Spectrum Management Reform and the Notion of the 'Spectrum Commons'

Dale N. Hatfield[1]

Adjunct Professor at the University of Colorado at Boulder and private consultant.

Abstract

Spectrum management is an extremely important part of telecommunications policy and regulation. The allocation of spectrum for particular uses, and development of specific technical and service rules governing those allocations, are crucial determinants of telecommunications industry structure and performance. Not only does the management of the resource have an enormous impact on a nation's economic and social well-being, it is also of critical importance to the safety of life and property, and to national defense. Fast-growing demand, coupled with rapid technological change, have put increased pressure on the traditional, centralised, often bureaucratic, "command-and-control" methods of managing the resource. One alternative to the traditional, centralised method is moving spectrum management in the direction of a market-oriented solution, wherein property-like rights in the resource are traded on a decentralised basis, more like other resources. Another method for reducing the rigidities in the current system is for policy-makers to move spectrum management in the direction of a "spectrum commons" solution. Under this alternative, anyone can gain access to a particular block of spectrum or set of channels, subject only to certain basic rules. Recently, there has been increased interest in the spectrum commons approach, because of the success of unlicensed spectrum in providing consumer benefits and increased opportunities for entrepreneurial activity. This paper explores the spectrum commons approach and concludes that, even in the face of significant challenges, the potential benefits are significant enough to warrant serious consideration by telecommunications policy-makers in their role as spectrum managers. This conclusion applies not only to developed countries but also to developing countries, where the more decentralised, less bureaucratic approach could empower individuals and communities to expand networks, applications and services on their own initiative.

I. Introduction

Radio spectrum refers to electromagnetic waves that travel through space within a frequency range between 3,000 cycles-per-second and 400 billion cycles-per-second.[2] These electromagnetic or radio waves are used to communicate information over distances without wires or other physical media. The radio spectrum is a natural resource with some unique characteristics, and it has both national and international dimensions, because radio waves do not respect political boundaries. One of its unique characteristics is that, unlike most natural resources such as oil, coal, iron or other mineral resources, it is not consumed by use. That is to say, one can, for example, use the resource to broadcast a high-power television signal today and still have the same amount of spectrum tomorrow. Said another way, the resource is infinitely renewable.[3]

1 In the past, Hatfield has served as Chief of the Office of Plans and Policy and Chief of the Office of Engineering and Technology at the US Federal Communications Commission (FCC).

2 The unit, cycles-per-second, is referred to as a Hertz and is abbreviated "Hz." One KHz is one thousand Hz, one MHz is one million Hz, and one GHz is one billion Hz.

3 Like air or water, however, the radio spectrum resource can be "polluted" by interference generated by natural sources of electromagnetic waves (e.g., lightning strikes) or by spurious emissions from radio transmitters or other man-made devices (e.g., florescent lights).

The radio spectrum can be shared in its frequency, time and space dimensions and, in theory at least, additional users can always be accommodated. Nevertheless, there are practical considerations in terms of cost and complexity that limit the number of users that can be served in a given geographic area at one time, and in that sense, the radio spectrum is a scarce resource. Hence, despite being infinitely renewable, it often has significant economic value, especially in geographic areas with intense demand for wireless communications.

Moreover, because different frequency ranges ("bands") within the radio spectrum have different technical characteristics, some bands are more attractive for particular purposes than others. Spectrum between 300 MHz and 3 GHz is particularly prized because the physical dimensions of the required antennas are reasonable, the associated transmitting and receiving devices are relatively inexpensive, and, more fundamentally, the radio waves are less susceptible than in other bands to being blocked or attenuated by natural or man-made obstacles such as hilly terrain or tall buildings.

The term "spectrum management," then, refers to the activities associated with the management of this somewhat unusual natural resource. It includes activities such as 1) allocating bands of frequencies for certain purposes (e.g., television broadcasting or terrestrial mobile radio services); 2) developing rules and regulations governing the use of the spectrum within the band (e.g., maximum transmitter power); 3) deciding, through the issuance of a license, who receives permission (or is denied permission) to use a channel or group of channels within a band in a specified geographical area; and 4) enforcing the associated rules and regulations once they are adopted. The focus of this article is on spectrum management and, in particular, on spectrum management reform at the national, rather than the international, level.

II. Importance of Spectrum Management

Spectrum management is an extremely important part of telecommunications policy and regulation. The allocation of spectrum for particular uses, and the development of specific technical and service rules governing those allocations, are crucial determinants of industry structure and performance. For example, without allocations/assignments, specific segments of the wireless industry would not exist at all. Providing more of the resource to a particular provider or segment of the industry allows costs to be reduced or, in the extreme, allows the scarce resource to be squandered. At the other extreme, allocating too little can make the associated service uneconomical. It is obvious that the amount of spectrum allocated, and how it is distributed among users, has a strong effect on industry performance. For instance, it determines the number of competitors and, therefore, has a major impact on the degree of competition.

Not only does the management of this scarce resource have an enormous impact on a nation's economic and social well-being, it is also of critical importance to the safety of life and property, and to national defense. Moreover, it is of added importance in developing countries, where wireless infrastructure is often proving to be the quickest and least expensive way of extending telecommunications services into unserved areas. In most developed countries, and in many developing countries, there is growing pressure for added spectrum to support more users, more uses (e.g., wireless Internet access), and more capacity (greater data rates or bandwidth) per user. There is typically pressure for added spectrum to support: more competition in the telecommunications sector; economic growth; greater access to telecommunications in unserved areas; and public safety/national defense.

In the past, at both the international and national levels, spectrum managers largely relied upon engineering-oriented, centralised "command-and-control" methods of managing the spectrum resource. Under the traditional command-and-control approach, spectrum managers have attempted to accommodate increased demand for the resource through four fundamental techniques. These four techniques, and their adequacy in the face of greatly increased demand for access to the resource, are described in the section that follows.

III. Traditional Methods of Relieving Spectrum Congestion

As mentioned above, spectrum managers have used four basic techniques, or combinations of these techniques, to accommodate more uses and users within the resource. The four solutions are reallocation, utilisation of higher frequencies, improved technology, and increased sharing.

As its name implies, reallocation means changing, through regulatory action, the utilisation of a block of spectrum from one use, say terrestrial television broadcasting, to another use, such as terrestrial mobile radio services. When spectrum is reallocated, the new use is judged to be of higher value than the old use. In some situations, displaced uses/users are accommodated in still a different band.

Reallocation from a lower-value use to a higher-value use has traditionally been utilised as a way of providing spectrum for new services or for the expansion of existing services. Reallocation is typically opposed by incumbent users of the affected spectrum, on the grounds that it will prematurely decrease the value of their investment in the associated radio equipment. In recent years, various techniques have been utilised (or at least identified) to reduce this opposition to reallocation under the traditional command-and-control approach to spectrum management. These techniques include providing a long time period for vacating the spectrum, having new users compensate the incumbent users for the value of the stranded investment, and creating a trust fund for compensation out of spectrum auction revenues. Despite these techniques, reallocation remains problematic, because of opposition from incumbent spectrum users and, more fundamentally, because simply reallocating spectrum from one use to another does not increase the total, aggregate amount of spectrum available. Thus, as spectrum use intensifies, it is becoming increasingly difficult (at international, regional and national levels) to find spectrum for new uses, or to find a new home for licensees/users displaced as a result of spectrum manager-ordered reallocations. Long-term reallocation tended to work when there were large blocks of under-utilised spectrum available, but this is often no longer the case. As a practical matter, this means that, in the future, spectrum managers will have to put more reliance on the remaining three spectrum management techniques.

A second technique that spectrum managers have traditionally used to accommodate more uses and users is to allocate higher and higher frequencies. While the total amount of spectrum available can be increased in this manner, the technique is becoming less useful because of technical constraints. Namely, in the upper ranges of the radio spectrum, the radio waves are easily obstructed and transmission ranges are typically very short. While these frequencies are useful for some purposes (e.g., very-short-range radar), they are of limited suitability for general wireless communications purposes. Thus, extending the upper limit of the useable spectrum range can no longer be relied upon to relieve spectrum shortages – especially for increasingly popular mobile applications that are best suited for the lower frequency ranges (e.g., 300 MHz to 3 GHz or so).

A third technique for accommodating more uses and users within the available spectrum is to improve the efficiency with which the resource is used. This is analogous to increasing the fuel efficiency of motor vehicles to reduce the amount of gasoline that a country consumes. The techniques for improving spectrum efficiency can be divided into various categories. For example, one category is associated with digital compression techniques that reduce the amount of bandwidth that is required to accommodate, say, a voice conversation. Another category, exemplified by cellular mobile radio systems, makes use of "frequency re-use." By keeping transmitter powers and antennas low, it is possible to limit the range of a given tower so that the same channels can be used multiple times in a geographic area. It is beyond the scope of this article to delve into these spectrum efficiency-building techniques in any detail. It is sufficient to say that certain technological developments hold the key to some of the spectrum reform efforts described later.[4] It should be noted that these techniques typically involve some trade-off in terms of quality, equipment complexity, or battery life. However, with the falling cost of computer processing power and the increasing value of the radio spectrum resource, these techniques are becoming increasingly important.

The fourth and final technique for accommodating additional uses and users is increased sharing of the resource. Spectrum-sharing of the type referred to here occurs when two different systems or services both use the same band or range of frequencies in the same geographic area. Avoiding interference between the two is accomplished by technical or operational means. For example, a fixed satellite communications service and a fixed terrestrial point-to-point microwave service can share the same spectrum by careful design that takes advantage of highly directive antennas. Because of the growing demand for spectrum and the increased difficulties associated with reallocation and extending the upper range of useful spectrum, additional sharing of the resource using advanced technologies appears to be unavoidable as a way of relieving congestion in the more desirable regions of the spectrum.

Broadly speaking, there are two ways of achieving increased sharing: 1) forced or involuntary sharing, wherein the frequency manager mandates sharing by making an additional allocation in already-encumbered spectrum; and 2) voluntary sharing, wherein the incumbent agrees to sharing in return for some financial consideration – some legal form of payment – from the new entrant. By and large, involuntary sharing is associated with traditional command-and-control regulation, wherein new users or uses of the spectrum are "engineered in" on a "non-interference" basis in long, drawn-out, often litigious proceedings characterised by vociferous objections from affected incumbent licensees. While more clearly-defined interference rights, increasingly powerful engineering modeling tools, and more sophisticated transmitting, receiving and control systems can help in such situations, there is a growing concern that the time-frames and difficulties associated with outright reallocations and involuntary sharing are fundamentally incompatible with the fast-growing demand, rapid technological change, and increasing dynamism in the wireless telecommunications market. In the United States, recognition of the problems with involuntary sharing has led to an upsurge in interest in alternative methods for facilitating voluntary sharing.

IV. Alternative Methods for Facilitating the Voluntary Sharing of the Spectrum Resource

With little prospect for dramatic and timely improvements in involuntary sharing under the traditional command-and-control approach to managing the spectrum resource, the focus of policy-makers must necessarily shift to alternative methods that facilitate and encourage voluntary sharing. Two very different candidate approaches have emerged. One method calls for increased reliance on decentralised, marketplace forces for encouraging voluntary reallocation and sharing, and the other method calls for increased reliance on what is referred to as the "spectrum commons" approach.[5] These two alternatives are discussed in more detail in the paragraphs that follow.

4 These advances include more flexible equipment, such as so-called "Software-Defined Radios," which rely heavily on software rather than hardware for their functionality. A related development is "Cognitive Radios," which can sense their surroundings (e.g., the interference environment), and adjust their characteristics accordingly.

5 These alternatives are examined in detail in the US context in a report by the Federal Communications Commission's Spectrum Policy Task Force. The report and related documents are available online at: http://www.fcc.gov/sptf/.

A. Market-Oriented Approach

The first alternative for encouraging voluntary sharing is for policy-makers to move spectrum management further in the direction of a market-oriented approach, wherein exclusive rights (i.e., property-like rights) to use the resource are traded on a decentralised basis, more like other resources. Earlier decisions by the US Federal Communications Commission (FCC) to allow cellular carriers to sell (to disaggregate and partition) their excess spectrum rights, and the more recent decision to allow certain classes of licensees to lease their spectrum rights on a contractual basis, are examples of such movement.[6] In the market-oriented approach, the profit motive reduces the rigidities by providing the incentive for voluntary sharing. Incumbents are more willing to share because they receive compensation when they do so.

B. Spectrum Commons Approach

The second method for reducing the rigidities in the current system is for policy-makers to move spectrum management further in the direction of a spectrum commons approach. Under this alternative, anyone can gain access to a block of spectrum or set of channels, subject only to certain basic rules. The spectrum commons approach is somewhat analogous to grazing lands that are used in common by herdsmen in a community, or to public parks or hunting lands that can be accessed by anyone. Another analogy is public roads that are owned by an entire community and are used by everyone in common. Even in countries with a strong market-oriented economic system, private property and property/facilities shared in common (e.g., land set aside for parks or highways) coexist side-by-side.

A commons-like approach has been used in spectrum management in the past where some of the resource has been set aside (i.e., allocated) for any eligible member of the public to use. A good example of this is the amateur radio service. In the amateur service, enthusiasts are allowed to communicate for non-commercial purposes in certain bands as long as they pass a technical examination designed to demonstrate their proficiency in the radio art and the necessary knowledge of the regulations governing amateur operation. There is no exclusive use of spectrum in the amateur bands, but technical rules and social norms help to minimise interference among users. There is no guarantee of interference-free operation, however. Other bands or channels may also be allocated or assigned on a non-exclusive basis. These might include certain private land mobile spectrum used by businesses like tow-truck operators or concrete delivery companies.

The least restrictive form of sharing occurs in so-called “unlicensed bands” or “license-free bands.” Operation in these bands is allowed without a license to transmit, as long as the equipment used conforms to specified technical standards (e.g., maximum power restrictions) and, perhaps, protocols (e.g., do not transmit on a particular channel if you detect that it is already in use). Although the rules vary somewhat from country to country (e.g., in terms of their restrictiveness), manufacturers are generally given a very wide latitude in terms of the equipment they can sell for use in the bands and, similarly, the public is given very wide latitude in terms of the purposes for which that equipment is used. In general, operators of the devices (say a cordless telephone or keyless entry system) are not allowed to cause harmful interference to licensed services and they must accept any interference from other devices as long as the other devices are operated within the specified technical standards (e.g., in terms of their maximum transmitter power). Because no one is denied access to the associated spectrum as long as they utilise properly-authorised equipment, essentially unlimited “voluntary” sharing of the allocated portion of the resource is achieved.[7] Accordingly, in the unlicensed bands, the delays and complexities associated with involuntary sharing are avoided.

6 The market-oriented approach can also reduce the difficulties associated with reallocations in the centralised command-and-control system. Giving existing licensees increased flexibility to use their spectrum for a different (higher economic value) purpose without seeking permission of the regulator can avoid the need for a long and contentious reallocation proceeding. Since the emphasis of this article is on spectrum-sharing rather than outright reallocations, these potential advantages of a more market-oriented approach will not be pursued further.

The market for unlicensed devices and systems operated on a shared, spectrum-commons basis has proven to be phenomenally successful. In the United States alone, the Consumer Electronics Association estimates that there are approximately 350 million such devices in use in applications such as cordless telephones, garage door openers, remote-control toys, baby monitors, home security systems and automobile keyless entry systems. More recently, unlicensed systems have rapidly grown in popularity as a way of providing broadband access to the Internet. These systems, known as Wireless Local Area Networks (W-LANs), typically rely upon a technology known as Wireless Fidelity or “Wi-Fi.” Wi-Fi systems, in turn, are built around a certified set of wireless networking products that conform to the IEEE 802.11x technical standard. (DeSilva, Dombrowsky and Senkowski, 2002) In the simplest configuration, these systems consist of a wireless base station or “access point” that extends a two-way, broadband connection via radio spectrum to individual devices such as laptop computers or Personal Digital Assistants (PDAs). These end-user devices are equipped with wireless network interface cards (NICs) or built-in circuitry that communicate(s) over the wireless link to the access point.

In large businesses or on university campuses, these unlicensed systems are often used as a way of providing wireless access to an existing wired LAN. Because of the low power and simple antennas involved, the ranges achieved are usually not greater than a hundred metres or so. Thus, multiple access points are needed to cover a large facility. In homes and small businesses, a single access point may suffice to provide wireless access to a broadband Digital Subscriber Line (DSL) connection obtained from the local telephone company or to a cable modem connection provided by the local cable television company.

With the initial Wi-Fi standards in place, and with the rapid growth (and falling prices) of the necessary equipment, entrepreneurs very quickly recognised an opportunity to offer broadband access to the general public through wireless access points located at high- traffic volume locations such as airports and other transportation hubs, hotel lobbies and coffee shops. Sometimes the access is offered free as a way of attracting customers to the location (e.g., the coffee shop), or in exchange for a one-time charge or a longer- term subscription. In addition, Internet Service Providers (ISPs) and other entrepreneurs recognised the possibility of using basically the same technology, but with more sophisticated external antennas, to extend broadband Internet access to homes or small businesses that were not able to get DSL or cable modem service via wired facilities. For example, an ISP in a small farming community might install an access point with a relatively sophisticated antenna on a high structure such as a water tower and thereby offer high-speed Internet access to an entire cluster of homes and small businesses. Because no radio license is required (only the use of widely-available, competitively-priced, approved equipment), these Wireless ISPs, or “WISPs” as they are sometimes called, can roll out service quickly and at low cost. Various manufacturers have recognised this as a potentially large market and have developed even more sophisticated “carrier-class” systems that operate over an extended range on an unlicensed basis.

7 The term “voluntary” appears in quotes in this sentence because an operator of equipment in an unlicensed band might like to prevent interference from other users of the same spectrum. However, accepting such interference is a condition of operating in the band and the acceptance of those conditions is voluntary.

Many spectrum managers and telecommunications policy analysts have observed the rapid innovation and growth that has occurred under the spectrum commons approach, with its minimal regulatory restrictions. They have concluded that it holds great promise for increasing sharing and reducing the rigidities of the current command-and-control system. Instead of using the profit motive under the market-oriented, property-rights approach to encourage increased sharing, the advocates of the spectrum commons approach urge spectrum managers to move in almost exactly the opposite direction. In the spectrum commons approach, the users do not have property rights or, more accurately perhaps, property-like rights, in a privatised resource, which protect them against interference from other users. On the contrary, they are compelled to share the resource.[8] It is interesting to observe that, in the US at least, there are groups that are arguing against the privatisation of spectrum, much like citizens' groups might argue for more public parklands that can be enjoyed by all.

Because the notion of a spectrum commons approach as a means of spectrum reform is still relatively new, the promise and challenges of the approach are examined in more detail in the next section.

V. The Promise and Challenges of the Spectrum Commons Approach

As noted above, the spectrum commons approach, as exemplified by the success of unlicensed spectrum, has already provided important consumer benefits and, at a minimum, is widely accepted as an important element of spectrum management policy in the future. Some advocates of the spectrum commons approach have an even bolder vision of the future. In the United States, these advocates include, among others, Lawrence Lessig, a Professor of Law at Stanford University, Yochai Benkler, a Professor of Law at Yale, and David P. Reed of Internet fame and Adjunct Professor at the Massachusetts Institute of Technology (MIT) Media Lab. The vision that is emerging from these advocates extends the spectrum commons approach in two major ways.

First, the advocates challenge the very notion of spectrum scarcity. They argue, with some justification, that any perceived scarcity is largely an artifact of the rigid, command-and-control approach to spectrum management. They envision a much more decentralised architecture, in which individual end-user devices are given significantly greater responsibility for finding suitable spectrum and minimising the interference caused to, and received from, other users. By employing techniques such as intensified frequency re-use, "cognizant" radios, interference avoidance/ cancellation, "smart" antennas, space-division multiplexing and a host of other techniques, they believe that spectrum can be shared on a much more efficient, opportunistic and real-time basis, thereby dramatically increasing the capacity of the resource. Once again, it is beyond the scope of this paper to describe these advanced technologies in any detail, but an example might be useful.

In some emerging architectures, an end-user device added to a network not only "consumes" spectrum when it communicates with other nodes, but it also adds capacity by relaying traffic for others. Thus, at a given instant in time, two arbitrary nodes could not only communicate directly over a point-to-point link between them, they could also gain added capacity by taking advantage of intermediate relays offered cooperatively by other nodes lying in other directions. Interference among these multiple paths would be avoided by using sophisticated, highly directive, multi-beam antennas and other techniques. Such a network is said to be "scalable," because the total capacity actually grows as the number of cooperating end-user devices increases.

8 Note that the spectrum commons model does not imply that access to the resource is necessarily free. A nominal fee can still be charged for using the resource, just like a fee might be charged for entering a national park. Even with a fee, the park is available to all and it remains a commons in that sense.

Second, some advocates of the spectrum commons approach also envision a network based upon unlicensed spectrum that would emulate the Internet, in terms of being open and non-proprietary and capable of efficiently handling voice, data, image and video traffic. One important characteristic of the Internet architecture is that, unlike traditional wired and wireless voice telephone networks, the computer power or "intelligence" used to create individual services resides in devices that lie at the edge of network (i.e., in clients and servers) and that are not under the control of the network provider. In the traditional wired and wireless voice networks, the intelligence used to create individual services resides in computers or logic internal to the network and under the control of the network provider. For this reason, it is sometimes said that the Internet is like the telephone network "turned inside out." Said in still another way, in the traditional wired and wireless voice networks, the end-user devices (e.g., an ordinary telephone) are "dumb" and the network is "intelligent," while the reverse is true in the Internet.

This fundamental difference in architecture has enormous implications in terms of control and hence, innovation. On the Internet, someone wanting to create a new service can do so by installing software residing in computers (e.g., in clients and servers) external to the "dumb" portion of the network controlled by the carrier or provider. Service creation and indeed, content production and distribution, are thereby opened up to imaginative people and entrepreneurs who do not have to own or control the underlying network in order to demonstrate their creativity. The popular services or applications that have driven the success of the Internet – e-mail, the World Wide Web, instant messaging, and file-sharing to name just the most prominent – have evolved in exactly this way. In short, advocates of the spectrum commons envision using decentralised intelligence not only as a means to dramatically increase spectrum-sharing, but also as a way of shifting greater control over service development (as well as content creation, distribution and consumption decisions) to the general public. The benefits and challenges associated with achieving this vision are described in the subsections that follow.

A. Benefits

The potential benefits of the spectrum commons approach described above should be readily apparent given the success of the Internet and the success of unlicensed devices. Unlike the situation in the current centralised, command-and-control approach to spectrum management, innovation in the development of more sophisticated radio equipment, and innovation in the protocols they use to communicate, would be facilitated. For example, an inventor would not have to go through a lengthy, litigious spectrum allocation process in order to introduce a more robust or benign radio technology, as long as the equipment used met certain conditions, (e.g., in terms of the maximum transmitter power). Likewise, innovation would be facilitated in the development of applications and services that use the decentralised, open and non–proprietary radio-based platform that the advocates envision. In short, there would be no "gatekeepers" at the spectrum access, service creation, or content distribution levels. Conceptually, this would mean that an entrepreneur desiring to develop a telemetry system for use in environmental monitoring, or an individual end-user desiring to stream unique video content on a "broadcast" basis, could do so even if they did not control the underlying spectrum or radio network.

Advocates also see value in the "bottom up" -- rather than traditional "top down" -approach to network development that is facilitated in the spectrum commons approach. In the more decentralised model, communities are less dependent upon actions taken by others – say the build-out plans of an incumbent cellular mobile radio service provider – because they can expand the network, the applications and the services on their own.

This model supports community involvement and empowers people to help themselves, just as small wireless ISPs are doing by using Wi-Fi technology to extend Internet access in isolated areas.

B. Challenges

The potential benefits of the spectrum commons approach are clear and striking. However, there are significant challenges as well. Perhaps the most fundamental one relates to what is referred to as the "tragedy of the commons." When a resource – like spectrum or land – is used in common (shared), there is an incentive for individual users to increase their consumption of the resource in order to make more profit or to benefit themselves in some other way. The problem is readily apparent using my earlier example of grazing lands that are used in common by herdsmen in a community. Individual herdsmen can increase their profit by grazing more animals on the common grazing land. As long as the amount of land is vast compared to the number of animals being grazed, this may not produce a problem. But as the numbers grow, at some point the carrying capacity of the grazing land is approached and the profits of other grazers are diminished. The problem is exacerbated if other users, facing diminished profits, attempt to recoup their profits by increasing the size of their own herds. At some point, the productive capacity of the grazing lands is destroyed through over-grazing. This depletion or destruction of a resource used in common is known as the "tragedy of the commons."

The analogous situation in the spectrum commons approach is readily apparent. An individual user can increase the performance of a communications link by increasing his or her transmitter power, thereby causing more interference to – and reducing the performance of – links operated by other users. Faced with diminished performance, the other users may retaliate by raising their own transmitter powers to compensate for the increased interference. As pointed out at the outset, spectrum, unlike many other resources, is not consumed by use, but nevertheless, the utility of the resource can be reduced drastically by such a *"power war"*. In the absence of a property rights system and associated price signals, the tragedy of the commons can be averted by informal social norms or by more formal laws and regulations governing the use of the resource. In the case of the pasture land, the restrictions might be in the form of limitations on the number of days and/or the number of animals that can be handled by a single herdsman. In the case of spectrum, the analogous restrictions might be in the form of constraints on the maximum transmitter power of the devices employed.

A closely-related issue to the spectrum commons approach is the amount of detail or specificity that is contained in the rules and regulations intended to avert the tragedy of the commons. Simple rules or protocols like "listen for other users before you transmit" or "use only the minimum amount of power to accomplish the needed communication" can reduce interference and improve the utilisation of the resource. Likewise, more complex rules limiting the types of signals that are transmitted can make it easier for receivers to reject interference. At some point, however, detailed restrictions – no matter how well-intended or well-crafted – can reduce the ability of the inventors and others to innovate without seeking changes in the associated rules and regulations. In the limit, a fundamental advantage of the spectrum commons approach – the ability to respond quickly to changes in technology and the marketplace – may be lost due to detailed restrictions. Thus, even spectrum managers who are supportive of the spectrum commons vision face a difficult trade-off between increased utilisation of the resource in the short term and potential greater innovation in the longer term. These are not easy issues to resolve.

Without suitable rules and regulations, the type of scalable system mentioned earlier may also suffer from "free rider" problems. In these types of systems, a new user not only consumes capacity

by transmitting and receiving messages but also adds to it by relaying messages for others. Since relaying messages may cost the user something (e.g., by requiring the user's equipment to be turned on all the time), there is an incentive for the user to consume network capacity but not "pay" for it by voluntarily relaying traffic for others. Even worse, there is a possibility that, for nefarious reasons, a user may only pretend to relay messages, or may modify them in some harmful way.

This discussion of rules and regulations designed to avoid the onset of the tragedy of the commons and the free rider problem leads to another significant challenge – enforcement. If the tragedy of the commons and the free rider problem are to be avoided, some level of enforcement is vital. Enforcement in the context of the spectrum commons vision is especially challenging for a number of reasons. First, the sheer number of devices involved and the decentralised nature of the network(s) may make it difficult to carry out enforcement activities. Second, unlike the audible or visible forms of interference associated with traditional radio and television broadcasting, interference in a data network may manifest itself in the form of slower or more erratic performance, and thus the source of the degradation may be difficult to ascertain. For example, slower data downloads might just as easily be caused by a legally-operated, close-by cordless telephone as by an illegal data network device operating at high power one kilometer away. The source of the interference may be difficult to discern without specialised equipment. Third, it may be difficult to get political support for taking enforcement actions against ordinary citizens when the harms are rather ethereal and widespread.

C. Overall Assessment of the Spectrum Commons Approach

Despite the very real challenges associated with the spectrum commons approach, it appears that the potential benefits are significant enough to warrant serious consideration by telecommunications policy-makers in their role as spectrum managers. This appears especially true given the increasing difficulties associated with the traditional centralised, often highly bureaucratic, command-and-control approach to the management of the spectrum resource. It also appears to be especially true in developing countries (and in more isolated parts of developed countries), where spectrum congestion is much less apt to be a problem and the potential tragedy of the commons even easier to avoid. Moreover, the prices of the current generation of unlicensed devices and systems (e.g., Wi-Fi) are being driven down by the large volumes involved and the intense competition associated with an increasingly popular, standardised set of products. This makes the provision of wireless Internet access (and Internet-enabled applications such as Voice-over-Internet Protocol, VoIP) on an unlicensed basis even more economical and well within the reach of small entrepreneurs and community groups in both developed and developing countries. While it is too early to tell whether or not all of the benefits envisioned by its advocates will be fully realised, it does appear that the short- to medium-term benefits are sufficient to justify expanded experimentation with, and research on, the spectrum commons approach.

VI. Summary and Conclusions

Spectrum management is an extremely important part of telecommunications policy and regulation. The allocation of spectrum for particular uses, and development of specific technical and service rules governing those allocations, are crucial determinants of telecommunications industry structure and performance. Not only does the management of the resource have an enormous impact on a nation's economic and social well-being; it is also of critical importance to the safety of life and property, and to national defense. In most developed countries, and in many developing countries, there is growing demand for more spectrum to support new users, more uses, and greater capacity per user of the resource. Fast-growing demand, coupled with rapid technological change, has put increased pressure on the traditional, centralised, often bureaucratic, command-and-control methods of managing the resource.

One alternative to the traditional, centralised method is moving spectrum management in the direction of a market-oriented solution, wherein property-like rights in the resource are traded on a decentralised basis, more like other resources. Another method for reducing the rigidities in the current system is for policy-makers to move spectrum management in the direction of a spectrum commons solution. Under this alternative, anyone can gain access to a particular block of spectrum or set of channels, subject only to certain basic rules. Recently, there has been increased interest in the spectrum commons approach because of the success of unlicensed spectrum in providing consumer benefits and increased opportunities for entrepreneurial activity.

Advocates of greater reliance on the spectrum commons approach envision the use of increasingly intelligent end-user devices – decentralised intelligence – to dramatically increase spectrum-sharing as well as to provide a platform that offers greater public control over service development as well as content creation, distribution and consumption decisions. This paper has explored the spectrum commons approach and concludes that, even in the face of significant challenges, the potential benefits are significant enough to warrant serious consideration by telecommunications policy-makers in their role as spectrum managers. This conclusion applies not only to developed countries but also to developing countries, where the more decentralised, less bureaucratic approach could empower individuals and communities to expand networks, applications and services on their own initiative.

VII. Further Reading

As noted in footnote 5, current thinking regarding spectrum reform and, in particular, the future roles of the command-and-control, market-oriented, and spectrum commons approaches in the US context can be found in the report of the Federal Communications Commission's Spectrum Policy Task Force. In addition to the report and related documents that are available online at http://www.fcc.gov/sptf, a copy of a more recent news release describing spectrum policy reform progress and initiatives can be found at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-241195A1.doc. The following is a selected list of additional papers for readers who may want to pursue these topics in more depth:

Benkler, Y (2002) 'Some economics of wireless communications', Harvard Journal of Law & Technology, Vol 16, No 1, Fall, 25-83, http://jolt.law.harvard.edu/articles/pdf/v16/16HarvJLTech025.pdf, retrieved December 2003.

Carter, KR, Lahjouji, A & McNeil, N (2003) 'Unlicensed and unshackled: A joint OSP-OET white paper on unlicensed devices and their regulatory issues', OSP Working Paper Series, No 39, May, Federal Communications Commission (FCC), Washington DC, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-234741A1.pdf, retrieved December 2003.

Faulhaber, GR & Farber, DJ (2002) 'Spectrum management: Property rights, markets and the commons', Working paper, December, AEI-Brookings Joint Center for Regulatory Studies, http://aei-brookings.org/admin/pdffiles/php84.pdf, retrieved December 2003.

Hazlett, T (2001) 'The wireless craze, the unlimited bandwidth myth, the spectrum auction faux pas, and the punchline to Ronald Coase's 'big joke': An essay on airwave allocation policy', Harvard Journal of Law & Technology, Vol 14, No 2, Spring, 336-469,

http://jolt.law.harvard.edu/articles/pdf/14HarvJLTech335.pdf, retrieved December 2003.

Kwerel, E & Williams, J (2002) 'A proposal for a rapid transition to market allocation of spectrum', *OPP Working Paper Series*, No. 38, November, Federal Communications Commission (FCC), Washington, DC, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228552A1.pdf, retrieved December 2003.

Reed, DP (2001) 'Why spectrum is not property - the case for an entirely new regime of wireless communications policy', draft paper, Reed's Locus web page, http://www.reed.com/dprframeweb/dprframe.asp?section=paper&fn=openspec.html, retrieved December 2003.

Reference

DeSilva, E, Dombrowsky, T & Senkowski, RM (2002) *Wi-Fi – The shape of things to come?*, Wiley Rein & Fielding LLP, Washington DC, http://www.wrf.com/db30/cgi-bin/pubs/WiFi_Primer_Final.pdf, retrieved December 2003.