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Efficiency of spectrum use

May 14, 2013 By Peter Rysavy

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Although technology has brought marvels in mobile computing, it has provided means to use all of the radio resources on which mobile computing depends. Wireless networks are a hundred times faster than just ten years ago, but their rich, interactive, streaming-oriented applications consume all available capacity and demand more. Managing this critical radio resource and determining the most effective spectrum-allocation policies require an understanding of what constitutes the most efficient use of spectrum.

Even though spectrum efficiency cannot be distilled into a single engineering value, technical and economic measures can be applied while at the same time considering societal good. Such analysis should lead to the best balance of unlicensed versus licensed spectrum, to understanding the extent to which government systems might share spectrum with commercial interests, and to determining which agencies, industries, or even companies should have how much spectrum.

Over the last ten years, I have been privileged to work on a series of papers for 4G Americas with some of the brightest technical minds in the wireless industry. Collaboratively we have published charts hat quantify the spectral efficiency of all major wireless technologies in realistic, deployable network configurations. Measured in bits per second per Hertz, the spectral efficiency indicates, for example, that LTE is about 40 percent more efficient than HSPA+ and that certain versions of LTE-Advanced can provide an additional 60 percent gain over LTE. These values are useful in determining how much capacity a network can provide in a coverage area for a specific amount of spectrum.

A technology that has greater spectral efficiency generally uses spectrum more efficiently than one with lower spectral efficiency; but spectral efficiency by itself only partly addresses how efficiently spectrum is used, for the density of deployment must also be considered. Because more cells translate to a correspondingly greater capacity, another measure might be the number of bits/second a network delivers in a specific coverage area for a certain amount of spectrum. The industry's current emphasis on small-cell technology development and deployment is evidence of this measure's importance.

Deploying huge numbers of small cells, however, may be efficient technically but not necessarily economically. Small cells represent a significant opportunity to increase network capacity but also present tremendous challenges regarding backhaul, interference, and management, making deployment uneconomic at some point on a massive scale. Technology advances will make small cells ever more viable, but for now operators are deploying them selectively to achieve the best balance of technical and economic efficiency. Although I am not an economist, I realize economists are discussing the economic efficiency of using spectrum and I do know operators are constrained by business models.

Other technical measures are also available for determining the spectral efficiency of licensed networks. One measure is the number of subscribers an operator has relative to the amount of spectrum held. This comparison is the most valid when comparing operators having similar licensed areas. Another measure is the average amount of data subscribers consume--even minutes of voice, although data increasingly consumes most of the capacity.

The data capacity of a coverage area provides a way to assess the efficiency of unlicensed spectrum. Wi-Fi is hugely efficient because coverage areas are small, resulting in extremely high bandwidth per square meter. If the coverage area were much larger than Wi-Fi, as planned for white-space networks, data density would plummet, making the efficiency of white-space networks questionable. On the other hand, white space networks might be the perfect solution in countries such as Africa and India where broadband penetration is low, for broadband can be delivered over large areas at low cost, resulting in high economic efficiency.

Efficiency also applies to current debates about spectrum sharing. On the surface, spectrum sharing between a government application, such as radar or satellite, and a commercial network appears to be efficient, especially if the government application operates in only some areas or for only some of the time. From a technical perspective, sharing may eventually lead to more efficient spectrum use, but excessive emphasis on sharing in the short term could needlessly slow down deployment and use of productive spectrum. Assessing the many parameters involved in a shared approach will take significant time. For instance, the AWS 1755-1780 MHz spectrum band controlled by the U.S. National Telecommunications and Information Administration (NTIA) is an opportunity to provide additional internationally-harmonized spectrum to the mobile broadband industry and could be shared initially with wireless carriers. Yet some initial investigations into spectrum sharing in the 1755-1780 MHz band reveal that technologists don't yet know how to measure meaningful interference to incumbent systems.

Hence, focusing on a small number of bands so that government and industry can together learn how best to share seems prudent. In this regard, the proposed 3.55 GHz small-cell band appears to be an ideal candidate, but regulators must be careful not to overreach. If rules are too restrictive or complex or if availability of spectrum is too unpredictable, expected users, such as operators, may not materialize, resulting in underuse of the spectrum.

When evaluating efficiency, ultimately societal good must be considered. For example, the decision to fund a nationwide, interoperable public-safety mobile broadband network contributes importantly to ordinary citizens' lives. The need for exclusive access to the public-safety spectrum for saving lives and responding to emergencies trumps any argument on technical or economic grounds.

Questions about efficiency also arise when considering whether to transfer spectrum from one group of existing licensees to another based on which provides the greater value. Policymakers' current discussion about how to auction 600 MHz spectrum follows Congress's legislation that supporting mobile broadband is more important than supporting broadcast services.

My take is that today's mobile broadband network succeed because they are efficient in multiple dimensions, balancing investment with capability and coverage. Advancement of this industry and others depending on spectrum will require careful consideration of which approach uses spectrum the most efficiently.

If this topic is of interest, you may wish to attend a workshop I'm chairing on June 14 in Washington, D.C.: *Optimal Coevolution of Mobile Broadband Technology and Spectrum Policy--A Technology and Policy Workshop*, http://www.pcca.org.

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Originally posted at http://www.fiercewireless.com/story/rysavy-efficiency-spectrum-use/2013-05-14