SPREAD SPECTRUM WIRELESS AND COMMUNICATIONS POLICY: A RADICAL VISION.

BY

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ABSTRACT

Spectrum is a communications resource which government is required to allocate. It must do so efficiently. This requires promoting competition while balancing the interests of the various stakeholders – government, the firms and the consumer. The current method of allocating spectrum falls short of this requirement. It is characterized by regulatory constraints on spectrum allocation and use resulting from the scarcity of spectrum. This scarcity is a consequence of available technology. New spread spectrum technology can alter this scarcity. A failure to recognise the impact of this technology will result in an artificial scarcity of the resource. Spread spectrum technology allows multiple interference free transmission of signals over a broad range of the radio spectrum. This will have a positive impact on the availability of spectrum, on innovation and the development of a robust communications infrastructure. The result will be the efficient, competitive and economically feasible delivery of communications services. It means that the current regulatory structure must be modified to make way for a new open access system. The design of the Internet's architecture has important lessons for this new ordering and can provide "best practices" insight on how to proceed.

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I. Introduction

"Some people believe that the future holds only two kinds of communications: fiber and wireless."[1] Wireless communications include telephony, broadcasting, radio (AM/FM and two-way radio, 'walkie talkies') and television. Wireless is a transmission medium. The input resource that makes wireless communications possible is "spectrum". Spectrum is a term often used to refer to the electromagnetic radiation spectrum. In this thesis spectrum is construed as a communications resource. On the one hand, it is a public good. This is so having regard to governments' continued commitment to manage its allocation on the basis of scarcity. On the other hand, it has been treated as a 'factor of production' in the provision of communications services. In this respect it has been 'commoditised' and sold off to the highest bidder. The result is the creation of "property rights" in spectrum. One of the ideas explored in this thesis is how this focus on the 'commoditisation' of the resource has contributed to inefficiencies in its allocation.

Spectrum is an important consideration in the formulation of communications policy. This is particularly so in so far as the aim of communications policy is to foster efficiency and competition. This requires that account be taken of the interests of the various stakeholders: consumers, the government and the firms and how they interact in the communications market place. The level of inputs available to the government to perform this balancing act is very important. In this context it has to be recognised that

1 A. S. Tanenbaum, *Computer Networks,* 3rd ed. (New Jersey: Prentice Hall, 1996) at 94

spectrum is not the sole input in the making of communications policy. What role does its allocation play in governments' effort to benefit consumers while creating an opportunity for the firms make a profit? What role does its allocation play in enabling governments to permit market entry on non-discriminatory terms without unfair detriment to the incumbent? The answer to these questions involves (a) a determination of the role and place of spectrum in the communications infrastructure (b) a consideration of technical possibilities, (c) consumer demand and (d) the implications of these considerations on the behaviour of the firms. The problem that faces governments in the making of communications policy is how best to balance these interests where there are limited resources. This thesis argues that implementing policies that promote efficient exploitation of resources such as spectrum is essential to achieving this end.

This thesis explores the relationship between law, economics and technology in the formation of policy. It takes a surgical approach so that the policy process is dissected to see how each modality rank in the determination of policy outcomes. This is relevant in so far as the exploitation of spectrum is an admixture of applied science (technology), economics and law. Its use and consumption is *technology* dependent. *Economic* principles determine its allocation and *law* structures the framework within which it is exploited and allocated. The underlying thesis is that in light of changing technologies, property rights are an inappropriate way to allocate spectrum. It is that technology drives communications policy. It will therefore propose that neutrality in governance rules and structures are required to achieve the goals of the policy. It is felt that insufficient attention is paid to this fact resulting in inefficiencies in allocation, which has a negative impact on the market structure. The fact that we speak at all of property rights in spectrum may be misleading. This is because the licensee does not own the relevant portion of spectrum. In fact, it is not scientifically possible because of the intangible nature of the resource. The license is really to permit certain devices to access particular portions of spectrum. In this sense it is the devices that are licensed although they are restricted to the assigned spectrum band. Rules are put in place to ensure that the devices do not emit radiation at a level that will cause interference to users of spectrum in adjacent bands. The argument is that the policies are based on the technology of the devices. Can we therefore concentrate on regulating the devices without speaking of property rights? Is that possible? This thesis suggests that it is possible. It will further suggest that changing technologies have a positive impact on how spectrum is "held"(accessed). This it will be argued depends on the standards and protocols embedded in the devices over time. Changes here, can impact on spectrum access and hence on communications policy.

So that such impact may be appreciated a distinction is made between conventional wireless access and spread spectrum wireless access. It is important to understand the policy implications of these access techniques. It will provide an appreciation for the argument that spectrum allocation policy is ripe for change. Change not because the policy was always bad, but because the policy has failed to keep pace with the evolution of technology. Change because it is time to recognise that access to spectrum was always about the technology of devices, not property.

Spectrum has been classified as a scarce resource. This notion is premised on its susceptibility to interference. Best practices for spectrum use therefore requires that a system be devised that can maximize its exploitation. A system that limits interference and encourages multiple uses and re-use would therefore be desirable. It is assumed that spectrum can be brought into more productive use with changes in technology. Three spectrum access techniques will be used to illustrate the dichotomy between the old and the new. Frequency Division Multiplexing Access and Time Division Multiplexing Access represent the old; Spread Spectrum Systems represent the new. The former represents "closed" access whereas the latter is representative of "open" access. The aim here will be to explain what they do, and a little of the how. This will enhance the understanding of the changes that are required to put spectrum to efficient use. The model of the Internet provides some useful insights for this purpose and will be used as the basis for creating a stylized model for spectrum allocation. The model will provide an important insight into how spectrum use and allocation can keep pace with technological relativism. It is important at the outset to understand that *open* does not mean *free*. It means non-discriminatory terms or conditions of access.

The ultimate aim of this thesis is to show that communications policy would benefit from being understood as a systematic application of specialized knowledge and/or techniques to the allocation of resources. In this context it will attempt to make predictions on the likely economic impact – allocative (the pattern of economic activities) and distributive (winners and losers) of pursuing an "open access" policy. The assumption is that people tend to respond rationally in their own self-interest to particular incentives or disincentives created by a policy. We can therefore begin with the basics of wireless transmissions. This is so that what is required for communication to take place may be better understood. Thereafter, the nature of spectrum itself is examined to see how it compromises this process. It is hoped that this will provide a background for determining how it may be accessed to achieve policy ends.

II. Wireless Transmission

Spectrum as a transmission medium facilitates the sending and receiving of information signals, which carry voice, data or video. It does so remotely, that is without wires or fibre optic cables. It uses radio and code to enable communication. Radio derives its name from the fact that it was first used to access the radio frequency band of the spectrum. They can be either transmitters or receivers, or a combination of both. Broadcasting is an example of the former in that it utilises one-way communications so that a transmission is effected from a transmitter to a receiver. This is fast changing in the digital era with the development of interactive TV. Telephony on the other hand, requires bi-directional communications so that there the technology of radio incorporates both transmitters and receivers. Bi-directional communications is made possible by duplexing techniques such as Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD). The use of the term radio to refer to the device that is used to access spectrum has led to one common misnomer that is associated with spectrum as a transmission medium. It is the practice of referring to all the waves of the electromagnetic radiation spectrum as radio waves. Discussion in Part III will show that this is not quite accurate.

The basic principle of all wireless communication is the transmission of signals from an appropriately sized antenna attached to an electric circuit (the 'radio') that is programmed to send a signal to a similar antenna, similarly attached, some distance away. Optimally, the receiving antenna should be able to discriminate between the various informational signals and select the one imposed by the transmitting device. The ability to discriminate between the signals is known as "selectivity".

Selectivity is determined by radio technology. Historically, "[t]he equipment was primitive and incapable of focussing on relatively narrow transmissions; time (scheduling transmissions) and space (placing transmitters far enough from each other) were the primary units that could be used to avoid interference"[2] as well as a crude model of channelisation by frequencies.

Where selectivity is compromised this results in interference. To the extent that interference exists it is more pronounced at the receivers. This is because the signal being received weakens as it travels over the distance between the transmitter and the receiver. Its power level is therefore lower than the power level of the interfering signal of the adjacent user. In other words, the transmitted signal is susceptible, due to distance, to interference from signals emanating from terminals that are located near to the receiving antenna. This is called the *near-far* problem. The interference is largely a result of the natural characteristics of spectrum but can be minimised by taking advantage of evolving technologies. This is very important as these technologies can transform the current technical assumptions that underlie spectrum allocation policies. "The baseline

2 Y. Benkler, *Overcoming Agoraphobia: Building the Commons of the Digitally Networked Environment,* Harvard Journal of Law and Technology (1998) at 12

technical assumption….is that in order for a transmission from a transmitter to be intelligible to a receiver, the signal sent by the transmitter must be "louder" than the combination of all other signals received by the receiver by a technically sufficient degree."[3] If each user from a group of multiple users use "this strategy for the same narrow frequency, neither can be heard."[4] This technical assumption contributes to the theory that spectrum is scarce. This scarcity forms the underlying rationale for current spectrum allocation policy, both administrative strictures and property rights. The policy is characterized by the grant of "exclusive transmission rights over narrow frequency bands."[5]

To the extent that this thesis challenges this technical assumption it is important to understand the nature of the medium, spectrum. That is the subject of the next part.

III. Spectrum: A Communications Resource.

A. What is Spectrum?

Spectrum is "[t]he entire range of wave lengths or frequencies of electromagnetic radiation extending from the largest radio waves to gamma rays and including invisible light."[6] Spectrum is a product of natural science and exists in the air or in space. Electromagnetic waves propagate through space and are created as a result of the movement of electrons. Each movement of the wave is called an oscillation. "The number of oscillations per second of an electromagnetic wave is called its **frequency (*f*)**,

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3 *Ibid* at 28
4 *Ibid* at 33
5 *Ibid*
6 *Merriam-Webster Online*, **online: <http://www.m-w.com/cgi.bin/dictionary> (last visited 13 March 2002) s. v. "Electromagnetic Radiation Spectrum".**

and is measured in **Hz**"[7] in honour of the German physicist, Hertz who first observed and produced it in 1887.

The waves oscillate at different rates of speed, which means that different sections of the spectrum have different frequencies. The division of the spectrum into seven bands follows on this frequency differential. Each band is further subdivided into a range of frequencies in ascending order. This conforms generally with international agreements and administrative bodies under the auspices of the International Telecommunications Union (ITU) given that the propagation of the waves transcends national laws and boundaries. It ranges from a low of 30kHz to in excess of 30GHz as illustrated in figure 1.1 which expresses these ranges in Hz.

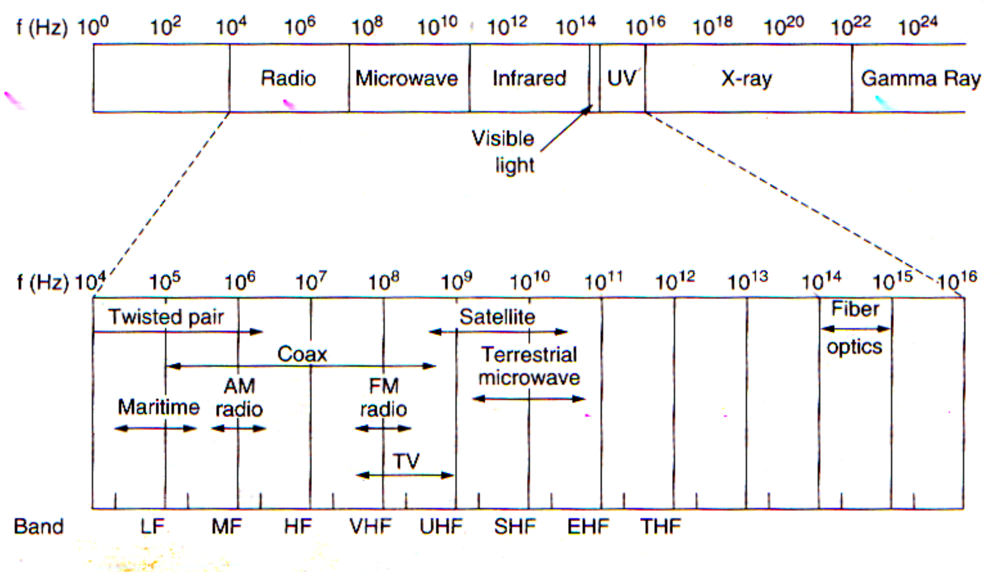

Figure 1.1 – The Electromagnetic Spectrum and its uses for communication.[8]

The International Telecommunications Union has also assigned microwave for an important use namely, the Industrial/Scientific and Medical bands (ISM). The

7 *Supra* note 1.
8 *Supra* note 1 at 95.

transmitters in these bands do not require government licensing and these span the 2.400 – 2.484 GHz band.[9] In some countries, for example Jamaica West Indies, the United States of America and Canada bands exists from 902-928 MHz for use by devices such as cordless telephones, gate openers and security gates. An additional allocation for this purpose was made in the United States of America on January 7, 1997 - the UN-II bands ranging from 5.15 GHz – 5.35 and 5.725 – 5.850 GHz. "The higher bands require more expensive electronics and are subject to interference from microwave ovens and radar installations. Nevertheless these bands are popular for various forms of short-range wireless networking because they avoid the problems associated with licensing."[10]

'Radio' and 'Radio spectrum' are generally used interchangeably to encompass and refer "to the use of *radio waves, for any purpose*, between 3 kilohertz and 300 gigahertz."[11] Figure 1.1 illustrates that this is technically inaccurate. It shows the different swaths of spectrum from radio waves to gamma rays and the different uses according to the band and the frequency.

The waves vary in their characteristics as shown in figure 1.2. The "[w]aves in the electromagnetic spectrum vary in size from very long radio waves the size of

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9 *Ibid*

10 *Ibid*

11 L. Lessig, *The Future of Ideas: The Fate of the Commons in a Connected World,* (New York: Random House, 2001) at page 73 [*Emphasis added*].

buildings, to very short gamma-rays smaller than the size of the nucleus of an atom."[12]

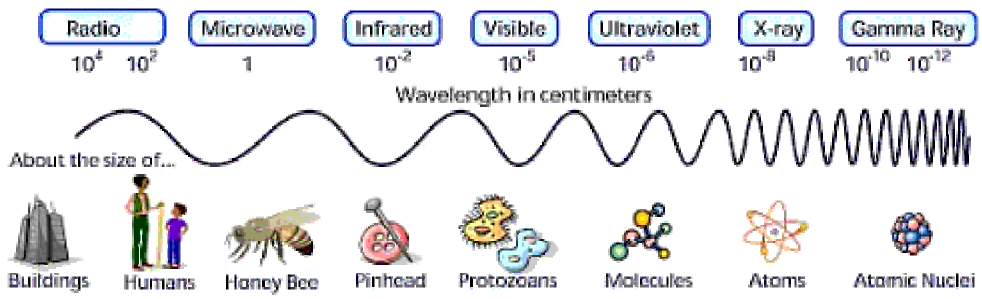

Figure 1.2 – The wavelengths of the various waves of the Electromagnetic Spectrum.[13]

There is an inverse relationship between wavelength and frequency. The wavelengths get shorter as the frequency increases. The variations in the wavelength have implications for the use of each band of the spectrum although there is some overlap at the low and high ends of adjoining bands.

Each frequency range is amenable to specific uses, meaning that some ranges are more effective for some uses more than others. A broad classification of bands by

[12] The Electromagnetic Spectrum, **online: Imagers <http://imagers.gsfc.nasa.gov/ems/waves3.html> (date accessed 20 March 2002).**

[13] *Ibid*

frequency ranges and their use is set out in table 1.[14]

Frequency	Band	Uses
30kHz to 300kHz	Low Frequency (LF)	Fixed, maritime mobile and navigational systems and radio broadcasting are among the users of this band.
300kHz to 3 MHz	Medium Frequency (MF)	Land, Maritime mobile and radio broadcasting are among the users of this band.
3 MHz to 30 MHz	High Frequency (HF) (Also called short waves)	Fixed, mobile, aeronautical and marine mobile, amateur radio, and radio broadcasting are of the users of this band.
30MHz to 144MHz 144MHz to 174 MHz 174MHz to 328.6MHz	Very High Frequency	Fixed, mobile, aeronautical and marine mobile, amateur radio, television and radio broadcasting, and radio navigation are among the users of this band.
328.6MHz to 450MHz 450MHz to 470MHz 470MHz to 806MHz 960MHz to 2.3GHz 2.3GHz to 2.8GHz	Ultra High Frequency (UHF)	Fixed, mobile, aeronautical and marine mobile, amateur radio, television, radio navigation and location, and space and satellite communication are among the users of this band.
2.3 GHz to 30GHz	Super High Frequency (SHF)	Fixed, mobile, Radio navigation and location, and space and satellite communication are among the users of this band.
30GHz and above	Extremely High Frequency (EHF)	Amateur radio, satellite, and earth and space exploration are among the users of this band.

Table 1 – Frequency Allocation, Classification and Use.

14 See generally, J. Neuhaus, Allocation of Radio Spectrum in the United States of America **online, John Neuhaus Homepage <http://www.jneuhaus.com/fccindex/spectrum.html>(last visited: 27 May 2002).**

Generally speaking, "[t]he radio, microwave, infrared, and visible light portion of the spectrum can all be used for transmitting information by modulating the amplitude frequency or phase of the waves."[15] Higher frequencies, Ultraviolet light, X-rays, and gamma rays, though better for transmission are not utilised for that purpose. This is because they are hard to produce, difficult to modulate, do not move well through buildings and are harmful to living things. This thesis will therefore be restricted to radio waves and microwaves, which correspond to the Low Frequency to Ultra High Frequency range.

Some applications can be used in two bands so that FM radio and television overlap at high end of the radio wave band (100MHz) and the lower end of the microwave band (1GHz). Mobile telephony occupies several frequency bands just under 1 GHz. The next two sections will focus on the characteristics of radio waves and microwaves. This is important to an understanding of the scarcity of spectrum.

1. The Radio Band

Radio waves travel in this band of the spectrum. These waves have several characteristics that make them suitable for transmission. Unlike gamma rays, X-rays and ultra violet light, radio waves are easy to generate. They are able to travel long distances because of their wavelength but are susceptible to interference. The waves are omni-directional. It is therefore not necessary for the transmitter and the receiver to be physically aligned when effecting a transmission. The integrity of the waves however, depends on their frequency.

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15 *Supra* note 1 at 95.

As they approach the higher frequencies within the band they, like microwaves, travel in a straight line, are absorbed by rain and bounce off obstacles. They are susceptible to interference from motors and electrical equipment at all frequencies. These waves pass through obstacles well at low frequencies but lose power with distance from the source as they propagate in the air. These natural characteristics form the basis of arguments for a scarcity of spectrum premised on interference between users. Figure 1.1 illustrates that this band is used for coaxial cable transmissions, maritime radio, twisted copper pair, AM radio, FM radio and Television. They are suitable and used for cellular telephony at the higher end where they meet the microwave band.

2. The Microwave Band

Microwave has always been used as the medium of transmission for long distance telecommunications in most countries. Some long distance carriers such as Microwave Communication Incorporated (MCI) relied totally on microwaves to build their pioneering competitive long distance communications network. Wireless telephony, at least for now, relies mainly on microwaves for transmission.

Microwaves travel in a straight line and for that reason the transmitting and receiving antenna must be physically aligned. It therefore requires a direct "line of sight" in order to effect a transmission. Transmission in this band requires a concentration of all "the energy into a small beam using a parabolic antenna (like the familiar satellite dish)"[16] so that a high signal to noise ratio can be achieved. This high signal to noise ratio is technically required to "drown" out interfering signals from sources transmitting

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16 *Supra* note 1 at 98.

at or near to the same frequency band. Physical alignment is achieved by placing multiple transmitters in a row to communicate with a corresponding number of receivers with a direct 'line of sight' to each other. The placement of the receivers at mathematically defined distances apart from each other reduces interference.

There are a number of drawbacks with microwaves that contribute to the theory of scarcity. First, they lose power with distance. For this reason repeaters are required to maintain signal strength over long distances. This is because they travel in a straight line and if the towers are too far apart the earth will become an obstruction. Second, they do not pass through obstacles well at the lower end of their frequency range. Third, even though the beams are well focused there is still some divergence in space. The result is that some waves take a longer time to arrive than others. These 'delayed waves', as they are called, "may arrive out of phase with the direct wave and thus cancel the signal. This effect is called multi-path fading and is a serious problem. It is weather and frequency dependent."[17] To minimise the problems caused by this some operators keep a small portion of their channels idle to enable a switch "when multipath fading wipes out some frequency band temporarily."[18]

Improvements in technology makes it possible to use higher frequencies as a result of which bands up to 10 GHz are now routinely in use. At this frequency, new problems set in, that is absorption by water. "These waves are only a few centimetres long and are absorbed by rain….for communication, it is a severe problem. As with

17 *Ibid* at 99
18 *Ibid*

multipath fading the only solution is to shut off links that are being rained on and route around them."[19]

The widespread use for "long distance communication, cellular telephones, television distribution and other uses,"[20] has caused a severe shortage of spectrum to develop. Digital technology has also made several new applications possible. All of these applications can be carried on wireless, in some cases more efficiently than wire line solutions. These applications include wireless LANS, wireless Internet, Personal Communication Services and 3-G wireless (pure spread spectrum technology).

B. Is it Scarce?

It is not an exaggeration to say that spectrum is scarce. This is so in light of its natural characteristics. The real question is how scarce. Spectrum is a natural resource. It exists in free space, the ether. This shows that scarcity is a scientific problem. The resource is limited by its natural characteristics. The natural characteristics that are of concern include the nature of the waves. Microwaves and radio waves at high frequencies are inherently susceptible to interference, absorption and multi-path fading as they travel over distances between the transmitter and the receiver. The effect is a delimiting of the number of channels available for the transmission and reception of information. The result is that users in a given area compete for a limited number of channels. It follows that as the number of persons who have access to spectrum increase, so does the incidence of interference and hence scarcity.

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[19] *Ibid*
[20] *Ibid*

The risk of interference increases with distance. The more distance that there is between the transmitting and the receiving device, the greater the separation required between the transmitter and the interfering device. A high signal to noise ratio is therefore necessary so that the signal from the receiving antenna is sufficiently strong to preclude interference from adjacent channels failing which the signal will be lost. Conventional solutions separate the channels using mathematically defined formulae in terms of frequency to ensure that the signals do not overlap. The areas of separation have been defined as buffer or 'guard' zones between competing users. These represent large swaths of unused spectrum, which results in spectrum underutilization. This confirms that there is not as much as appears at first glance. Spectrum quantum and usefulness are subject to spatial placement, frequency and weather. Spectrum sharing is not possible without technological intervention.

This technology is the standards and protocols that are embedded in the radios that are used to access it. Technology is dynamic. Over the history of spectrum use, technology has been used to minimise scarcity by developing applications that take advantage of economies of scale that can maximize use. This thesis therefore proceeds on the hypothesis that spectrum is only *relatively* scarce. It suggests that the rules of allocation must be tailored to encourage technological experimentation. This is necessary because there is new, emerging technology that enables more people to share the same frequency with little or no interference. "The technological shift derives from various techniques – such as spread spectrum and code division multiple access, time division multiple access, frequency hopping…"[21] These techniques are not a panacea as they are at once complementary and conflicting in their interactions. The important point is to see how these techniques challenge the existing paradigm of regulatory strictures and property rights: "that the only way to assure high quality wireless communications is to assign one person the right to transmit in a given frequency band."[22]

Policy choices need to be revisited in light of these shifts. The next section examines various access techniques. It will show how, each technique progressively challenges and supports calls for modification of existing justifications for spectrum management and allocation.

IV. Spectrum Access Techniques

Spectrum access and scarcity are influenced by available technology. Technology is relative. The solution to the problem of scarcity is as effective as the available technology. "Change the technology, and the economics and the law of spectrum use must change too."[23] Spectrum access techniques may be divided into two types, conventional access techniques and spread spectrum access techniques. The main difference between conventional spectrum access techniques and spread spectrum access techniques is that the former transmits over a narrowband of frequencies. The frequencies require separation into channels and sub-channels to prevent interference. Spread spectrum systems are not new, and have been around for sometime and were, in

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21 *Supra* note 2 at 35

22 *Ibid*

23 E. Noam, "Beyond Spectrum Auctions: Open Access" in Tom W. Bell and Solveig Singleton, eds., *Regulator's Revenge: The Future of Telecommunications Deregulation* (Cato Institute, 1998) 113 at 113.

fact, widely used during and since World War II. Digital technology has made it possible to migrate from these conventional access techniques to commercial spread spectrum systems. Time-Division Multiplexing Access (TDMA) is a digital technology that transmits over narrowband frequencies.

A. Conventional Spectrum Access Techniques

1. Frequency Division Multiplexing Access

This is the basis on "which all radio communications have been built. This includes military and commercial communications systems, not to mention all television and broadcast radio systems."[24] This method of access enables multiple users to access spectrum using the frequency dimension. To give effect to this technique the spectrum is *divided into non-overlapping channels* to which specified multiple users have access for the duration of their call. These channels are known as sub-channels or sub-carriers. The transmitters must have 'bandpass filters'. Bandpass filters are used to suppress the signal power in adjacent channels. The receiver on the other hand has similar filters that reject signals from adjacent channels. The guard bands are necessary since each sub-channel or carrier is treated as an independent channel.

One limitation on these systems "is in the technology of the bandpass filters used in the transmitter and receiver, and the frequency uncertainties they must contend with."[25] Another limitation is that the guard band filters lowers the efficiency of the bandwidth so that in some systems "up to 50 percent of the available bandwidth is wasted. An equally

[24] R. C. Dixon, Spread Spectrum Systems with Commercial Applications, 3ed (1994: Wiley, New York) at page 400.
[25] *Ibid* at page 401

important limitation for these purposes is that in most FDMA systems, individual users are segmented to a particular sub-carrier. Therefore, their burst rate cannot exceed the capacity of that sub-carrier. If some sub-carriers *are idle their bandwidth* *<u>cannot be shared</u>* *with other sub-carriers."*[26] The result is a waste or underutilization of spectrum. This profligate system is generally associated with analog signals and is still commonly used for broadcasting, AM, FM and Television.

2. Time Division Multiplexing Access

This is a digital access method that, at least in voice telephony, replaces reliance on the FDMA system. Recall that waves are more susceptible at higher frequencies to loss of signal. The TDMA system is more effective at separating users than the bandpass filters used in the FDMA system at higher frequencies. The signals can operate together with no near-far problem at all.

It operates by dividing up the spectrum according to bursts of time within each frequency band. The time slots are non-overlapping and the users occupy a channel for the duration of their call. The time slots are occupied in a sequential manner. The frames are self-repeating at a very rapid rate in this way preventing interruptions or delay in conversations. Yet even here, spectrum is wasted because each time slot is treated as a separate channel and idle bandwidth *cannot be shared* with other sub-channels or sub-carriers.

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[26] "Overcoming Multipath in High-speed Microwave Links", **online:** Cisco.com, <http://www.cisco.com/warp/public/cc/pd/witc/wt2700/multpt_wp.htm at page 6 (date accessed: 10 April, 2002.[*emphasis added*]

B. Spread Spectrum Systems

Spread spectrum systems use a technique that causes the transmission signal to be deliberately varied over a large section of the electromagnetic radiation spectrum. Spread spectrum systems are versatile. In these systems:

> [B]andwidth occupied by the signal is wider than the bandwidth of the information signal being transmitted. For example, a voice conversation spread with a bandwidth of just 3 kHz or so would be spread over 1 MHz or more of spectrum. In spread spectrum systems, multiple conversations (up to some maximum) simultaneously share the available spectrum in both time and frequency dimensions.[27]

Spread spectrum systems use several different combinations of techniques to spread the signal. These include: Direct-Sequence Code Division Multiplexing Access (DS-CDMA), Frequency Hopping (FH), Time Hopping (TH) and Multi-carrier CDMA (MC-CDMA). This study is limited to the two most frequently applied techniques. These are Direct-Sequence and Frequency Hopping.

1. Code Division Multiplexing Access

This is a modulation and access method that uses the spread spectrum concept. Codes are used to separate the signals (conversations). The receiving and the transmitting device are each assigned a unique code to recognise the signal that is meant for each one. This code is used to 'spread' the signal over the available bandwidth. The other information signals are assigned different codes as a result of which other conversations represent background noise. Unless a receiver is programmed with the

27 D. N. Hatfield, "Technological Trends in Wireless Communications" at page 11(1996), **online: Gallaudett University, Technology Access Program <http://tap.gallaudett.edu/hatfield.htm> (last modified July 11, 1997).**

same code it is not able to intercept the information being transmitted. The codes used tend to have a "low enough mutual cross-correlation that they do not significantly interfere with one another over the dynamic range of signals presented to any receiver in a CDMA network."[28]

One advantage of this system is that it enables several simultaneous transmissions to occur. This means that the available bandwidth is shared over several users. All the users are located in the same frequency band. The process begins by multiplying each data stream with a pseudorandom noise code. The individual signals are spread out on top of each other and then overlaid by using a spreading code within the same time slot. The transmission signal is later de-spread (demodulated) at the receiver using the pseudorandom code. The data that is transmitted by other users that would formerly be regarded as interference seems like white noise. This is filtered out during reception. Narrow band noise is dispersed during the de-spreading of the signal.

A disadvantage however, is that proper power management is required where there are multiple transmitters and receivers so that one user does not overpower other users in the same band. FDMA and TDMA are more tolerant of power fluctuations however.

a) Direct-Sequence

This is one application of the CDMA technique and is also known as direct sequence code division multiple access (DS-CDMA). It operates in a similar way to packet switching in that the information to be transmitted is broken into bits "each of

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[28] *Supra* Note 24 at page 404

which is allocated to a frequency channel across the spectrum."[29] The carrier remains fixed within the assigned frequency band. The data signal is transmitted over a wider range of frequencies within the bandwidth as opposed to conventional wireless transmissions such as FDMA and TDMA that transmit on a narrowband.

b) Frequency Hopping

This achieves the same result as Direct Sequence spread spectrum but in a different way. With this technique the data signal is modulated with a carrier signal that hops from frequency to frequency as a function of time over a wide band of frequencies. As the name suggests, the carrier frequency ranges are not fixed. "*The frequency hopping technique reduces interference because an interfering signal from a narrowband system will only affect the spread spectrum signal if both are transmitting at the same frequency at the same time.*"[30] Thus, the signal to noise ratio is very high. This translates into a lower aggregate interference "resulting in little or no bit errors. A frequency hopping radio, for example, will hop the carrier frequency over the 2.4 GHz frequency band between 2.4 GHz and 2.483 GHz."[31]

The frequencies and the order in which the radio will transmit in these frequencies are determined by a pseudo-random hopping code. In order for a transmission to be properly effected, the transmitter and the receiver are set at the same hopping code. The receiver is programmed to listen to the incoming signal at the right time and correct frequency. The equipment is embedded with protocols to determine the number of

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29 J. Geier, **online: Wireless-Nets Consulting Services Home-page < http://www.wireless-nets.com/articles/whitepaper_spread.htm>(date accessed: 14, April 2002).**

30 *Ibid*

31 *Ibid*

frequencies per transmission channel and the maximum time to be spent on each frequency during a single hop. When the radio encounters interference on a frequency, the "radio will retransmit the signal on a subsequent hop on another frequency. Because of the nature of its modulation technique, frequency hopping can achieve up to"[32] 3 Mbps data rates. Assuming that radios use a different hopping pattern, this makes it possible for radios to transmit in the same band and not interfere with each other. It is possible to have operating radios use spread spectrum within the same frequency band and not interfere, assuming they each use a different hopping pattern. There is no spreading of the signal when this technique is used. Interference is minimised because of the small amount of time that is spent on each frequency during a transmission.

C. Spread Spectrum Systems and the Scarcity of Spectrum

The three access techniques remain useful but:

> Spread spectrum systems are often touted as a solution to the lack of spectrum frequency availability, as every bit of frequency from ELF through EHF is allocated to some use. In some isolated cases, spread spectrum techniques may be at least a partial solution, but they are not in any way a panacea. In fact, the number of spread spectrum signals that can be accommodated in a given bandwidth is similar to (if not less than) the number of narrowband signals accommodated in the same bandwidth.[33]

FDMA and TDMA remain relevant for narrowband transmissions. They remain relevant since they can coexist with the broadband signals of spread spectrum systems. The capability of the radios to enable multiple and shared use of the spectrum improves incrementally as one goes from FDMA, to TDMA to spread spectrum systems. Spread

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32 *Ibid*

33 *Supra* note 24 at 399

spectrum technologies reduce, and in the case of direct sequence spread spectrum eliminates the “unit size of the most efficient frequency/time/space dimension that a user must occupy exclusively in order to communicate without interference. The relevant time units might be as small as 10 milliseconds; and the relevant space no more than 50 yards or so. These units are so small as to make the transaction costs involved in negotiating allocation of exclusive property rights to them prohibitive. ”[34]

The technical characteristics and effects of spread spectrum systems, although tending to occupy a wider bandwidth than their narrowband counterpart, operate to minimise spectrum scarcity. First, spectral density is low powered. This means that there is no need for ‘loud’ transmissions. The result is that the signal is spread over a large frequency band thus, interference with narrow band signals is greatly minimised. This is what enables the spectrum sharing capability. The spectrum sharing capability is enabled by the use of spectrum overlay technology. This is a technique that makes it possible for spread spectrum signals to co-exist with narrowband signals in the same frequency. Second, because the low powered spectral density reduces interference the entire spectrum can be more fully utilised. An example of how this is useful is that it enables the use of channels formerly left idle in the event of multi-path fading. Third, the use of random codes enhances privacy. Fourth, it reduces interference caused from the multi-path effects. Fifth, it enables users to start their transmission at any time. Sixth, it has good anti-jam performance.

[34] *Supra* note 2 at 35.

Notwithstanding, it is important to recognise that there is currently no clear way of designing a system that can combat extreme multi-path issues, especially in densely populated urban centres where it is difficult to obtain a direct 'line of sight'. Spread spectrum access techniques are therefore only a partial solution. Technology continues to improve however, and with it hope of newer and more improved ways of accessing spectrum.

Spread spectrum technologies support the argument that spectrum is relatively scarce. They make "more" spectrum available. "More", in restricted conditions has the same effect as if there is no change in the status quo. The restricted conditions already exist in most jurisdictions and cannot be unceremoniously altered. A transitional and technology neutral approach is therefore the way forward to "open" access spectrum. In this context it is important to consider some concrete examples of applications that can be enhanced or made possible with spread spectrum systems.

V. Spread Spectrum Applications

Spread spectrum is widely used in the ISM bands in Jamaica, Canada and the United States of America but has not been authorized for general application. Some of the applications of spread spectrum systems are:

1. Global Positioning systems: These applications employ the direct sequence technique and are spread spectrum dependent;

2. Spread spectrum signals have been used to overlay narrow-band signals with minimal interference between the two. An example of this is where microwave point to point systems are overlaid by direct sequence signals;

3. Use of unwanted or under utilised spectrum: Spread spectrum has been utilised in bands that are susceptible of 'catastrophic' interference such as the ISM bands. One example is the use of the 902-928 MHz frequency for cordless phones.

Spread spectrum technology makes it possible to provide basic telecommunications services in underserved areas. This will be discussed below in the context of encouraging the expansion of unlicensed bands as a starting point for "open access" spectrum allocation. Arguably however, the best example to date of the utility of spread spectrum applications is the Kingdom of Tonga Project spearheaded by the Dandin Group. This is illustrated in the next section.

A. Wireless Internet – The Tonga Project

In 1998 the Dandin Group led by Dewayne Hendricks set up a wireless network for the provision of the Internet and other services in the Kingdom of Tonga.[35] This is a group of Islands in the South Pacific with a population of about 100, 000. Hendricks has toyed with amateur radios all his life. He was eager to test out the new spread spectrum technology, as well as other new technologies that support its application. These include ultra wide band (UWB) and spectrum overlay technology, and the Internet applications that these technologies enable, as well as Software Defined Radios (SDR).

The regulatory framework in the United States of America has restrictions on spectrum use and access. It was not receptive to these new applications. Tonga does not have any of these restrictions. The project was therefore moved to Tonga on the

35 See generally D. Hendricks, Dandin Group, **online: Dandingroup Homepage < http//www.dandin.com> (date accessed: 19 May 2002). See especially**, Networking Tonga from the Ground Up and the SkyDown, **online: Dandingroup <http://www.dandin.com/pdf/GIP_3.2000.pdf>(date accessed: 19 May 2002)**

invitation of the Crown Prince of that Kingdom. The goal is to move the island from a wired to a totally wireless infrastructure. Although, several inputs were used to give effect to this project, the principal interest in it for our purposes is the use of the spread spectrum technology. The infrastructure was set up using spread spectrum and ultra wide band technology, very small aperture terminals (VSAT) and support for Internet appliances. The project is up and running and is so far a success. Tonga now has a multiservice IP network. The services include VoIP, Internet data transmissions, video and a smart card access for services and billing. This has been provided at a fraction of the cost of these services in the United States of America. Tonga now enjoys arguably the cheapest Internet access in the world.

This project is an example of how spread spectrum techniques can fulfil predictions of wireless transmission as a technical substitute for wire line solutions. It shows that wireless can be a first and last mile solution. It also demonstrates that basic telecommunications services can include broadband Internet connectivity. This is good because basic telecommunications services as a minimum obligation formerly contemplated only basic voice telephony. It was constrained by costs and narrowband transmissions. Now with spread spectrum and its supporting technologies, cost is not an issue as enhanced services can be provided at way below the cost of the alternative wire line narrowband solutions.

Current spectrum allocation policies impede the deployment of these broadband wireless technologies especially in rural areas where it could be used to fulfil universal service mandates by enabling connectivity for underserved communities and schools.

Three examples of wireless applications that can benefit from spread spectrum applications are discussed in the next section. If these are possible using narrow band signals, there is no imagining what broadband solutions can achieve.

VI. Experimentation in the Unlicensed Bands

The Kingdom of Tonga project illustrates how spread spectrum techniques can be implemented with positive results where there are no regulatory restrictions. The unlicensed bands are equivalent to, or at best the most apt analogy of, the absence of regulatory restrictions in each jurisdiction. The unlicensed bands therefore provide an ideal testing ground for the implementation of an alternative model of spectrum allocation using spread spectrum and it's supporting broadband technologies. The unlicensed bands are currently being used in some countries to provide various types of communication services outside of the regulatory framework of the licensed bands. This section examines some of these services. The aim is to show that it is possible to use the unlicensed bands in the transition to the deployment of spread spectrum systems and an open access communications policy.

A. Universal Service Mandates

The basic reason for the cost effectiveness of wireless solutions is that unlike wire line solutions they are not distance dependent. Generally speaking, the cost of wire line solutions increase with distance from the central office whereas wireless solutions tend to remain constant. The Tonga project demonstrates that wireless can "obviate the need for the very expensive politically complicated counterproductive mechanisms now in place to enforce "universal service" and "wiring schools" mandates."[36] In the United States of America, The National Science Foundation conducted a survey and assisted a number of school districts that needed to connect the schools within the district to each other as well as to the Internet. They did this by taking advantage of the unlicensed bands. These tests have proven how unlicensed spectrum access can be an "alternative solution for public schools' data connection needs, using a different approach from the long term subsidies that are at the core of current universal service efforts."[37]

1. Wireless Local Loop

In February 2002, Cable and Wireless Jamaica Limited's figures for five regions serviced by it revealed that the Wireless Local Loop is the dominant method or compares well with traditional wire line solutions in providing basic telephone service. This data is represented in Table 2.

REGION	Total Telephone Service Distribution by Region	Wireless Local Loop Service Distribution by Region
Central	12.0%	41.2%
Kingston North	25.5%	6.0%
Kingston South	20.7%	0.0%
North East	9.4%	15.6%
St. Catherine	18.4%	18.7%
Western	14.0%	18.5%

Table 2 – Comparison of Wireless and Wire Line Distribution by Region (Jamaica West Indies).

36 T. W. Hazlett, "Underregulation: The Case of Radio Spectrum" in T. W. Bell and S. Singleton, eds., *Regulator's Revenge: The Future of Telecommunications Deregulation* (Cato Institute, 1998) 85 at 90 [emphasis in original]

37 *Supra* note 2 at 39

In Jamaica the WLL can be provided in the unlicensed bands only if the radiated power does not exceed 100mW.

B. Wide Area Networks (WAN)

Wide area networks are cost effective substitutes for wire line solutions and are especially useful in connecting educational institutions and enabling connectivity in remote areas.

> Another field study involves the wireless wide area network and Internet gateway installed by School District 20 in Colorado Springs. This network combines *unlicensed* spread spectrum wireless, licensed microwave wireless backbones, and fiber components to link to each other and to the Internet 26 of the total 28 sites in the district of 14, 000 students and 3000 staff, at about 27% the cost of a wired network with similar capabilities.[38]

These experiments in the unlicensed bands and the Tonga project show how "a wireless architecture utilising wideband and eventually SDR technologies in the first mile can effectively leverage natural concentrations of population surrounding educational institutions, furthering both residential and institutional opportunities for Internet enabled education."[39] The current method of spectrum allocation threatens or undermines this development. It stunts innovation and competition at the expense of consumers and entrepreneurs.

It is appropriate at this point to discuss the origins of spectrum regulation. This will aid an appreciation of the current basis for spectrum regulation. It will create a platform from which the arguments for modification can be advocated and understood.

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38 *Ibid* at 41

39 B. Hawkins and T. Davis, Comments of the Higher Education Parties: Educase American Indian Higher Education Consortium **In the matter of Extending Wireless Communications to Tribal Lands, WT Docket No. 99-266 Online: Dandin Group Home Page** <http://www.dandin.com/pdf/FCC_WT-99-266_991101.pdf> (date accessed 23 April 2002.

The United States of America is a pioneer in radio regulation and therefore provides a useful historical foundation on which most if not all spectrum regulation is built. Section VII describes the origins of spectrum regulation in the United States of America and the normative claims that underlie current allocation policies.

VII. Spectrum Allocation

A. The Origins of Spectrum Regulation

Spectrum regulation in the United States of America commenced and continues because of the technical assumptions related to interference and neo-classical economic analysis. In the pre-regulation era spectrum use was characterized by chaos. In some quarters chaos was blamed on the failure of private enterprise to create an orderly system of access to the spectrum. Generally speaking however, the chaos was blamed on the shortage of the resource. The shortage is the reason for the interference that is experienced when too many persons try to access it at the same time.

In order to put an end to chaos, the Radio Act 1927 was passed which charged the Federal Radio Commission (now the Federal Communications Commission) with the function of issuing licenses to those who wanted to have access to the spectrum. Since there were many persons who needed to use the scarce resource, it became necessary to devise a method to determine the person to whom the license would be granted. This function was initially fulfilled solely by the "public interest, convenience or necessity" requirement. It was not a satisfactory mechanism in the sense that there was no way of deciding between two equally qualified claimants.

Economist Ronald Coase challenged the idea that private enterprise had failed and that the public interest licensing was sufficient to determine who should have access to spectrum. Coase argued that the:

> real cause of the trouble was that no property rights were created in these scarce frequencies…A private enterprise system cannot function properly unless property rights are created in the resources, and, when this is done, someone wishing to use a resource has to pay the owner to obtain it. *Chaos disappears;* and so does the government except that a legal system to define property rights and to arbitrate disputes is, of course necessary…[40]

It is from this theory that the auction paradigm was born. It was not immediately acted upon however. It was not until 1993 that Congress authorized auctions as the bidding mechanism to determine to whom the licenses should be issued. The next section will set out the normative claims that underlie Coase's theory.

B. A Normative Analysis

The central question is, what is the best distributive mechanism under conditions of scarcity? The basic tool of Coase's theorem is neoclassical economic analysis. It assumes that man is a rationally self-interested animal. It is based on a set of assumptions that are used to predict human behaviour given a well-defined set of variables. "The central preoccupation of economics is the question of choice of policy under conditions of scarcity."[41] The scarcity arises because generally people want to use more of each resource than is available. Spectrum is no different. Scarcity creates the need to find a mechanism that can determine who from among a number of claimants has access to this resource. Coase argued that the best distributive mechanism is price. For this purpose

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40 R. Coase, "The Federal Communications Commission" (1959) 2 Journal of L & Econ. 1 at 14.

41 M. J. Trebilcock, "An Introduction to Law and Economics"(1997) 23 Monash University Law Review, 123 at 125.

access to spectrum is equated with property. The prediction here is that property rights provide incentives to which human beings are likely to respond positively in terms of maximizing on the exploitation of resources.

The theory proceeds on the assumption that "[e]conomies must allocate resources between the production and consumption of the four major classes of goods"[42] only three of which are relevant for these purposes, *rivalrous, excludable* and *non-excludable.* Spectrum is an inherently *rivalrous* resource because "no two persons can consume the same unit."[43] It is also naturally *non-excludable* because "when once produced, there is no way to stop anyone from consuming it."[44] These combined characteristics make it a *common property resource.* A fortiori, it is subject to over-exploitation and subsequent depletion. It is scarce. This is because everyone is likely to act in his own rational self-interest and so no account is taken of the cost that is imposed on existing users. This will result in the tragedy of the commons - chaos.

The solution is that the State creates property rights over spectrum:

> The main reason for government regulation of the radio industry is to prevent interference. It is clear that, if signals are transmitted simultaneously on a given frequency by several people, the signals would interfere with each other and would make reception of messages transmitted by any one person difficult, if not impossible. The use of a piece of land simultaneously for growing wheat and as a parking lot would produce similar results…The way this is to be avoided is to create property rights (rights that is to exclusive use) in land. The creation of similar rights in spectrum would enable the problem to be solved in the same way in the radio industry.[45]

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42 R. G. Lipsey & K. A. Chrystal, *Principles of Economics,* (Oxford: University Press, 1999) at 289.
43 *Ibid*
44 *Ibid*
45 *Supra* note 40 at 25.

It is assumed that this type of allocation best maximises society's goals because "economic agents…. *respond to incentives.*"[46] The incentive is the right to exclude others. Spectrum is therefore transformed into an *excudable* resource. Excludability is premised on property rights. It is allocated to those who (a) value its use most (b) are willing to pay for that right and (c) are willing to pay to prevent others from interfering with that right, subject to any external constraints. The prediction on this type of analysis is that spectrum will be made "relatively less scarce."[47] Societal goals in terms of competitive and efficient communications markets, consumer welfare and profits for the various firms will be realised. This is because more goals are realised when more resources are available.

C. Spectrum Allocation – An Empirical Case

In Jamaica the Telecommunications Act 2000[48] (the Jamaican Act) sets up the regulatory framework for spectrum management and allocation. The existing policy closely follows on the United States framework policy and allocation choice except that there is no rule making process or public interest requirement. The mechanism to determine *whom* the licensee is, is the auction paradigm. Under this system, spectrum licences are auctioned off to the highest bidder. This is the person who is willing to pay most for the resource because he values it and will accordingly maximize its use. It is important to recognise that the auctions do not determine the allocation of spectrum. They merely determine who, from a number of qualified claimants, the licensee is.

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46 *Supra* note 40 at 128.
47 *Ibid*
48 Act 1 2000, Part IV

A top down administrative structure determines spectrum use and allocation and fixes the allocation system. The frequency bands are zoned for particular uses,[49] for example, "AM radio, broadcast TV, cellular telephone, point to point private communications, satellite messaging etc."[50] The licenses are issued for restrictive purposes,[51] for specified services and facilities.[52]

The holders of the licenses have been given a right to exclude others from utilising even unused portions of the assigned spectrum band. The right to exclude is premised on the notion of interference. Spectrum access is therefore "closed" both because of regulatory restrictions on access and the instrument of choice. The instrument of choice "closes" access because for the period of the license the licensee has "property rights" to the assigned spectrum. The licensee can (a) determine its use within the confines of the regulatory restrictions (b) who has access to it and, (c) can enforce those rights against any person who infringes the rights conferred by the licence.

D. Critiquing the Existing Policy

This "system is structurally hostile to new competitors."[53] The decision as to who has access always rests with one person or entity, the highest bidder or with the regulator. In addition, auctions require substantial inputs of capital on the part of the purchasers. Innovative entrepreneurs are precluded by costs and the restrictions from entering the

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49 *Ibid* s. 20(2)(c)

50 T. W. Hazlett, "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", (2001) at page 18, **online: AEI-Brookings Joint Center for Regulatory Studies <http://www.aei.brookings.org/publications/working/working_01_02.pdf> (date accessed: 28 February 2002).**

51 *Supra* Note 48 at s. 25

52 *Ibid* at s.20 (2)(a)

53 *Supra* note 50 at page 19.

market. This encourages or perpetuates the development of monopolistic and/or oligopolistic market structures, neither of which benefits the market or the consumer. The policy results in the underutilization of this valuable resource. On the one hand, incumbents are unable to optimize spectrum. On the other hand, they are able to "hoard" spectrum leaving it idle and away from competitors or potential market entrants.

Further, in most instances, revenue generation has become the main focus of spectrum allocation policy. Spectrum auctions generate billions for governments and often degenerate into revenue tools. This is understandable to the extent that it props up the budget and makes for nice looking and sounding political party manifestos and speeches respectively. "Conceived in the original sin of budget politics rather than communications policy, spectrum auctions are doomed to serve as collection tools first and allocation mechanisms second."[54]

Another problem is that communications policy is being treated as structurally monolithic. Insufficient attention is being paid to *policy choices* in the face of changing inputs (resources). Far from being monolithic however, communications policy is multidimensional. It is an outcome of various policy choices that include the nature of the resource and exogeneous factors that have an impact on the availability of the resource. Policy choices should be transformed when the amount or type of a resource changes. This has not been the approach to current spectrum allocation policy. First, little or no account is taken of technological effect. Second, little or no attention is paid to the fact that spectrum is an unusual resource in the sense that it does not fit neatly

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[54] *Supra* note 23 at 116

within economist's classifications of the factors of production. The importance of these two factors is dealt with in the next two subsections.

1. Technology

Technology has an impact on scarcity and can influence allocation choices. As technology is relative, so is scarcity. *Rivalrousness* is fixed and is determined by the nature of the resource. The same is not true of excludability; it depends on the particular circumstances and the nature of the available technology. Technology can avert the tragedy of the commons and maximize on a resource in much the same way that a "property rights" regime can at a given stage of technology. It can make access less controlled.

2. The Nature of the Resource

The primary characteristic of spectrum is that it is 'ethereal'. It is not scarce in finite and infinite terms. It is not tangible; humans have nothing to do with its production. It is scarce in an unusual way too. There is so much of it and yet so 'little'. There is so 'little' because of the problems associated with it, not because it is finite. Because of the ethereal 'characteristic' of spectrum it is insensible to talk about producing more or conserving it in the strictest sense of the word. It is about maximizing what is.

The availability of this resource is not about its quantum but about access to it. This is important in the sense that property may be subject to the 'law' of diminishing returns, not so with spectrum. It means that whereas exploitation literally depletes and diminishes the former the same is not true for the latter. It means that if there are ways to ensure multiple-access, and there are, to the spectrum then property rights would defeat the benefits to be derived from efficient spectrum use.

Efficient spectrum access is about preventing interference. Once this can be achieved there is no end to the amount of spectrum that can be made available for use. The reliance on property rights in these circumstances is inappropriate. It compromises on the economies of spectrum use. It has led to monopolistic and exclusionary behaviour. It is the private owners who hold the information on how spectrum may be optimally allocated. Auctions do not necessarily result in the disclosure of this information. The result is informational asymmetry. The regulator and those wanting to enter the market will not necessarily get access to this information to use or to in anyway favourably impact either consumers or the market. This is what happens when access is controlled or 'closed'. The question is how should spectrum allocation policy be modified to keep pace with rapid technological changes? Can changes in the allocation choice aid in achieving the ends of communications policy? Reforms are needed to enable the entry of competitive entrants and protect their right to use spectrum.

VIII. Approaching the Task of Rethinking Spectrum Allocation

Because wireless communications have been construed as a technical substitute for wire line solutions, rethinking spectrum allocation requires recognition that it is one aspect or even one-half of communications policy. Spectrum allocation is therefore discussed with reference to communications policy as a whole.

Communications policy is the outcome of a number of choices. It is goal-oriented. The main goals are consumer welfare and efficiency in the market structure. This requires a balancing of the interest of the various stakeholders while enhancing competitiveness. The goals[55] should focus on (a) any regulation that unduly restricts the development of competition, (b) any regulation, which impacts on the consumer's ability to have a broader choice of goods and services in the market place and (c) any restriction, which favours the 'producers' (firms) interests over those of consumers or new 'producers' (firms). Generally speaking, the aim should be to:

1. Dismantle the regulatory barriers to entry and competition in the marketplace;
2. Ensure that new entrants gain access to scarce resources that are controlled by the incumbent, such as rights to spectrum, rights of way, infrastructure sharing and telephone numbering blocks;
3. Address interconnection issues so that consumers are not forced to remain with an inefficient supplier because of an inability by a competitor to reach other consumers;
4. Create a system that militates against anti-competitive behaviour on the part of the incumbents as well as the new entrants.

These are important considerations. When there are no barriers to entry, innovation and growth are stimulated. The effect is to stimulate competition in the marketplace.

[55] See generally, World Bank Reports **online: World Bank Homepage, <http://www-wds.worldbank.org> subtitle Telecommunications and Infomatics.**

Competition enhances consumer welfare by making available the best range of goods and services in the marketplace at competitive prices.

These goals have been at the forefront of telecommunications policy since the 1980's. Since that time communications policy has been subject to reform and transformation as a part of the process of globalization and liberalisation. Wireless liberalisation has however, been left to lag behind its wire line counterpart in most jurisdictions. This is as applicable to Jamaica in 2000[56] as it was to the United States of America in 1996. The essence of the disparity in the treatment of wire line and wireless solutions is captured in the following passage, which refers to the United States Telecommunications Act:

> The "comprehensive" and "sweeping" Telecommunications Act of 1996 left one-half of our telecom marketplace untouched by legislative reform. Great commotion accompanied the rules enacted by Congress for the regulation of wire line communications systems, particularly with regard to interconnection of local exchange and long-distance telephone companies. Meanwhile, this once-in-a-lifetime opportunity to revamp the rules governing our *wireless* technologies – a regulatory system concocted in 1927- ***slipped pass with scarcely a yawn.***[57]

The rationale for this lopsided treatment of the communications infrastructure is based on the scarcity of spectrum.

The scarcity theory is now an artificial claim in light of the spread spectrum technology. Allocating spectrum by property rights is contrary to the goals of communications policy in these circumstances. The available technology makes it possible for more persons to use spectrum than hitherto without interference. The variety of spread spectrum applications illustrate that wireless is not merely a technical

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56 *Supra* note 48
57 *Supra* note 36 at 85. [**emphasis added**]

substitute for wire line solutions. It can support shared uses and new applications such as enhanced services. This augurs well for diversity in the marketplace. Spread spectrum techniques challenge the basis for continuing to allocate spectrum to private owners in "clearly defined narrow channels."[58] This means that the basis for the administrative and property-based restrictions that determine (a) how the allocated portion will be used and (b) who can best maximize its use, as a basis for excluding others needs to be modified. Liberating wireless in the same way as wires can contribute to competition in the market place. The obverse is equally true; failing to liberate wireless will result in a failure to achieve the goals of communications policy. This is because wireless as an alternative or substitute 'good' can threaten firms and entrepreneurs that persist in inefficiencies.

This thesis will explore the predictions that can be made on the path to be taken by policy analysts in designing communications policy in the face of changing technologies. What predictions can be made about 'open' access? The prediction of this thesis is that that the promotion of "greater and less constrained access to the frequencies will maximize the social value of the radio waves, where social value includes both producer and consumer gains."[59] This will have an impact on communications policy generally as a wireless alternative will be able to compete effectively with wire line solutions to drive down prices. It will reduce the costs of inputs. "When the cost of an input falls, economic welfare rises."[60] This begs three questions. First, what is the level of inputs available to the various stakeholders, that is, the incumbent and entrepreneurs? Second, how will they be distributed? Third, what is the mechanism for distribution? The

58 *Supra* note 2 at page 35
59 *Supra* note 36.
60 *Ibid*

answers to these questions lie at the core of the choices that policy makers must make on the difficult path to efficient communications policy. The model of the Internet provides an empirical study from which some important lessons can be learnt.

IX. End To End: The Design Of The Internet's Network Architecture

The Internet has revolutionized communications since it was placed in the public domain in the 1990's. This has been attributed to its design that is, the architectural principle of end to end (e2e). The principle of e2e is based on the placement of functions within a network. The Internet's standards and the protocols implementing those standards are *open*. The principles underlying this design have social as well as technological significance. "They have been meant to implement values as well as enable communications….one aspect of this social significance is the competition and innovation that the Internet enables. The tremendous innovation that has occurred on the Internet,….depends crucially on its open nature."[61]

The Internet has four layers. They are the physical layer, the logical layer, the application layer and the content/transaction layer. The physical layer represents the ends of the network. This is where the intelligence of the network is situated. It is the various transmission media that enable communications such as wires, wireless, fibre optics or coaxial cable. E2e means that anyone can connect to the network. The logical layer contains the underlying protocols that make the Internet what it is. It is 'dumb' and cannot be strategically optimized for any particular use or in favour of any particular

[61] Mark A. Lemley and Lawrence Lessig, "The End of End-to-End: Preserving the Architecture of the Internet in the Broadband era", 48 UCLA L. Review 925(2001) 926 at 930.

user. The application layer comprises the software that enables content to be posted on the Internet. The underlying logical layer enables easy access to it so that each user can have content posted on the Internet. The content layer is the data and transactions that are posted on the Internet as a consequence of the open nature of its underlying structures.

The e2e arguments are based on engineering principles but have implications for the way communications policy can be designed. E2e reduces informational asymmetry by influencing the flow of information and applications over the network. This is because in an e2e system the "intelligence" of the network is at its ends. It enables non-discriminatory applications and diffuses situations that enable strategic behaviour which compromises innovation and competition. It means that:

> [l]ower level network layers should provide a broad range of resources that are not particular to or optimized for any single application…Higher level layers, more specific to an application, are free (and thus expected) to organize lower level network resources to achieve application – specific design goals efficiently (application autonomy); [l]ower level layers, which support many independent applications, should provide only resources of broad utility across applications, while providing to applications useable means for effective sharing of resources and resolution of resource conflicts (network transparency)…[62]

The result is a maximization of "the number of entities that can compete for the use and applications of the network [*spectrum and spectrum access techniques*]. As there is no single strategic actor who can tilt the competitive environment the (network) [*the use of spectrum and hence the market*] in favour of itself, or no hierarchical entity that

62 *Ibid* at 931

can favor some applications over others, an e2e network creates a maximally competitive..."[63] [market]. The e2e can facilitate a robust communications infrastructure.

X. Rethinking Spectrum Allocation

Current spectrum allocation policy is like the traditional telephone network. The design of the old telephone network is optimized for telephony and the owner of the network controlled the applications. The owner determined who is connected to the network and what can be connected to the network. The owner of the network controlled innovation. This led to a monopoly in the communications market. The control by the monopoly resulted in a bottleneck and the monopolist strategically controlled the network to the exclusion of competitive and innovative uses.

E2e has enabled the creativity that gave birth to the World Wide Web. No small group of innovators controlled the network. The non-discrimination kept the cost of entry low and encouraged experimentation that facilitated a kind of interaction and development that had been impossible in the old telephone network. Spectrum allocation and communications policy can benefit from a system whose history "compellingly demonstrates the wisdom of letting a myriad of possible improvers work free of the constraints of central authority, public or private."[64] A failure to take these lessons can undermine the marketplace by "putting one or few companies in charge of deciding what new uses can be made of the network [of spectrum]."[65]

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63 *Ibid* [words in square brackets added].
64 *Ibid* at 933
65 *Ibid* [words added]

There is need to act now, especially in developing countries that have only recently opened their markets to competition, before the entire spectrum is sliced up and sold off as property. Once that happens, it will be difficult to alter ownership rights. It will perpetuate the legacy of the old telephone network in an era of liberalisation. True liberalisation means freeing up the markets and opening them up to competition. The legacy of the old telephone network will persist unless active steps are taken to alter the forces that stymie competition.

A. A Stylized Model for Spectrum Access and Communications Policy

The model of the Internet has shown how the placement of functions within a network has given rise to innovation and creativity. Those lessons can be replicated in communications policy with the same result. They demonstrate how the approach to rulemaking and functions can change the way inputs are exploited and influence the communications market structure. This is premised on the notion that the communications market structure is as much a function of the distribution of the various factors in the policy framework, as the nature of the network is influenced by placement of its functions.

The lessons from the Internet's design can therefore provide a guide to an open access communications policy. On this premise e2e is being construed as a model of allocation in formulating communications policy. It forms the basis for the creation of a stylized model or framework to replace the current administrative structure. For the purpose of this analysis, the model is construed as a blue print or architectural design, a plan. It has a foundation, a sub-structure, a structure and a superstructure. Like the content/application layer of the Internet, the superstructure and the structure are closely integrated and can be construed together as the underlying stratum of the superstructure and its contents. This 'layout' can be analogised to the Internet's four layers – the physical layer, the logical layer and the content layer. Table 3 is an illustration of this stylized model. To the extent that we accept that the communications market structure is a function of policy choices, the model is intended to foster an appreciation of the synergy between (a) the various factors that influence spectrum allocation policies and, (b) how these policies in turn influence the communications market structure.

The Internet's Layers	**Internet Functionality**	**Spectrum Use Allocation**	**Allocation Rules and Communications Policy**
Content/transaction Layer	The data available by means of, and facilitated by the Internet	Market – Outputs ***(Superstructure)***	Diversity in Prices, products, consumer welfare
Application Layer	The Server and client software which makes Internet Content available and enables Internet Transactions	Spread Spectrum Techniques or other access techniques ***Structure – (experimentation)***	New and innovative uses encouraged – experimentation.
Logical Layer	The technical functions within the Internet which facilitate the transmission of packets	Regulation (Law), Technology and Economics (Open) *(Regulatory* ***Sub-structure)***	Technology neutral Open Access, Lower costs of entry, economies of scale - (multiple users and uses)
The Physical Layer	The media over which the logical layer operates (both wire line and wireless.	Market Inputs - Spectrum(wireless) v. Wire line. ***The Foundation***	Low or No barriers to access – no single player can strategically control. Entry allowed on non-discriminatory terms translates into more entrants.

Table 3 – A Model for Spectrum Policy Analysis[66]

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66 The data contained under Internet's Layers and Internet Functionality are extracted from, C. McTaggart, "A Layered Approach to Internet Legal Analysis" Internet Law and Governance

1. The Physical Layer

This layer contains the tangible (telecommunications networks using wire line fibre optics or coaxial cable) and intangible (spectrum) inputs in the communications market structure. These are the various transmission media that make communication possible. For wireless communications this would include spectrum, radios and other equipment as inputs to enable transmission. It is in this layer that consideration is to be given to the level of inputs that are available to the various stakeholders. It represents the foundation of the communications market structure. That the nature of the foundation of any design influences the superstructure is uncontroversial.

The physical layer is a little more than the lifeless, inactive tangible or intangible media. It consists of activity and people, the stakeholders – the incumbents and entrepreneurs who want to influence the ownership and placement of the inputs in the market place. We have seen that it is unwise to have a few 'self-interested' persons control the market structure especially where the resource is scarce. This is because the distribution of inputs in this layer influences and shapes the superstructure. The distribution of the inputs in this layer is in turn influenced by logical layer functions that provide the answer to the second question of how the inputs will be distributed.

This thesis, argues that spectrum is relatively scarce. There is certainly now more spectrum than at the time of the framing of the current regulations. It means that more

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Seminar, Faculty of Law, University of Toronto, 28 January 2002, online**: Centre for Innovation Law & Policy Homepage <http://www.innovationlaw.org/cm/ilg2002 /reading/layered1.pdf>(date accessed: 14, April 2002)** persons, within practical limits, are now able to access this resource. If this is the case then there is every reason to modify the restrictions on its access. Any restriction on access to the resource will have an impact on its availability. The more restrictions, the 'less' there is to distribute. This translates into less persons having access to it. The restrictions become 'walls' between the 'active' and the 'inactive'. The 'walls' are barriers to access. The model of the Internet has shown how the removal of these barriers can have a positive impact on innovation and competition. In terms of spread spectrum wireless the removal of the barriers will impact on its role in the creation of a more robust communications infrastructure.

The structures, functions and rules existing at the logical layer must be a reflection of the type of foundation and superstructure required. The logical layer is the vital link between the two. It is like an umbilical cord. It gives life to the foundation and the superstructure. The structures, functions and rules of the logical layer should therefore be directed at striking down the 'walls' thereby removing or lowering barriers to entry and encouraging competition. It means 'open access'. Once the barriers are lowered, then there will be one platform on which the various media can be "alternate goods" which enable broader consumer choice among the services offered at the superstructure. For example wireless and wire line could compete with each other to offer services. This would affect the price at which dial up and wireless access services are available to those who occupy the superstructure, the consumers. It would have the effect of reducing the bottleneck created by the local incumbent telephone carriers' "narrowband copper wires."[67] The Dandin Group shows how spread spectrum wireless can change the content of basic communications services. This is by the low cost provisioning of Internet and communications services in the Kingdom of Tonga.

The nature of the rules directed at the foundation is important. If only one producer were possible then there would be no need to be concerned with a layered analysis, as competition would be an academic issue. The single player would control the inputs at the foundation and determine the outputs at the content layer. E2e counsels 'open' access at this layer. This has implications for "users, service providers and network providers."[68] This translates into a more porous physical layer that will have an impact on the evolution of the "industry base as well as the technologies they supply and use. For these purposes, it is assumed that the market can accommodate more than one firm. Assuming also, that there is the requisite consumer demand, spread spectrum architectures make it possible to accommodate multiple firms in this layer.

This will encourage the type of diversity and entrepreneurship that communications policy is aimed at. This includes first, the fostering of continuing innovation in the management and deployment of communication services. Second, it will enable the preservation of access to a "full set of content and services that are made"[69] possible through experimentation. Third, "[i]t will foster competition as a means of ensuring innovation, access and affordability."[70] These, therefore, are the factors that

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67 *Ibid*

68 Computer Science and Telecommunications Board, National Research Council, Commission on Physical Sciences, Mathematics and Applications and Committee on the Internet in the Evolving Information Infrastructure, *The Internet's Coming of Age,* (Washington D. C.: National Academy Press, 2001) at 4.

69 *Ibid page* at 11

70 *Ibid*

must guide logical layer rules and functions. This is necessary because logical layer functions influence the distribution of the inputs in this layer.

2. The Logical Layer

This layer influences the number of firms in the 'foundation'. It does so by determining the rules of the game as it were. As with the Internet the placement of 'functions' in this layer can be further subdivided into: (a) the "regulatory function" in terms of the rules that are set up for the management of spectrum; (b) the technical considerations that impact on the distribution of resources (c) The producers or service providers and (d) consumer access. These will be examined below:

a) The Regulatory Function

The regulatory function can "counteract, enhance, or give direction to… technological effect."[71] The "regulatory function" refers to the role of the regulator in policymaking. Two modalities interplay in this sub-layer. First, the legal system plays a very important role in creating the structures within which the choices can be made. Second, the regulatory function facilitates the choices by making a determination of the rules, the instrument and model of allocation to be adopted in specified circumstances.

In the Internet code was used to ensure that no one person could optimize the network in his or her favour. Code acted as a constraint on monopolistic behaviour. In this model law serves the same purpose. The laws are to be used to encourage competition and discourage monopolies. These laws should ensure that the firms compete

[71] Supra note 2 at 91

on a level playing field. For example, to ensure that access to physical layer resources is allowed on non-discriminatory terms.

To make this possible, consideration should be given to the effects of technological change. This is because technological change has an impact on regulatory and market structure and can enhance or impede effective policymaking. "Innovation is encouraged by a strongly competitive environment and is discouraged by monopoly practices. Competition among three or four large firms often produces innovation, but a single firm, especially if it serves a secure ….market protected by barriers seems much less inclined to innovate."[72] "Government interventions that are designed to encourage innovation often allow the firms in an industry to work together as one. Unless great care is exercised, and unless sufficient….competition exists, the result may be a national monopoly that will discourage risk-taking rather than encourage it, as the policy intends."[73] "Success in real-world competition often depends more on success in managing innovation than on success in adopting the right pricing polices or in making the right capacity decisions from already known technological possibilities."[74]

The policymaker must create a set of circumstances that encourage innovation. The market will do the rest. The race to keep up with their competitors to develop new and improved products will enhance consumer welfare by increasing their choices in the market. The possibility of multiple suppliers increases as technology improves; this has the effect of invalidating the natural monopoly argument. The structures and rules must therefore be designed to diffuse the monopoly structures that exist at the physical layer.

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72 *Supra* note 42 at 556

73 *Ibid*

74 *Ibid*

The success of the Dandin Group can be seen in this context. In Tonga the organisational and regulatory structures were free of strictures of the FCC.

"Changes in technology are often endogenous responses to changing economic signals; that is they result from responses by firms to the same things that induce the substitution of one factor for another within the confines of a given technology."[75] The model of the Internet illustrates that technology neutrality is very important. E2e has shown how a technology neutral logical layer enables innovation and experimentation. Rules should therefore be made on technology neutral terms. The focus is to move away from specific technologies to how the resource is accessed. Technology specific rules create rigid categories that are difficult to adapt to changing circumstances. It leads to the creation of rights that are not readily reversible when things change. Rigid rules should not be used to apply to dynamic 'subjects'. This is the problem with current allocation rules. They are premised on an outdated technology under which decisions were taken to allocate spectrum according to property rights. It seems as if no thought was given to the longevity of the technology. What is to become of those rights in the face of changing technology? The evolution of spectrum access technology has rendered obsolete traditional justifications for the restrictive rules, which govern spectrum access. As the services change from time to time new access techniques are developed in tandem with these changes. A technology neutral law will create flexibility in the introduction of new services and experimentation with new technologies as they become available.

[75] *Ibid* at 133

In the case of spectrum, history has demonstrated that regulation is really about the devices that are used to access spectrum. In those circumstances, it is more instructive first, to recognise that when we speak of spectrum regulation we are really talking about the regulation of the devices that are used to access spectrum. Second, it is important that we continue to regulate the devices to see how the scientific difficulties of spectrum access can be minimised. Finally, it is important to bear in mind that technological dynamism dictates that today's highly touted solution might become tomorrow's hindrance. What standards and protocols should therefore govern access? This is the subject of the next section.

b) Technology and Standards

It has been demonstrated that technology is dynamic. Generally therefore, it should be an important consideration in the formulation of communications policy. It is particularly important in this context; this is because it influences the way that spectrum is accessed. The current method of allocating spectrum through licensing and property rights is premised on a particular technological state. At that stage of technological development spectrum was scarcer than it is today. Accordingly, the information was coded into narrow band frequencies in order to enable orderly access. The spectrum was also sliced up and allocated to various users for different types of uses. But that technology was relatively simple. This was therefore the most practical method that could be devised in the circumstances to ensure efficient spectrum use. The result is that the system was monitored in a way that created barriers to entry into the market –

excludability. It is now evident that this resulted from insufficient attention being paid to technological dynamism and relativism.

This approach is out of place in an era of innovation spurred on by the development of digital technology, the Internet and Spread Spectrum Systems. Regulators must now recognise that "[c]hanges come quickly and unpredictably."[76] Rapid changes in technology mean that "in many cases the perceived problem may fix itself or evolve into an entirely different problem. *In such a dynamic environment, flexibility is essential and* ***regulatory caution is a virtue***."[77] This flexibility can be achieved in an atmosphere of open or technology neutral policymaking and regulations. These will minimise drastic policy shifts and changes in the face of changing technology. The policymaker must therefore promote open access and open standards.

What then, are the implications of these open standards for spectrum allocation? In this regard, the analysis of early spectrum management and regulation produces some interesting results. Even then, quite unwittingly it seems, regulation was focussed on co-ordination. It was directed at the power level of radios and antenna heights and co-location issues in order to prevent interference. Once it is accepted that co-ordination is at the core of access to spectrum, then the next step is to recognise that equipment standardisation will play an important role in achieving the goal of an open access policy. Standardisation is very important in the context of technology neutral laws. It is not enough that there are standards; these standards must be open. This is so that no one player can manipulate or optimize them in his favour. The aim is two-fold. First, it

[76] *Supra* note 68 at page 25
[77] *Ibid* [emphases added]

allows the customers of various vendors to "mix products from one vendor with products from another.."[78] Second, it enables interoperability so that applications created by multiple vendors can operate over each other's platform or infrastructure.

> *Openness* relies crucially on the development and the adoption of standards…Standardization processes enable multiple vendors to co-operate on the development of new elements that will allow them to develop new markets – markets that are much larger than would be if each developed its own competing technology. Then the vendors compete by providing competitive products built on standardised elements. *When this process works well, it results in greater benefits for both vendors and customers.*[79]

The Internet was built on open standards – open software. Spectrum use can be promoted on open standards too. Technology exists to make this possible in the form of open hardware. The device that makes this possible is the Software Defined Radio used in the Kingdom of Tonga project. Software Defined Radios are also called smart radios. These radios are programmable and affect the way that spectrum is used. They enable a shift of control over how spectrum is used from the radio operator to end-users. This is possible because the control of the radio functions are embedded in the algorithms which can then be coded to specific spectrum and network environments.

These radios are therefore completely "open" – open software and hardware. The blueprint for this radio can be found on the Internet.[80] It is part of the efforts of the Dandin Group to spearhead the "open hardware" movement. They have several advantages that make them appropriate and relevant to the open access system being

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78 *Supra* note 68 at 125

79 *Ibid* [emphasis added].

80 **See generally** Dandingroup Home page **online: <www.dandin.com>; <http://www.fcc.gov/speeches/misc/dnh061700.html>**

proposed.[81] First, one unit or device contains multiple standards. The benefit here is that it minimises or eliminates concerns that now exist in terms of different standards in the field of wireless technologies. It therefore answers concerns about costs to consumers, firms and equipment manufacturers in terms of existing equipment becoming obsolete in the face of changing technology. Second, it solves concerns relating to interoperability so that different types of radios can interlink with each other if necessary. Third, manufacturers may achieve economies of scale by producing radios on a "common hardware platform but wait until the product is about to be shipped before loading software to create a specific type of device."[82] Fourth, the radios would be upgraded in much the same way as one upgrades personal computers today. The software, and this has not happened yet could be obtained, "off the Internet or from over the air."[83] Fifth, as with developments in the computer field, hardware manufacturers could sell components that enable end users to build their own radio, and purchase their own software to get it running. Sixth, it may be possible with evolving technology to programme these radios to deal with interference in real time.

"Software Defined Radios hold a revolutionary potential as an effective tool for broadband wireless for the first mile…[t]he time is now for the [policymaker] to take a close look at SDR, and alter spectrum management and certification polices to encourage its commercial development and deployment."[84] This is necessary given the positive

81 See generally, D. N. Hatfield, "The Role of Amateur Radio in the New Century, **online: Federal Communications Commission Home Page <http://www.fcc.gov/Speeches/misc/dnh061700.html> (date accessed: 17 April 2002)**

82 *Ibid.*

83 *Ibid*

84 *Supra* note 39

impact that it can have on promoting efficient spectrum use and effective regulation. The shift does not have to be drastic; it can be transitional and can start in the unlicensed bands. The policy maker's role in this context is not to set fixed or specific rules but to encourage research and development by providing innovators and researchers with the ability to develop technologies that can increase the robustness of the infrastructure.

c) The Market – the Firms

The market consists of incumbents and entrepreneurs and consumers. Open standards and rules result in 'open' markets. If there is only one player then a monopoly results. Service providers have expanded from those who offer conventional telephony, to those that offer wireless telephony, wireless Internet and a wide range of personal communications services. One firm monopolizing this area or having control over the technology can influence the market in his favour to determine what services are offered to consumers and at what price. The rules must therefore be such that no one person can optimize the market his favour. They must be such as to encourage entry to keep up competition. Competition in this area enhances the flow of information within the market. The result is lower prices and greater access to goods and services. This is because the competition reduces the informational asymmetry between the consumers and the firms.

3. The Application Layer

Once the rules and standards in the logical layer have been set on technology neutral terms everyone can access spectrum provided they play within the rules. Once the person can access spectrum without interference then he should be allowed to do so, using whatever technology is available. The sole test would be to ensure that whatever, technology is being used does not interfere with existing use. Standardisation therefore, is not to specify which technology can be used. It is to specify which technology cannot be used on the basis that it causes interference. It would mean that everything is permitted except where it causes interference. Once this is done the market will take care of itself and no one firm can optimize a particular technology to the exclusion of others and at the expense of the market and consumers. It means that there will be a significant amount of experimentation in this layer to provide new ways of offering new products and services at the content layer. Examples of this include I P telephony as a substitute for the PSTN especially in Private Networks. Private networks have gone wireless by setting up wireless LANs and Wireless Internet.

Logical layer rules impact on the number of players in the market. In terms of applications, new entrants have more incentives than incumbents to engage in experimentation. The incumbent firm calculates that it is likely to lose out on a portion of its profit if a new product replaces it. The new entrant does not have this kind of opportunity costs and is more likely to create new products. Competition in terms of available applications ensures continuing innovation since each stakeholder would want to continue to innovate to stay ahead of the pack. The obverse is also true the competition will weed out the inefficient players.

4. The 'Content' of the Market

Competition influences the content of the market. The result is a higher level of outputs. This is good for consumer welfare in that it gives them the opportunity to choose between various goods and services and menus of tariffs. This derives from the fact that the businesses are encouraged to be innovative and efficient. Inefficient players will be eliminated.

XI. What Mechanisms For Open Access?

The auction paradigm as it is now administered is unworkable in an open access system. One reason is that it creates individualistic behaviour. This is so to the extent that it rests on the rational self-interested actions of each human animal. The result is that it is exclusionary, non-egalitarian and hierarchical. The hierarchical nature is evidenced in the fact that one person or entity determines how the resource is to be managed, maximized and accessed. An open access system requires a more egalitarian and participatory approach. In fact, this is what has made the Internet what it is. In Internet governance we witness a transition from government to private hands. Can a similar private ordering manage spectrum access? What incentives do private actors face to manage spectrum as a collective? So far it has been demonstrated that communications policy can benefit from implementing an open access policy framework for spectrum management. Having suggested an open access system for managing spectrum, the question is what mechanism will be used to determine access? Which mechanism from a set of alternatives can best achieve the aims of communications policy? The aim here is to sensitise policymakers to the fact that there are these alternatives not to suggest a solution as this area is still developing and is dependent on experimentation with new technologies.

A. The Stakeholders - Etiquette?

The FCC has been experimenting with open access spectrum since the 1980's. In 1985 it amended Part 15 of its rules to increase "power limits on the unlicensed use of spectrum bands used by the ISM low power applications. This was improved on in 1994 when it ratified the unlicensed personal communications spectrum (U-PCS). This was opened to all users of asynchronous data and isochronous time-division duplex voice. This system operates by a type of "spectrum etiquette". The users co-ordinate access "in real time, based on rules agreed upon by the industry."[85] The system was managed by a group of U-PCS equipment vendors U-TAM Inc. They supported the system in proportion with the sales of their equipment and *co-ordinated* the use of the bands including relocation of existing unlicensed users, definition of channels and geographical regions.[86] The disadvantage of this system is that it deals with "scarcity and congestion by technological coordination. The best "etiquette" for the allocation of a scarce resource in our society is a market-clearing price."[87] This makes sense. After all, "open" does not mean free.

The pricing mechanism is required to determine priority in terms of access. The priority will go to the person, group or entity that is willing to pay most for it. A refinement of this idea is to allocate the spectrum to the person who has the most use for

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85 *Ibid* Note 23 at 120
86 *Ibid*
87 *Ibid*

it at a particular moment. This is a precursor to dynamic frequency planning so that no one person has access to it for long periods save to the extent that it is being utilised.[88] This means that access will vary with demand. The system of determining priority could therefore be designed to ensure that each applicant has a fair chance at accessing spectrum for particular uses. The auction paradigm with modifications such as credit sales would be a useful tool in this regard. Credit sales reduce the inequalities created by the dichotomy between those who can pay for access at any price and those who want access but are unable to bid at any price. It will undermine the rationale to create property rights in the resource.

B. Collective Governance?

One of the accomplishments of economics is that even rationally self-interested individuals can benefit from a mutual exchange. This is the case in relation to a small class of public goods. Spectrum is one such public good. Generally speaking the nature of "public goods provide the *raison d'être* for collective choice."[89] This is because the supply of public goods is indivisible. The indivisibility of supply is the incentive for making "co-operative collective"[90] decisions that benefit the stakeholders.

The Internet is a model of collective governance. It began on the basis of co-operation and that has continued to date. The model of Internet governance is one strategy for a successful system of collective governance. Another strategy for achieving collective governance is where each stakeholder abides by the rules of the game so long

88 Technology Advisory Council Meeting – April 26, 2002, **online: Federal Communications Commission Homepage, <http://www.fcc.gov/realaudio/mt042602.ram>(date accessed: 1 June 2002).**

89 D. C. Mueller, *Public Choice* (Cambridge University Press: 1979) at page 14.

90 *Ibid*

as all the others do. Implicitly, or so it seems those who refuse to play by the rules of the game will suffer banishment or other punishment that will force a return. No one wants to know the consequences of non-co-operation and so all comply. The incentive in this latter case is the implicit threat of punishment.

The collective governance system has been criticized on several bases. First, it is based on voluntary compliance. The result is that in large communities this normally leads to freeloading. Freeloading in turn results in under or non-provisioning. Then too there are the social costs of monitoring non-compliance. It has been suggested that the risk of non-participation can be minimised by providing individual incentives in the form of monetary sanctions for non-compliance. Second, there is the problem of access to the resource by incumbents and prospective entrants. By what mechanism would access be determined? It may be that a public - private partnering approach would solve the problem.

C. Public - Private Partnering?

Collective action is possible. It has worked on the Internet. Stakeholder interests manage the Internet. A modified version is suggested for spectrum access. This is because first, incumbent rights are entrenched. Second, its allocation did not have its genesis in co-operation as has the Internet. Third, the Internet was never conceived of in the nature of a public good or a scarce resource.

Scarcity raises issues of allocation choices not applicable to the Internet governance issues. For this reason, a transitional approach is recommended. During this period standards of behaviour could be developed to determine access. Neoclassical economic analysis teaches that some form of price or incentive mechanism is required to determine priority of access.

Technology can be brought in aid. This would be made possible using the Software defined radios described herein. They could be embedded with codes that enable them to wait and listen prior to transmitting. This is possible but the experimentation is in its early stages. It would mean the adoption of a system similar to the behaviour required at a level crossing – *stop, listen and transmit*. It is in this area that stakeholder interests are most evident. Vendors of the various products are the innovators and are often instrumental in the creation of new technology. Given a greater stake in how spectrum allocation is managed may be a form of incentive for creativity and further investments in research and development. This is particularly relevant in developing countries where it may be argued that governments can ill-afford the sizeable amounts required for research and development projects.

The government's role in the partnership would be to act as a balance between consumers, entrepreneurs and incumbents. This could truly be regarded as a collective in so far as all stakeholder interests would be represented. This method of managing the resource is attractive because when managed as a collective whole, it is hoped that the "marginal social benefits and the marginal social costs will be fully equated."[91]

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91 *Supra* note 41 at 140.

XII. Conclusion.

Current spectrum regulation was borne out of necessity. It grew out of an era when the first spectrum users were pioneers and amateurs. However, with commercialisation came an increased number of persons who wanted to access this resource. The result was chaos. Governments at the time recognised that unless it were regulated, spectrum would be of little or no utility to society. Spectrum came to be the subject of public/private restrictions that constrain its use and allocation. The administrative restrictions determine the rules and the terms under which the resource is allocated. For this purpose the instrument of choice is licensing. The licenses create private rights in favour of the licensees. This system is best described as closed and proprietary.

Spectrum however, is an important component of the communications infrastructure. It has been classified as a scarce resource. For this reason its significance to the liberalisation of the rest of the communications infrastructure went un-noticed. Its allocation is characterized by a "closed" and "proprietary" approach. This has meant that communications policy is for the most part half-baked.

Technology was always at the core of spectrum use. This fact, though known to regulators, has not influenced their approach to spectrum management and allocation. This should not be surprising. Administrative change, if change there is to be, has always been slave to the sluggish nature of bureaucratic processes. Technology on the other hand is dynamic and changes at an almost astronomical pace. The pace of change increases over time. This thesis sought to address how spectrum allocation and communications policy can benefit from these rapid changes.

History has always held important lessons for development. Communications policy is no different. The Internet is relatively new but its nature and the pace of its phenomenal growth is now of historical significance. There are several lessons to be learnt from its rapid transformation from a government communications tool to a worldwide public communications and commercial infrastructure. The factors that gave rise to this rapid transformation are its open and non-proprietary standards.

These standards are of especial significance when technology is an important tool in the policymaker's tool kit. The Internet is a product of technology. It is an example of how the placement of functions in a network can influence communications. The placement of these functions influences access to the network. It teaches that networks, systems and policies that are built on open and universally interoperable standards can encourage innovation and development. Innovation is important as being a product of experimentation that is only possible when there is "open" access to the "factors of production". It has been seen that the better approach to policymaking especially in the face of changing technological inputs is technology neutral rules and systems. These systems, it has been argued allow for the kind of flexibility that is not possible with or in non-proprietary systems. This lesson can be well adapted to spectrum allocation. It means that even with spread spectrum systems the policy design is to be neutral to allow for rapid technological change. Rapid technological change will no doubt impact positively on the economies of spectrum use.

The administrative structure of current spectrum allocation represents its governance mechanism. Modifying that system begs for a governance alternative. The issue is not whether to govern or not to govern, but what type of governance. This thesis has suggested that shared governance might be the best alternative. It is a unique type of sharing not among the stakeholders but between governments and stakeholder interests. Governments' input is necessary given that the resource is a public good. The commercial stakeholders will protect their own interest. Government will protect the interest of the consumers. Compliance can be achieved by the explicit or implicit incentives in the form of punishment. It may be to make the cost of not participating unattractive.

The point is that human hands made the Internet. Policy is made in much the same way. If the Internet can benefit from such openness and participatory governance, so too can communications policy. Spectrum allocation and communications policy suffer not from the lack of experimentation or innovative will. They suffer from the lack of collective wisdom that can be had when systems, networks and policies are "open". The time is ripe for a change. To benefit, the change must be now.

GLOSSARY[92]

Amplitude:	The maximum departure of a waveform from its average value.
Amplitude Modulation:	One the three basic ways to add information to a sine wave signal: the magnitude of the sine wave, or carrier, is modified in accordance with the information to be transmitted.
Analog Signal:	The analog signal varies continuously between a minimum and a maximum value. Analog signalling has been overtaken by the use of digital signals due to the superior ability of digital signals to resist interference and hostile user intervention.
Bandpass:	The portion of a band, expressed in frequency differences (bandwidth), in which the signal loss (attenuation) of any frequency when compared with the strength of a reference frequency is less than the value specified in the measurement.
Band pass filters:	1. Circuit embedded in the radio that enhances the ability of the radio to discriminate between interfering signals and those intended for it FDM.

92 G. Held, *Dictionary of Communications Technology* 2ed.(England: Wiley, 1995)

2. A device or circuit, which passes a specific group of frequencies between cutoff frequencies.

Bandwidth — The range of signal frequencies, which can be carried by a communications channel subject to, specified conditions of signal loss or distortion. Measured in hertz (cycles per second). Bandwidth is an analog term, which provides a measure of a circuit's information capacity. There are three general ranges of frequencies for transmission:

Narrow Band – 2 to 300 Hz

Voice Band – 300 – 3, 000 Hz

Wide band – Over 3, 000 Hz

Burst Rate: — A maximum rate of continual signal transmission.

Broadband — 1. In general, communications channel having a bandwidth greater than a voice-grade channel and potentially capable of much higher transmission rates; also called wideband. 2. In LAN technology, a system in which multiple channels access a medium (usually coaxial cable) that has a large bandwidth (50 Mbps is typical) using radio frequency modems.

Carrier:	A continuous signal which is modulated with a second, information carrying signal.
Carrier wave:	A wave upon which a signal is superimposed.
Channel:	In telecommunications this refers through a separate part through which signals can flow.
Digital Signal:	The digital signal takes a limited set of values for a given time *t*, where *t* is constant.
Frequency Division Duplexing:	Facilities transmission in both directions simultaneous in the frequency domain.
Frequency:	The rate at which a signal alternates; typically, the number of complete cycles per second, normally expressed in hertz (Hz).
Frequency Modulation:	One of three basic ways to add information to sine wave signal; the frequency of sine wave, or carrier, is modified in accordance with information to be transmitted.
Modulating:	Regulate or adjust to a proper measure or proportion or to cause the amplitude, frequency, phase or intensity of (a carrier wave) to vary.
Oscillation:	A variation between maximum and minimum values of a cycle.

Phase: A measure of signal position with respect to a reference signal. The unit of measure is the angular degree.

Protocols: 1. A set of rules governing information flow in a communications system. Sometimes called "data link control. 2. The set of rules followed by two computers when they communicate with one another.

Local Area Network: (LAN) – A data communications network confined to a limited geographic area (up to 6 miles or about 10 kilometres) with moderate to high data rates (100 Kbps to 50 Mbps). The area served may consist of a single building, a cluster of buildings, or a campus type arrangement. It is owned by its user, includes some type of switching technology, and does not use common carrier circuits – although it may have gateways or bridges to other public or private networks.

Spread Spectrum Communications: The process of modulating a signal over a significantly larger bandwidth than is necessary for the given data rate for the purpose of lowering the

	bit error rate (BER) in the presence of strong interfering signals.
Selectivity	The degree to which a receiver is capable of discriminating between the desired signal and all other signals.
Signal:	An electric current or electromagnetic field used to convey data from one place to another.
Time Division Duplexing:	Facilitating transmission in both directions simultaneously in the time domain.
Wide Area Network:	(WAN) – A network, which connects geographically separated areas.
White Noise:	Background noise caused by thermal agitation of electrons. Also referred to as Gaussian noise.

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