ENGINEERING COMPETITION THROUGH SPECTRUM POLICY: PREVIOUS APPROACHES AND WHY 5G NEEDS CHANGE

By Martin Cave & William Webb[1]

I. INTRODUCTION

Thirty years ago, spectrum management was a backwater, in which the resource (not usually in short supply) was allocated to the generally very small number of users – many in the public sector – by administrative or command-and-control methods. Where competition for it existed, recourse was had to beauty contests as an assignment method.

The development of terrestrial and satellite multi-channel television, and the unprecedentedly fast global diffusion first of mobile voice and now of mobile broadband, have changed all that, and alerted governments throughout the world to the realizable value to commercial organizations of an asset which they control, and which the data suggest is an important contributor to economic growth in all countries – rich and poor.

These factors have focused attention on new ways of using markets and prices for distributing spectrum across different uses ("allocation") and to individual users ("assignment"), in a matter which improves technical efficiency – for example by reducing waste and hoarding – and achieves greater allocative efficiency, by directing spectrum to its most efficient users. These goals are sought not only from commercial spectrum users, but also from users in the public sector, which collectively account for about one half of total spectrum use.

[1] Martin Cave is a regulatory economist specializing in competition law and in the network industries, including airports, broadcasting, energy, posts, railways, telecommunications and water. William Webb is a highly experienced strategist, technologist and Board member. His experience spans industry, Government and academia and roles include CTO, CSO, CEO, Board Chairman, consultant and advisor.

This paper reviews these developments in "marketizing" spectrum, but it also addresses new approaches to spectrum management based upon sharing, either via so-called spectrum commons or by a more limited set of users. This method is particularly apposite to the next great challenge facing spectrum management, the development of 5G mobile networks.[2]

II. MARKET METHODS AND SPECTRUM MANAGEMENT

Spectrum is a natural resource which is an input into many production processes. Its economic and military applications came into prominence at the time of the First World War, when it became subject to government control. Thereafter it remained subject to command and control regulation until a first fully developed proposal by Ronald Coase in 1959 to subject spectrum used for broadcasting to allocation by a market process.[3]

This proposal initially met with little success, and it took several more decades until the use of auctions to assign spectrum licenses first came into use in New Zealand in 1989. But what really propelled the use of auctions globally was the development of mobile voice communications in the following years. Mobile communications were capable of being provided by several operators, and the choice of those operators could be accomplished by a competitive process which should in principle direct the spectrum into the hands of those best able to use it – to the ultimate benefit of end users. Since then, auction data show that more than 14,000 national or regional lots have been auctioned, each characterized by the number of MHz available, (often) the technology to be used, (almost invariably) the nature of the service to be provided, the geographical coverage of the permitted service, the duration of the license and limitations on the interference which use of the band can inflict on adjoining bands or geographies.

Auction design changed considerably in this period. Initially, a specified number (typically two to five) of broadly similar licenses were auctioned, one to each operator – the number chosen determining the starting market structure. But as operators acquired portfolios in different bands and diverged in their market shares, it became common to sell larger quantities of lots of smaller size, permitting more flexible choices and sharpening competitive tensions. Spectrum in different bands was often auctioned together, again widening choice. Auction design adapted to deal with these cases, as the economics profession responded strongly to the challenge by developing sophisticated new procedures, notably the simultaneous multiple round auction and combination clock auctions.

As with other allocation methods, auctions can go wrong, for a catalogue of reasons. The successful bidder may be not the most efficient user of the resource, but the most optimistic (a phenomenon known as the "winner's curse"). Bidders with market power in downstream communications services may have an incentive to use the auction to deny rivals access to market: as the U.S. Department of Justice puts it, their bids may have a "foreclosure motive," as well as an "efficiency motive." More generally the spectrum regulator may wish to use the auction process expressly to promote or protect competition in

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[2] Some of these points are elaborated further in Martin Cave and William Webb, "Spectrum Management: using the airwaves for maximum social and economic benefit," Cambridge University Press, 2015

[3] On the proposal's reception and on U.S. spectrum policy more generally, see Thomas J Hazlett, "The Political Spectrum," Yale University Press, 2017.

downstream markets.

This has led to the inclusion within auctions of a variety of mechanisms associated with competition goals. The most common (though not in U.S. auctions) is a limitation on the amount of spectrum an operator can buy – a spectrum cap. Or some operators can receive preference in bidding, by means of a spectrum floor. Or spectrum can be set aside for new entrants.

On top of this, auctions can incorporate measures to achieve equity or universal service objectives. Thus, one license may carry with it an obligation to provide service to a specified proportion of land mass or population – a "coverage obligation." If this bites, greater coverage is achieved at a cost to auction revenues. Spectrum auctions have generally risen to the challenge of delivering these goals, although there have been some failures.

In most auction processes, full payment for the license is made up-front. Thus, while a firm's willingness to pay is determined by its expectation of how competition will evolve in the relevant service market, the amount paid becomes (in the absence of trading opportunities) a sunk cost, having – according to economic theory – no impact of future prices. This proposition has been disputed by those claiming that higher auction prices "cause" service prices to rise. But recent empirical evidence appears broadly to support the "sunk cost" view.

Of course, this does not preclude the government from withholding available spectrum from sale, and increasing its revenues by acting as a straightforward monopolist. But given the impact of communications services on growth, and the resulting tax revenues it brings, this is likely to be a short-sighted policy only making sense within a limited time horizon.

Auctions in the primary market are clearly the jewel in the crown of market instruments applied to spectrum. Many jurisdictions have also made provision for secondary trading within the period of a license. But while very substantial trades have taken place in the U.S., many of them associated with the withdrawal of sometimes quite large regional operators selling out to the diminishing number of national operators such as AT&T and Verizon, trading in other jurisdictions has been largely confined to licenses supporting lower value uses such as by taxi firms. Mobile communications firms may see their spectrum as a strategic asset which they are unwilling to trade to their rivals in the service market.

A subset of trades or re-auctions of spectrum has, however, been triggered by the wave of consolidation affecting the mobile communications sector. The European Commission in particular, acting as a competition authority, has made approval of the merger conditional upon the release of spectrum by the combined entity, with a view to "replacing" the lost competitor.

An alternative approach often adopted where auctions cannot be applied involves charging users a price which is set administratively, rather than derived from a market process. Under the old regime users paid charges which in combination were intended to defray the costs of the spectrum management agency. These charges are now dwarfed by the economic value of spectrum in certain uses, revealed in auctions. Cost recovery prices thus fail as a price signal. In a competitive market, the price for a spectrum band would be determined by its opportunity cost – the cost of the next best alternative to that spectrum in producing the service in question. This can be estimated, and used as a price. The process is not fool-proof, but, after making suitable adjustments to manage the risk of error, it can discourage the hoarding of valuable spectrum in inefficient uses.

III. APPLICATION IN PUBLIC SECTOR

The public sector typically sits on half of the total spectrum available, and retrieving surplus spectrum from such users is an essential component of any spectrum policy. Several approaches have been tried: conducting spectrum use audits; charging such users an administrative price (which will only work provided that the finance ministry does not increase that user's budget precisely to compensate for its additional cost of spectrum); setting spectrum release targets; and allowing public sector users to trade spectrum to the commercial sector and keep part of the proceeds. The last approach effectively integrates public and commercial spectrum markets (as most input markets for, say, electricity and commercial space are integrated) in a way which might in the long run lead to substantial efficiency benefits, but such measures are still in their infancy. It is probably most productive to try cumulatively a variety of approaches, and seek to wear down resistance.

IV. HOW SUCCESSFUL HAS LIBERALISATION BEEN?

What does this add up to? Auctions have made a big difference, generally for the good, despite tendencies for some governments to restrict supply. The effect which they have on allocative efficiency is a factor, as is their ability to convert what would otherwise be private scarcity rents into rents which accrue to the state. The other approaches such as trading and pricing so far play an auxiliary role.[4] However, we now turn to another approach – spectrum sharing – which is having an increasing impact on solving spectrum shortages, with the potential for a much greater effect.

A. 5G and Its Spectrum Requirements

The main thrust of spectrum regulatory activity around the world is now turning towards 5G, and with its many different elements and issues. This provides a useful framework to discuss the key challenges facing regulators over the coming decade.

5G differs from previous cellular generations in both its breadth and its uncertainty. In the past a new generation has broadly been faster than the previous one, with specific frequency bands designated near-globally to support it. There is not the space here for a detailed discussion of the arguments around 5G's role, but broadly it is expected that it will be faster than 4G, provide greater capacity especially in urban areas, provide support for the Internet of Things ("IoT"), integrate better with other systems such as WiFi, and potentially enable new services via extremely fast links. Equally, some have noted that with mobile network operators ("MNOs") seeing declining profitability and end-users generally not paying more for faster services, the business case for many of these is unclear, and it is possible that 5G may just end up being the continued evolution of 4G. Robust competition between MNOs is seen by many regulators as a way to ensure rapid deployment of 5G services but the costs of delivering multiple 5G networks are driving operators to consider cooperative models.

Achieving all of these aims requires a range of different bands of spectrum but the

[4] On this see further Martin Sims and Toby Youell, "Understanding Spectrum Liberalisation," CRC Press, 2015.

uncertainty means that timing and modes of access need to be flexible. Current methods of spectrum access for 5G being discussed include:

"Classic" access to harmonized bands agreed world-wide. As discussed in the first part of this paper, the preferred approach is for regulators to clear the bands then auction them with exclusive licenses to the mobile operators. The key focus is the 700MHz band but others are also discussed.

Access to bands below 6GHz on a license assisted basis. Operators consider that they will need substantial spectrum below 6GHz to provide capacity and relatively high data rates. Attention has focused on the 4GHz band but this is used globally by a range of other services such as air-traffic control and fixed links. It seems unlikely that it can be cleared and auctioned within the timescales desired and so approaches to sharing with incumbents, with an agreed priority of access, are being investigated.

Use of unlicensed spectrum as an additional resource. Even with all these bands some fear that there will be insufficient spectrum and that making use of the unlicensed bands at 5GHz may be necessary. These bands are widely used for WiFi – raising fears of interference. Various approaches where the MNOs might opportunistically use the bands for additional downloading have been proposed.

Access to high-frequency bands for new business cases. The ultra-fast solutions will require use of very high frequency bands likely above 20GHz. With their short-range propagation, and with the uncertainty of the timing and success of 5G solutions, shared access may be suitable.

B. 5G and Shared Access

From the discussion above it is clear that only a small part of 5G spectrum will be found through classical "clear and auction." Much of the rest will come from some form of shared access. Here we provide an overview of sharing, show which elements are relevant to 5G and consider whether sharing can foster competition.

Primitive forms of spectrum sharing among alternative uses or users have been in place from the beginning of spectrum use. For example, spectrum can be shared temporally or geographically via a conventional licensing process. So-called spectrum commons have also existed for a long period. Here users of very low powered devices (which are unlikely to interfere with one another) can transmit without a license provided that they obey specified power limits.

However, it is now apparent that a more efficient way of sharing the spectrum in a wider class of environments is via "dynamic" spectrum sharing, which allows one user opportunistic access to spectrum not being used by another user. The structure we follow in this section is set out in the simple table below which has two dimensions – whether access is restricted and whether interference is controlled in any way once access has been granted.

	Unrestricted access	**Restricted access**
No interference control	Commons	Classical sharing
Controlled interference	Database-controlled access	Collaborative working with incumbent

We can see how these apply to 5G in the modified table below.

	Unrestricted access	Restricted access
No interference control	(1) Cellular use of unlicensed bands at 5GHz	(2) Sharing with incumbents in high-frequency bands
Controlled interference	(3) Not used (but some non-5G projects still active in places)	(4) Working with air traffic control and others at 4GHz

We discuss each of these below.

Case (1) – access to 5GHz bands. The 5GHz band is classic "spectrum commons," with no licenses granted[5] and access allowed to technologies that meet general rules on power levels and politeness. In principle, as long as the variant of 5G proposed for this band meets such requirements there should be little debate as to whether to allow it. However, a case of "too big to fail" has developed which causes regulators and others to pause for thought. The band is currently almost exclusively used by WiFi. If the 5GHz band were to become congested due to 5G using the band this might cause significant consumer detriment.

This issue raises interesting questions as to whether regulators should recognize unlicensed applications that have become successful and offer them some degree of protection. It would intuitively appear that this is both appropriate and hard to avoid, but it sets precedents that may lead to mis-matched expectations in the future. It also shows that the value derived from unlicensed bands is substantial – perhaps greater than that derived from licensed bands on a per MHz basis. This implies a much greater focus on regulation of unlicensed spectrum moving forward, including more efforts to identify additional bands for unlicensed usage and to monitor and manage existing bands. Such efforts would be most effective on a global basis. Generally, unlicensed usage does not hinder competition, but equally does not actively encourage it either.

Case (2) –sharing with incumbents in high frequency bands. In these bands the existing license holders are often satellite users and fixed links. Both are static, with directional antenna and in many cases tend to be outside of urban areas. Given that the best bands for 5G are not yet determined, and the extent of deployment and business model for 5G ultra-fast solutions very unclear, then clearing these users appears premature. Instead, 5G could work around them. Where sharing has been proposed, regulators tend towards geographical exclusions zones around existing users.

The biggest challenge with this approach is the tendency for exclusion zones to become excessively large once a worst-case modeling exercise is performed. This can be resolved by making greater use of measurements to determine interference rather than predictions and adding some incentive on the incumbents to share as widely as possible. As with case (1) this should not hinder competition but equally it does little to promote it.

Case (3) – TV white space and similar. In this case, unlicensed access is allowed into licensed bands when interference can be carefully controlled, typically through the use of a database that unlicensed devices have to query prior to transmission. This was the concept

[5] With the exception of some radar use in some countries which unlicensed users have to detect and work around.

behind TV white space, which garnered much interest around 2010. However, interest has faded partly because it has proven hard to get regulatory approval in all but a handful of countries, partly because the TV spectrum has progressively shrunk as bands have been identified at 800MHz then 700MHz for cellular, and partly because alternative approaches have been found for applications such as IoT that were proposed for TV white space.

Case (4) – Collaborative access in 4GHz bands. Collaborative access has been proposed where (1) clearance of bands looks problematic and likely to take overly long and (2) the incumbents do not have uses that can readily be ring-fenced geographically. In these situations, operators see collaborative access as a "next-best" approach where they negotiate with the license holder(s) as to how they can best gain access.

There is still much to be worked out with collaborative access, especially where it is the regulator that assigns the shared rights, as might be the case where the incumbent is a governmental user such as defense. Here the form of the license, the number of licenses granted, and the auction approach adopted still require attention. It may be that 5G will be a valuable first deployment that will pave the way for more widespread usage. Incumbents may prefer to share with only one other player, or with a subset of MNOs. This could reduce competition but the grounds for regulatory intervention in such cases appear weak.

V. CONCLUSIONS

We have shown how spectrum management has changed to introduce market forces and promote competition, primarily through the use of auctions as a tool to assign spectrum. This has led to vibrant and innovative mobile broadband deployment around the world. However, through discussion of the spectrum needs for 5G, we have illustrated how the approach of clearance and auctioning can only be used for a subset of the spectrum needed and that a range of sharing mechanisms are more appropriate for some bands. Equally, we have discussed how these sharing tools can be difficult to introduce, still have details to be determined and could, in some cases, hinder competition.

Clearly, there is much still that needs to be done, predominantly by regulators and competition authorities. Our recommendations are:

- *Move to a position where (almost) all licensees are shared*. The case of 5G has shown that much of its access will be shared. Sharing has been assisted by the development of new real time technologies for dynamic spectrum sharing which allow multiple users to coexist. It is time for these possibilities to be reflected more fully in rights of access to spectrum by the replacement of exclusive licenses by arrangements which allow access to multiple users, possibly on a hierarchical basis which gives some users priority over others. The result to be expected is much greater flexibility in use of spectrum and lower prices of access to it. This could be accomplished by a process of progressively replacing exclusive licenses with less restrictive alternatives, introduced in ways which managed the associated risks. We recommend in the future a brisk increase in the number of licenses recast in this way, even if in practice some of these will continue to be exclusively.
- *Reconsider ways to derive technical sharing criteria.* History has shown that sharing calculations are almost always excessively cautious leading to much

spectrum being unused. Changing license conditions towards the amount of interference that a user is allowed to generate, measuring actual interference rather than modeling it, specifying the minimum performance levels expected of receivers, and utilizing real-time databases to modify transmitter powers when interference does occur will allow for very substantial improvements in efficiency as well as providing the tools for a range of novel approaches to sharing.

- *Intervene where necessary to promote competition.* Some sharing arrangements may see only a subset of MNOs able to access a band. Regulators will need to form a view as to whether this prevents robust competition and if so, to find some remedy. Given the uncertainties as to how sharing will evolve it seems better to examine outcomes and act where needed rather than restrict activities in advance.
- *Reconsider regional and global spectrum management*. Spectrum for 5G and for unlicensed applications ideally needs allocating on a global basis and yet we have seen national interests put first in some cases leading to fragmentation and delay. There is greater scope for regional collaboration if appropriate frameworks can be found that do not limit innovation. Regional bodies should study their role and look for where they can add additional value. This is an issue of fundamental importance which deserves careful and disinterested study at a very high level.