Spectrum Sharing

Taxonomy and Economics

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February 6, 2014

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Funding for this report was provided by Verizon. All results and any errors are the responsibility of the authors and do not necessarily represent the opinion of The Brattle Group, Inc. or its clients.

Acknowledgement: We acknowledge the valuable contributions of many individuals to this report and to the underlying analysis, including Maura Coughlin and Katie Lee.

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Executive Summary

As demand for more complex wireless technologies increases, so does the demand for spectrum suitable for wireless broadband services. This is true for both government and commercial users. On the commercial side, Cisco famously predicted that U.S. mobile data traffic will grow 9-fold between 2012 and 2017. On the federal side, users have over 240,000 frequency assignments and their needs are increasing. Sharing between federal and commercial users will be a key component of the strategy to meet growing demands for spectrum.

Allocating shared spectrum "efficiently," however, requires balancing competing demands to assign the spectrum use rights to the user(s) who value(s) them most. In principle, when managing the trade-offs from competing demands, efficient spectrum management policy should seek to maximize total social and economic value of spectrum, subject to the priorities set by policymakers. When applied to spectrum sharing proposals, these principles of efficient spectrum allocation lead to two findings. First, spectrum sharing should only be implemented if the foregone value to the primary user from sharing is less than the added value to the secondary user(s). Second, spectrum sharing is efficient when the cumulative value to all users is higher than the potential value to a single user.

The economic value of spectrum today is simply the present value of the cumulative future profits that can be earned using the resource. When spectrum is shared amongst multiple users, this cumulative profit includes the total profits for all services deployed on the spectrum (including the value created by public uses.) The profits from a band of spectrum are the net revenues, or revenues less investment and operating costs, of deploying the spectrum band. For each user, the derived value of spectrum is based on the additional value, or net profit for commercial users, that spectrum adds to a particular spectrum based service. The value of a band of spectrum, then, is related to the value created by all users.

Since the value of spectrum is defined by the profitability of the spectrum based services deployed, any factor that impacts the residual profits of using a band of spectrum will impact the value of that band. This includes restrictions to use rights that reduce potential ***revenues*** from service, increase the ***costs*** of deployment, or create added ***uncertainty*** about the potential for realizing future profits. The effect from sharing on each of these factors is likely to diminish the profitability, and hence value, of a band a band of spectrum.

There are several different types of spectrum sharing currently proposed or in use.

- Under ***geographic sharing***, a given spectrum user's transmissions are limited to a predefined service area. Several proposals are already being considered for geographic sharing arrangements between federal and commercial users in the 1695-1710 MHz band and the 1755-1850 MHz band.

- Another commonly considered type of sharing is ***temporal sharing***. In this case, two or more users would share access to the same band of spectrum in the same geographic area, but at different times. Such arrangements can be divided into two major categories: predictable and random. Under a ***predictable temporal sharing*** regime, one user agrees not to transmit during particular pre-defined times to accommodate the other user's services. The impact of predictable sharing on the value to a given user depends, in part, on the timing, frequency and certainty of when interruptions might occur. ***Unpredictable or random temporal sharing*** occurs when the secondary user may have to stop using the specific spectrum on short notice or without warning. This type of sharing was initially proposed for the 700 MHz D Block. Typically, the greater the sharing obligations and the less predictable they are, the greater the diminution in value for the user(s) that have to accommodate or yield in their use to allow the sharing.

- ***Coordinated sharing*** refers to sharing arrangements where two or more users are using the same band of spectrum in the same geographic area at the same time. To prevent harmful interference, users' devices must detect what other devices are operating in the same geographic area and on the same frequencies, and then respond accordingly. The two potential mechanisms for coordination are databases and cognitive radios. Cognitive radio networks or devices automatically detect devices in its vicinity and coordinate usage in response. Alternatively, spectrum databases register their location and devices, and then identify which spectrum is available for use. This is the approach already in use for unlicensed devices operating in the television bands.

- ***Uncoordinated Rule-Based sharing*** refers to situations where rules of use are designed to prevent harmful interference. Uncoordinated sharing typically occurs over unlicensed spectrum in which devices that meet a particular set of criteria are allowed to transmit over the spectrum. This approach is typically employed for low power devices, such as baby monitors and wireless microphones, WiFi, and radio astronomy.

We numerically illustrate the impact of sharing on spectrum value through a series of examples, both hypothetical and grounded in CSMAC recommendations. For example, geographic exclusion areas would reduce the potential value of a band. We show that for the 1695 MHz – 1710 MHz band, excluding 12% of the population in the currently proposed exclusion zones could reduce the value of the band by 16%, but relocating some of the exclusion zones from urban to rural areas would only reduce the value of the band by 7%. This option increases total value so long as the cost of relocating the exclusion zones is less than the value created. As an alternative to exclusion zones, it may be possible to use additional filters on base stations. We illustrate this impact of increased cost on spectrum value by modeling a 20% capital cost increase for 15% of the network impacted by exclusion zones. In this case, that added cost reduces the value of the spectrum by 11%, an option that preserves more value than the 16% loss associated with the currently proposed exclusion zones, but potentially less (depending on the relocation costs) than the 7% loss when the exclusion zones are relocated to less populated areas. In a separate, illustrative, analysis we show how increased uncertainty in the form of a 1% increase in the firm's cost of capital can reduce the value of a band of spectrum by 29%.

It is widely accepted that until Federal users internalize the costs associated with their spectrum use, they have little incentive to use spectrum more efficiently or support proposals to share their spectrum. If federal users paid for spectrums use, they would internalize the cost associated with holding spectrum assignments that prevent other productive uses of the frequencies. Recognizing the costs of spectrum through a federal fee would incentivize federal users to adjust their usage to reduce costs. While there are limitations to a fee-based approach, it would require government users to incur some cost for spectrum usage. By imposing a spectrum based fee, the cost of spectrum based services for federal users will reflect the use of this scarce resource. The question is: *what should the fee be tied to?* Consistent with the principle that government spectrum users should consider the forgone economic value of spectrum deployed for their services, we suggest that a federal user fee should be based on the commercial value of spectrum. By tying the fee for federal spectrum to spectrum's commercial price, federal users would be incurring the foregone economic value or opportunity cost of the spectrum in deploying these federal services. A fee based on the commercial value of spectrum would require that federal users at least acknowledge this opportunity cost of the spectrum use and publically argue that the value of their use of the spectrum exceeds this opportunity cost.