (however, most of the US population lives in these coastal regions). The CBRS proposal uses DSA to protect the incumbent military in the same manner as in TVWS, however, it adds additional complexity with a three-tier approach. In this approach, the military has the highest level of access, being guaranteed protection from interference. The second tier is termed a priority access licensed and is intended to provide some certainty both in terms of availability of spectrum and protection from interference. The third tier is termed general authorised access and is similar to the sharing use in TVWS. All users are coordinated through a dynamic database which may be assisted by coastal monitoring stations which can detect whether there is any nearby radar operation. There are many complexities around the number of second tier licenses, their geographical and spectrum extent and much more, which we do not explore further here.

At present, CBRS is still being debated, with lobbying around the balance of spectrum between the different tiers, the way that the quasi-licenses of the mid-tier are to be awarded and indeed whether clearance and auction should be used instead. There remains high levels of enthusiasm within the industry[15] – but that was also the case for TVWS at this stage in its proceedings. CBRS is given impetus by the fact that these bands have become the major 5G bands in other parts of the world, ensuring good equipment availability. Hence, somewhat perversely, shared use in one area is given assistance by exclusivity elsewhere. However, if this exclusive use is shown to be very valuable, it may crowd out the shared usage in the US.

Even if CBRS does succeed it may remain a US initiative since these frequency bands have already been cleared ready for auction in many countries. However, the three-tier concept and some of the other ideas such as monitoring stations are being looked at with interest by regulators elsewhere.

6. mmWave bands

5G anticipates the need to use some very high frequencies in the range 24-28GHz, termed the mmWave bands. These are bands that are in use by a various applications around the world including fixed links and satellite systems. At this stage it is unclear what use 5G will make of these bands. Possible applications include fixed wireless access, backhaul connectivity, dense

[15] For example, in 2017 Nokia announced a small cell product that could operator in these bands and be deployed by a third party or building owner. There was not the same level of interest from major vendors in TVWS.

city centre systems or ultra-low latency solutions. Depending on the application the geographical extent might be limited to city centres, or might favour residential areas. Bandwidth requirements are also unclear with estimates from 100MHz to 1GHz per operator.

It is possible that other entities might want to deploy 5G-related systems, for example a business park might wish to deploy a mmWave solution to provide very high-speed connectivity. This suggests that allowing some form of unlicensed access might be appropriate.

The fact that operators are unlikely to deploy mmWave systems extensively, that there are incumbent users who may be hard to move (and there may be no need to do so), that other entities may wish to self-deploy and that there is much uncertainty which might require flexibility all suggests that some form of flexible, shared access is appropriate. But it is unclear what this should be.

At these frequencies the range is very short – perhaps 100-200m. This means that the approaches used for TVWS and CBRS may be overly complex. Regulators to date have hedged their bets suggesting the band might be split into different channels, some of which might be licensed, others light-licensed. Most have felt that completely unlicensed access would be inappropriate, with the risk that it would not allow subsequent changes to access if needed, but this is a simplistic conclusion and DSA approaches could reduce such risk.

Compared to the other bands, uncertainty remains a key issue, but in this case the uncertainty is around the use that the expected key players will make of the spectrum rather than the amount of spectrum or possible changes to its provision over time. Regulators again appear keen to favour the key telecoms providers – in this case the mobile operators – rather than shared users in their thinking around the best ways to manage the band.

7. Conclusions

Few would dispute that, in principle, sharing of spectrum is a good idea. Sharing uses spectrum more efficiently, provides opportunities for innovation and leads to consumer benefits. Regulators profess to be strong supporters of sharing; opportunities for sharing abound; and the tools for sharing have been trialled experimentally. But despite these compelling reasons for sharing spectrum, it rarely happens on a commercial scale.

Predominantly this lack of sharing arises because it is insufficiently in the interests of the organisations which control the spectrum and because the regulators give insufficiently proactive support to new approaches or new entrants. A combination of risk-aversion and a desire to base decisions on evidence tends to bias regulators away from new approaches. How then to change the incentives and rules of participation to enable sharing to come about?

The best way ahead appears to be some successful "case studies" of commercial applications that can demonstrate the potential and "flush out" the risks and details. Restricting initial focus to specific bands both reduces the risks and focuses effort. There has been some attempt to focus – for example on TV white spaces – but without the drive to force an outcome beyond that which the market provides. Instead of just implementing a framework that allows sharing, regulators and other relevant bodies need to provide pressure and incentives to actually make sharing happen.

This will require proactive regulatory support, likely in the face of resistance from incumbents. Regulators may find it easier to proceed in areas where there is clear consumer benefit such as in-building or rural cellular coverage. Once successful examples are visible regulatory support

can likely be relaxed. Such intervention may not sit comfortably with many regulators but absent intervention it is hard to see any change in the current levels of sharing.