HISTORY AND CONCEPTUAL DEVELOPMENT OF SPECTRUM COMMONS IN THE USA

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Abstract

The wireless devices that use radio communication are a part of day-to-day activities ranging from the garage opener, remote control, toys, Closed Circuit Television (CCTV), navigation system (land, air and sea), earphone, cordless telephone and card reader to Internet connection (Wi-Fi) in the smart phone. Most of these appliances are low-power and unlicensed devices, whose uses have increased over time. The unlicensed devices share the frequency or spectrum commons authorized by the National Regulatory Authority (NRA) in each country, which has established rules in order to manage the spectrum. The rules allow the user to use a device without prior authorization, but with no protective rights. Users must accept the interference generated from other users. However, these uses of devices should not cause harmful interference to licensed users. Thus, the unlicensed devices must comply with the standard before they are marketed or imported. This paper provides a chronological account of how the spectrum commons developed in the USA. A survey of the literature provides the rationale for spectrum commons and why this concept is so important. Furthermore, the debate on each spectrum assignment approach and the trend of the use of spectrum commons are described.

Keywords: spectrum commons, spectrum management, spectrum assignment, spectrum usage, historical approach

Introduction

A particular spectrum is a subset of electromagnetic waves with frequencies less than 3000 GHz which is used as a carrier of communication. A signal using relatively high frequencies reaches relatively short distances, but has a larger bandwidth . This characteristic limits the applications of the spectrum as a whole.

Spectrum is globally used in many services such as broadcasting services (TV and radio), satellite service (long-distance and international services), amateur services (amateur radio), maritime service (ship-to-shore, ship-to-ship communications), mobile services (mobile phone, trunk radio, and walkie-talkie). Spectrum management has been implemented to control the use of spectrum and prevent harmful interference. Its management activities include allocation[1] , allotment[2] and assignment[3]. Allocation and allotment are conducted in world radio communication conferences, and assignments are conducted by National Regulatory Authorities (NRAs). Spectrum assignment has three main methods: command and control, market-based approaches, and spectrum commons (collective use of spectrum: CUS).

In the earlier days of radiocommunication there were no regulations. Everyone had a right to use the spectrum without limitation. When a particular spectrum was filled up or overused, it created harmful interference. This situation was called "Tragedy of Commons". In order to manage the spectrum and prevent harmful interference, NRA had to regulate the use of the spectrum through legislation such as the Radio Act. This intervention is one

[1] *allocation* (of a frequency band)*:* Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space *radiocommunication services* or the *radio astronomy service* under specified conditions. This term shall also be applied to the frequency band concerned. (International Telecommunication Union – Radio Regulation 2008)
[2] *allotment* (of a radio frequency or radio frequency channel)*:* Entry of a designated frequency channel in an agreed plan, adopted by a competent conference, for use by one or more administrations for a terrestrial or space *radiocommunication service* in one or more identified countries or geographical areas and under specified conditions. (International Telecommunication Union – Radio Regulation 2008)
[3] *assignment* (of a radio frequency or radio frequency channel)*:* Authorization given by an administration for a radio *station* to use a radio frequency or radio frequency channel under specified conditions. (International Telecommunication Union – Radio Regulation 2008)

of the spectrum assignment approaches – command and control that imposed conditions and constraints on the use of the spectrum.

The command and control approach has been used by NRA up to now; however, it does not reflect the best use of a spectrum because the strict regulations render the spectrum inflexible. For example, when new advanced technology emerges and the existing users would like to change to the new technology, they must submit the application to the NRA for approval prior to use, which is time-consuming.

The development of a new spectrum management approach uses market mechanisms developed by economists. Economists believe that the market mechanisms will allocate the spectrum to users who value it the most. Thus, a spectrum has property rights that can be exclusively used, and transferred by market-based selling or buying. In the primary market, the bidding or auction awards the spectrum to whoever bids the highest price. In the secondary market, a resale of a spectrum transfers the right of use to other parties.

However, the market mechanisms limit access to spectrum. The use of spectrum is limited to a small group of users, and users can only obtain access to the spectrum by monetary means.

The third spectrum assignment approach, spectrum commons, was developed to open up the spectrum to everyone. The users can share a spectrum as commons without prior authorization from the NRA. Because of the unlicensed nature of this scheme, its uses are increasing. Unlicensed devices share a frequency or spectrum with other users, which are authorized by the NRA in each country. The NRA has fixed regulations for controlling the use of the spectrum. The rules allow users to use their devices without prior authorization, but with no protective rights. They must accept any interference generated from other users. Yet the use of devices must not cause harmful interference to licensed users. The unlicensed devices must comply with the standard before they are marketed or imported.

This paper provides a chronological account of how the spectrum commons developed in the USA[4]. It is divided into five sections. Section 1 describes the era of no regulation. Sections 2, 3, and 4 describe the development of command and control, the market-based approach and spectrum commons, respectively. Chapter 5 concludes the discussion of spectrum commons.

1. No regulation – Tragedy of commons

The first mechanism for radiocommunication was patented by Marconi in 1897. Marconi's original "spark gap" transmitter sent signals across a whole range of frequencies. Only one transmitter could operate in a specific place and time in order to avoid harmful interference. In the beginning, everyone could use a transmitter.

On March 30, 1910, the Department of the Navy attempted to regulate radio frequencies over land by passing a law through the Senate committee of commerce. However, the bill passed by the Senate was not accepted by the House of Representatives.

Congress later passed a bill to regulate radiocommunication by authorization of the Secretary of Commerce and Labor and the President of the United States, which differed from the previous draft. This was the first time that radiocommunication over land was regulated by giving licenses to licensees, including ownership, location, wavelength and operating hours. However, the Act of 1912 did not give the control or enforcement power of the use of radiocommunication to the Secretary of Commerce and Labor.

In 1921, the Secretary of Commerce and Labor refused to renew the license of the Intercity Radio Company because the use of frequency would interfere with the signals of other stations, and the company filed a court case in 1923.

In 1922, the Secretary of Commerce and Labor attempted to regulate radiocommunication by adding detailed conditions of licenses; however, it was prevented by a Court decision which interpreted the 1912 Act.

[4] The events are taken from Coase (1959), Hazlett (1998a) and Carter (2009).

Consequently, the number of radio stations increased from 60 stations on March 1 to 564 stations by November 1, 1922.

In 1922, the government by the authority of the President set up an Inter-department Radio Advisory Committee to regulate the government radio stations.

In 1923, a court decision withdrew the Secretary of Commerce and Labor's refusal and stated that the Secretary of Commerce and Labor had no authority to refuse a license and had no control over the number of stations that could be established. However, the Secretary of Commerce and Labor implied that he did have power to choose the wavelength which licensees could use.

In 1925, the Zenith Radio Corporation obtained an unwanted wavelength from the Secretary of Commerce and Labor, but the company never used it. The company then decided to use other wavelengths illegally. Thus, the Secretary of Commerce and Labor filed a court case against the company.

In April, 1926, the court decision was that the 1912 Act did not give the Secretary of Commerce and Labor power to make regulations. The Act authorized the Secretary of Commerce and Labor to issue a license only. Thus the licensees decided to select the power of their stations, hours to operate and the wavelength by themselves. This court decision created "Chaos in Broadcasting" or "a Tragedy of Commons".

A summary of significant events is shown in Table 1.

Table 1: Period of no regulation

Time	Event
1897	Marconi invented a radiocommunication device
1910	First attempt to regulate radio frequency by Navy
1912	Act of 1912 authorized Secretary of Commerce and Labor and President to regulate radiocommunication
1921	Secretary of Commerce and Labor refused to renew a license
1922	Inter-department Radio Advisory Committee set up
1923/1926	Court rejected Secretary of Commerce and Labor attempt to regulate radiocommunication

2. Heavy regulation – Command and control

In July 1926, Congress decreed the "Joint Resolution" whereby no license would be granted for more than ninety days for a broadcasting station, or for more than two years for any other type of station (in order to prevent licensees from establishing property rights on frequencies).

In December 1926, Congress reconvened and passed the Radio Act on February 23, 1927. The Radio Act 1927 was enacted and established the Federal Radio Commission in order to categorize radio stations, prescribe the nature of the service, assign wavelengths, determine the power and location of the transmitters, regulate the kind of apparatus used, and prevent interference. The Federal Radio Commission had full authority to regulate the radio industry for commercial use, excluding censorship of the programs.

However, the Radio Act imposed some restrictions on station programs – e.g. obscene, indecent or profane language was prohibited. Re-broadcasted programs should be authorized by the original station. The names of people paying for or sponsoring programs should be announced. Equal opportunities for legally qualified candidates should be given.

The Commission granted or renewed licenses if licensees served the public interest, convenience or necessity. Licenses could not be transferred without prior approval of the Commission. These rules clearly defined the property rights of the owner of a frequency, which could be transferred to other licensees and could be managed by a market mechanism.

In 1934, the Communication Act was enacted, which founded the Federal Communications Commission (FCC). There were two differences from the Act of 1927: the addition of a prohibition against advertisement or lotteries, and additional licenses for the foreign programs that could be heard in USA.

The Commission faced problems when renewing the licenses in 1940, 1946, 1948 and 1954 for Mayflower, Blue Book, Daily News and Mr. Edward Lamb, respectively. The Commission was supposed to act as "the traffic policeman of the ether" and used the concerns of Congress: public interest, necessity or convenience according to the First Amendment of the United States Constitution. The Commission needed interpretation of these concerns in order to renew the licenses.

In the command and control period, the regulators, who had previous experience of everyone over-using the spectrum and creating interference, made restrictions and constraints in order to avoid harmful interference and ensured that "Tragedy of Commons" never happened again.

A summary of significant events is shown in Table 2.

Table 2: Period of heavy regulation

Time	Event
1926	Joint Resolution – 90 days
1927	Radio Act 1927 enacted
1934	Federal Communications Commission founded
1940, 1946, 1948 and 1954	Highly regulated by authority – licensed renewal

3. Auction – Market-based

In 1951, Leo Herzel proposed that a price mechanism should be used to allocate frequency. However, this was opposed by Dallas W. Smythe on the ground that the price mechanism could not solve the allocation of frequency (a scarce resource) if there was imperfect competition.

In 1958, a hearing concerning subscription to television, before the House Committee on Interstate and Foreign Commerce, was initiated and suggested that frequency licenses could be given to the highest bidders.

While there were many arguments about the price mechanism in allocating frequency, the Commission had approved transferences of frequency in 1955, 1957 and 1958 in the case of selling the stations WNEW, WDTC and WCAV, respectively. These approvals by the Commission could imply that the private property character of frequency was already in place.

In 1959, Ronald Coase proposed using market mechanisms to assign a spectrum to a user because the command and control method was inefficient. He suggested that the market was the most efficient mechanism to allocate this scarce resource. The government should issue the property right attached to a spectrum, so that the licensee would be able to trade, subdivide, combine or modify the property through mutual negotiation.

In 1993, Congress permitted the FCC to use auctions for assigning frequency. The first auction was on July 25, 1994 with the amount of 20 billion USD.

There were many debates regarding how to define property rights, private and public property rights, ownership and right of use. A spectrum is public property; even the licensees do not have exclusive rights of use. Contrary

to private property which has ownership or exclusive rights, there is a proposal to push the FCC to turn the spectrum into private property (Coase, 1959). Another idea is of sharing the spectrum as open access by implementing a charging mechanism on the use of spectrum (E. M. Noam, 1995;E. Noam, 1998).

Faulhaber & Farber (2002) suggested that property rights should include the high power and dedicated frequency which are sufficient to avoid harmful interference for defining the property rights.

A summary of significant events is shown in Table 3.

Table 3: Period of market mechanism

Time	Event
1951	Herzel proposed a price mechanism
1958	House Committee on Interstate and Foreign Commerce proposed private property
1955, 1957 and 1958	Frequency transferred of WNEW, WDTC and WCAV
1959	Coase repeated the market mechanism proposal
1993	Congress permitted FCC to auction
1994	First auction of 20 billion USD

4. Unlicensed – spectrum commons

In 1938, the Federal Communication Commission (FCC) allowed unlicensed devices in Part 15 of the Communications Act of 1934. The unlicensed devices might emit radiowaves without previously obtaining a station or user authorization on the specific frequency. The use of unlicensed devices had no protection rights. However, unlicensed devices had to be authorized by the FCC before marketing or importation. At this time, the FCC allowed unlicensed devices in the medium frequency (0.3–3 MHz) and high frequency (3–30 MHz) bands.

In December 1955, the FCC issued a Further Notice for Proposing Rule Making (FNPRM) to allow an additional 30–890 MHz and exempted transmitters operating above 1000 MHz from field strength measurements.

During the 1960s-1980s, the FCC amended Part 15 and allowed the use of emerging equipment such as wireless microphones, telemetry systems, garage door openers, auditory assistance devices, control and security alarm devices, and cordless telephones.

However, the technical characteristics of Part 15 were too complex, inconsistent and outdated. Thus, a revision of Part 15's technical and administrative provisions was made in 1985. Furthermore, the FCC expanded Part 15 to include the use of low-power devices and unlicensed spread-spectrum systems in the band of 900–928, 2,400–2,483.5, and 5,725–5,825 MHz.

In 1989, the FCC reclassified unlicensed devices into three categories: unintentional radiators, incidental radiators, and intentional radiators. The devices in Part 15 required pre-approval through an authorization process, prior to sale to the public, in order to comply with the technical standard.

In 1993, the FCC allowed unlicensed personal communications services in the band of 1,910–1,930 and 2,390–2,400 MHz. It also allowed the millimeter wave band of 59–64 GHz in 1995 and later an additional 2 GHz in the band of 57–64 GHz. In 1997, the FCC allowed unlicensed national information infrastructure in the band of 5.15–5.35 and 5.725–5.825 GHz.

In February 2002, the FCC decided to allow ultra-wideband devices with workable technical standards and emission restrictions without causing interference to the primary user. The use of ultra-wideband worked across several gigahertz bands. In July 2002, the FCC's Spectrum Policy Task Force sought comments from industry

regarding the spectrum policy. There were more than 200 comments, and commentators generally supported the additional frequency for the unlicensed band. The FCC allowed an additional 255 MHz in the band of 5.47–5.725 GHz.

In December 2002, the FCC released a Notice of Inquiry seeking feedback on allowing unlicensed devices to operate in the TV broadcast spectrum when it was not in use.

The spectrum commons allows people to share frequency within the same technical constraints such as the frequency, power limitation and field strength. All unlicensed devices used in the spectrum commons scheme without protection rights must not cause harmful interference to the primary users. The development of unlicensed devices stimulates more innovation in both application and usage. Moreover, the unlicensed devices in spectrum commons increase the frequency utilization more than the two other spectrum assignment approaches, because there is no exclusive right to use a spectrum with spectrum commons. Everyone is able to use a spectrum as much as possible within the same constraints.

A summary of significant events is shown in Table 3.

Table 4: Period of spectrum commons

Time	Event
1938	FCC permitted Part 15 of Communications Act of 1934 (0.3 – 3 MHz and 3 – 30 MHz)
1955	Allowed addition of 30 – 890 MHz band and exempted receivers above 1000 MHz from field strength measurements.
1985	Part 15 revision allowing addition of 900 – 928, 2,400 – 2,483.5, and 5,725 – 5,825 MHz bands
1989	Part 15 reclassified
1993	Allowed addition of 1,910 – 1,930, 2,390 – 2,400 MHz and 57 – 64 GHz
1997	Allowed addition of 5.15 – 5.35 and 5.725 – 5.825 GHz
2002	Allowed addition of 5.47 – 5.725 GHz.

5. Discussion

As seen in the above sections, the development of the spectrum assignment approach provides the characteristics of spectrum commons – unlicensed, free use but with constraints. According to the observations of Hardin (1968), spectrum commons allows everyone to use the resource until it becomes overused or overpopulated – i.e. the tragedy of the commons. Hardin (1968) also suggested that this problem cannot be solved by technical means, except by implementing the concept that 'freedom is the recognition of necessity'. This means there should be some constraints to control the use of resources. This reflects the basic characteristics of spectrum commons, i.e. unlimited access to resources but with constraints. However, there was an opposite view from Heller (1998) of an underused resource with multiple owners who had exclusive rights, as a new property right defined by the government. Heller (1998) also suggested managing this underused resource by concentrating on the content of a property bundle rather than on the clarity of rights.

Regarding the frequency or spectrum as property, there are two main kinds of property: public and private. Heller (1999) defined the boundaries of private property that lie between the commons and the anticommons. Moreover, the public also claimed property when the property was physically capable of being monopolized by private persons, and properties themselves were most valuable when used by indefinite and unlimited numbers of persons (Rose, 1986). In terms of property, the spectrum commons had no exclusivity, alienation or management by itself (Wang, 2009). Another extreme idea came from Werbach (2004) regarding "Supercommons": it had open entry and open boundaries, a white space which encouraged different business

models to use spectrum with impermissible interference. The concept of Supercommons is hard to implement and goes far beyond the spectrum commons. It cannot be implemented with the current technology at present.

As a further interesting concept, Faulhaber (2006) and Faulhaber & Farber (2002) proposed a mix between market- and common-based regimes which can meet future needs. E. M. Noam (1995) and E. Noam (1998) suggested a similar mix with full openness of entry for all users and payment of an access fee dynamically and automatically by clearing-house. The access fee would depend on demand and supply conditions at access time. This idea has been opposed by Brennan (1998) and Hazlett (1998b) who argue that it would take a long time to prove the open-access concept, and that the mechanism would duplicate the efficiencies of the market and make the spectrum resource under-utilized. This concept of open access needs more advanced technology to implement and might take time to prove.

The practical discussion regarding how to implement spectrum commons is also interesting. Benkler (1998) proposed a model building on non-owned components and an information infrastructure based on unlicensed wireless devices as commons, and suggested that the computer hardware and software market necessary to operate in an unlicensed environment will drive the innovation and deployment of the infrastructure. Werbach (2003) suggested that the regulators should make more unlicensed spectrum available through the dedicated open-access band, with low-power underlay and opportunistic sharing to overcome the spectrum scarcities. Lehr & Crowcroft (2005) provided a concept to manage spectrum commons by implementing the appropriate protocol including liquidity, being decentralized/distributed and adaptive and flexible. Peha (2005) suggested that a licensing scheme works better for use with a QoS requirement, and that an unlicensed one works better for wireless connection between computer and cable modems. Furthermore, Munzer (2004) argued that there would be issues for the intellectual in the future regarding commons and anticommons.

6. Conclusion

This paper has reviewed the history and conceptual development of spectrum commons in the USA. The concept of spectrum assignment first arose after the tragedy of commons when the spectrum had been overused in 1926. The command and control method of implementing a heavily regulated protocol for the use of spectrum was introduced. Because of the lack of flexibility and inefficiency in using spectrum, the use of market mechanisms was introduced in order to allocate a spectrum to users who valued it the most. Creating market mechanisms for the spectrum by property right enables the users to trade, subdivide, combine or modify it through mutual negotiation. However, the argument of public and private property regarding the ownership of a spectrum, or an exclusive right, has continued. On the other hand, the development of spectrum commons occurred alongside the command and control approach by allowing unlicensed devices to share a spectrum as commons without protection right on some specific frequency band and with technical limitations. Under spectrum commons, users have non-exclusive rights to use a spectrum, creating an opportunity for everyone to use it with the same technical constraints. The spectrum commons stimulates innovation in application and usage through the development of unlicensed devices. Its use increases the spectrum efficiency more than the other two spectrum assignment methods. Finally, the use of spectrum commons allows everyone to use the spectrum equally and efficiently.

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