Spot markets: a quantum leap in spectrum efficiency?

The technology is already here to establish an exchange where frequencies are bought by the minute says former FCC chief technical officer Michael Marcus. He argues that these can even work in public safety bands.

Naturally, a key input into mobile communications systems is spectrum and its efficient use. The laws of physics limit the amount of spectrum available for efficient mobile use and in many ways limit the efficiency of spectrum. In recent decades, technical efficiency of spectrum use has increased signifi cantly to the point where there are few options available for making quantum improvements in efficiency. Spot markets are one possible approach to make a large efficiency improvement in spectrum use by using "white space" – spectrum that is properly licensed but which is actually unused at a given location at a given time. There is a lot of white space and even in dense urban areas it is usually the majority of the spectrum. This is the inevitable result of traditional spectrum management which is all that is possible with traditional radio technology. But cellular and trucked radios have included microprocessors and frequency synthesizers for over a decade and more effective harnessing of this technology in cognitive radios (CR) could lead to a quantum jump in spectrum efficiency.

A spot market for general users

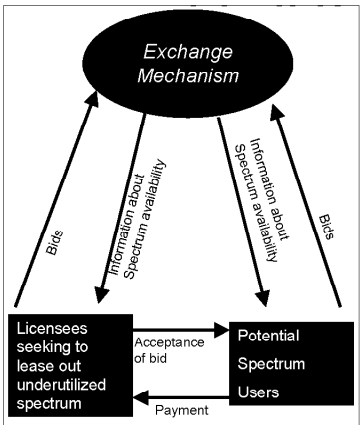
There are two types of spot markets that will be discussed here: A real time commodity-like market for general types of users and an "interruptible spectrum" system that addresses the special needs of public safety users, e.g. police, fire protection, and military. In the US both of these spot markets are allowed under "secondary market" rules now to a limited degree and they may be considered in Europe in the near future in the context of spectrum trading. In the commodity market area, spectrum licensees could look at their spectrum use in close to real time and work through an exchange mechanism, as shown in Figure 1, to contact potential spectrum users and negotiate prices.

In order for such a market to work there has to be definitions of the units of spectrum that would be traded, just as oil markets work because there is a standard definition of what a barrel of oil is and how to deal with oil that is not quite standard. At present, such definitions do not exist in the formal sense but appear to be reachable in a consensus standards process.

CR technology could be used to negotiate the transactions with the exchange mechanisms shown in figure 1 to buy or sell rights to use spectrum for a time period and also to implement a secure mechanism to send messages with electronic signatures to radios that would use the leased spectrum. CR radios can be designed that will only use a new frequency if the authorization message has a valid electronic signature giving the frequency, power, geographic area and authorized time period.

A spot market for public safety spectrum

"Interruptible spectrum" is a type of spot market for the specialized case of public safety spectrum that generally has very high peak-to-average use ratios because of the nature of public safety requirements. Public safety organizations have a vital requirement for spectrum access during emergencies and other peak communication periods for their organizations. Normally this is met by allocating to them spectrum sized for their peak requirements, but CR allows new options.



1. Exchange mechanism for a commodity-like market

Figure 2 shows the basic concepts of interruptible spectrum. A full time public safety block is paired with a block of spectrum with commercial users. This public safety block is sized to handle public safety requirements for 90+% of the time, that is, enough to handle most day-to-day requirements. The commercial users also have their own dedicated block, but can use the block between them and the public safety users most of the time.

When public safety demand surges the public safety users can use a preemption mechanism to signal that the commercial users must vacate the middle block. The vacating must be fast but not instantaneous if the public safety users order preemption in stages and start as demand surges but before their dedicated spectrum saturates. Demands

About the author

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are time variable but have finite time constants so a properly designed system will allow the preemption mechanism a few seconds to work. Several types of preemption mechanism are possible, but for the purpose of showing feasibility of highly reliable preemption one could postulate a beacon system with electronically signed time signals that indicate the spectrum is available for nonpublic safety use.

Without a signature provision, someone might be able to restrict public safety access in time of emergency by sending a counterfeit beacon signal. The signed time signal prevents valid beacon signals being sent by unauthorized parties. The commercial users could continue to use a block of interruptible spectrum only if a valid signed beacon signal is received within so many seconds. Jamming of the beacon signal or bad propagation conditions would result in a fail-safe reversion of the spectrum to public safety use.

A boost for spectrum efficiency

If these spot market mechanisms are implemented we could use the present white space in markets that now have spectrum shortages and hence create new opportunities for radio systems. While some of this goal could be achieved by spectrum regulators pressing users to use less spectrum, in the real world regulators have trouble forcing users to do things that are of no direct benefit to those who incur costs. The spot markets described above both make new spectrum available and reward existing licensees for sharing their spectrum with others

Required technology for implementation

The basic hardware need for spot markets is already available in that transceivers generally contain more than enough processor power for the functions described above. By contrast, today's radio microprocessors probably do not have enough computational power to do highly reliable sensing of whether channels are free for uncooperative use. Thus the required technology for implementation is basically software technology which would build upon known basic concepts. In addition, there is a need to develop consensus standards for defining quantities of spectrum use that can be traded and for defining the details of the exchange mechanism.

Spot markets will clearly require radios with more frequency agility than is typical today in commercial products. Already, triband cellular radios are available for world travelers at prices and sizes slightly higher than single band units. Research and development for military SDRs, where frequency agility is key for operations, is leading to new design techniques that will permit wide frequency agility. In particular, new approaches to antenna technology are needed to get the usual antenna gain over a broad continuous frequency range with typical portable antenna sizes. However, spot market concepts can be introduced today with the frequency agility that has been typical with land mobile radios, e.g. 136-174 MHz and 450-520 MHz. New technology will allow more agility as time progresses. •

More information

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How interruptible spectrum might work