International Journal of Humanities Social Science and Management (IJHSSM)
Volume 5, Issue 2, Mar.-Apr., 2025, pp: 883-894 ISSN: 3048-6874
www.ijhssm.org

Methods of Spectrum Allocation and its Pricing

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Date of Submission: 01-04-2025 Date of Acceptance: 11-04-2025

Abstract
According to the "Handbook on National Spectrum Management" published by ITU in year 2015, the increasing use of radio spectrum has tremendously highlighted the importance of spectrum and its management. The efficient use of radio spectrum highly depends upon a country's spectrum management and allocation policy. For a successful spectrum management system, objectives and goals of a nation should be clearly defined. It is hard to measure the success of spectrum management system. However, in general if a system of spectrum allocation is able to achieve desired goal and objective set by the nation, same can be considered as a successful spectrum allocation system. The telecom spectrum is the backbone of ICTs services and plays a significant role in terms of bridging the digital divide and digitization of telecom sector which in turn benefits the economic growth of a country and thereby laying foundation for further development. Likewise, telecom spectrum distribution also significantly impacts digitalization and thereby, development of a nation. The telecom spectrum is a scarce natural asset whose misallocation is probably going to adversely affect an economy. It is accordingly critical for a nation to guarantee effective distribution of telecom spectrum at reasonable pricing. Spectrum allocation and regulation is done primarily for the maximum utilization of public property so that larger public interest is taken care of. With this backdrop, the author will discuss the various methods of spectrum allocation used internationally and in India. The article will also explore the various factors and parameters which can be used to developed an effective and efficient spectrum allocation method.

Keywords: Spectrum Allocation, Pricing, Auctions, FCFS and Lottery

I. Introduction

The term "Spectrum" in common terminology refers to a set of different types of invisible radio-waves which are used specifically for communication purposes. On the other hand, spectrum allocation is a process of allocation in which electromagnetic spectrum is divided into various bands of radio frequencies having different wavelengths. Spectrum management as a concept emerged because of the consistent rising demand for wireless telecommunications technology in order to fulfill requirements of transfer of data at a brisk pace and for communication purposes. All the wireless services (such as mobile phone calls, internet services, radio services, *etc*.) use these invisible radio-waves for communication. Hence, the spectrum may be called as "the lifeblood of wireless networks."[2] These radio frequencies are just a part of the electromagnetic spectrum which also includes other frequencies that are not even familiar to us[3]. The spectrum bands can be divided into low frequency and high frequency spectrum (depending upon the degree of frequency of an electromagnetic spectrum). For example, low-frequency electromagnetic waves can travel for long-distance and can pass through many objects. However, it can carry a small amount of data. On the other hand, the high-frequency spectrum can carry a large amount of data but cannot pass through a thick wall and other dense objects. Talking about the different kinds of frequency bands, electromagnetic spectrum can be categorized into low, mid and high frequency bands. Bands below 2.6 GHz frequencies are called low bands. Bands between 3GHz frequencies to 7GHz

[1] The views in the article are personal and do not reflect the views of the Competition Commission of India.
[2]Sheffer, R. (2015, January, 17). *Why spectrum is the lifeblood of a wireless network.* https://finance.yahoo.com/news/why-spectrum-lifeblood-wireless-network-211337078.html
[3]CITA (2018, June 5). *What is Spectrum? A Brief Explainer*. https://www.ctia.org/news/what-is-spectrum-a-brief-explainer

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Volume 5, Issue 2, Mar.-Apr., 2025, pp: 883-894 ISSN: 3048-6874
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frequencies are called 'mid bands' and the 'high bands' are those whose frequencies are measured in the millimeter-wave. For different telecommunications purposes, the most recommended spectrum is that the one ranging from 400 MHz to 4GHz and specific standards are laid down for their maximum and efficient utilization throughout the world and to use these bands, various standards like GSM, LTE etc. are developed globally with time[4].

Spectrum Allocation Methods

Spectrum is not only used for mobile phone services but also used for various other services like broadcasting, radio navigation, radiolocation, fixed and mobile satellite service, aeronautical satellite service, radio navigational satellite service *etc*. Effective and reasonable allocation/regulation of electromagnetic spectrum into various radio frequency bands and granting of licenses is the prime responsibility of the government and must be done keeping in mind the proper balance between economic growth of the country and needs of the consumers. Electromagnetic spectrum being a public property must be utilized to its fullest and should be allocated wisely and reasonably by the government and its organizations. As we know spectrum is a non-consumable natural resource. If we do not use it, it would go in waste anyway. Given the importance and characteristics of the spectrum, we will discuss the various spectrum allocation methods in following paragraphs:

Decentralized Method

In this uncommon method of spectrum allocation, the authority to grant licenses for determination of spectrum allocation is delegated to private players itself, *i.e.,* Industry. In this method, the government tells all the interested firms to bargain among themselves to determine who should get licenses. Japan (1950) used a decentralized method to allocate radio broadcast licenses. However, this system may be ineffective in situations where firms are unable to reach a consensus as to who should be awarded the license.

Administrative Process

The administrative process is one of the oldest and widely used methods for spectrum allocation in telecom history which was mostly common in Canada and European countries. In the administrative process, government or government department (*i.e.,* DoT, India) invites proposals from private telecom service providers and evaluates them. The standards for the distribution of spectrum are created by the administration and afterwards, an in-house advisory group of specialists check different recommendations. The standards are given finality by the administration after analyzing the proposals and picking out the best and reasonable proposals with necessary amendments, if any. Such method gives a great deal of adaptability to the administration in deciding the allocation of spectrum.

This method of spectrum allocation has its own disadvantages as well such as non-transparency and time-consuming. It often takes a long time to finalize the allocation of spectrum invitation and evaluation of applications. This makes the administrative process slow, wasteful, and non-transparent. Although, this method is time taking, yet it also tends to cling more to the administration plans and goals. In many cases, it has been found that the winner had effective lobbyists. In this regard, it may be noted that South Korea (1992) used an administrative process to distribute cellular license. Winner Company was Sunkyong Group, whose Chairman was related to the President Roe-Woo. Similarly, in France (1994), mobile telecommunication service license was granted to Bouygues (a company), which had political clout.

Beauty Contest

A 'beauty contest' is fundamentally the same process as 'administration allocation'. This method has been used in Bangladesh for spectrum allotment. In this process, the relevant committee lays down certain criteria with requisite requirements and weightings and then a candidate's proposal is analyzed by the jury, which aims to select the proposal that contains the best mixture of relevant criteria as laid down by the committee. The criteria may be general or specific in nature. General criteria may include minimal requirements of financial resources, investment or reliability in conducting research. Specific criteria may include technology, quality, pricing, competitiveness, speed of network etc.

Lottery

Lottery is one of the quickest methods of spectrum allocation and many countries have used

[4] Sathe, G. (2016, July 31). *Tech 101: What Is Spectrum, and Why Is It Being Auctioned?* https://gadgets.ndtv.com/telecom/features/tech-101-what-is-spectrum-and-why-is-it-being-auctioned-824721

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this. Under this method, the government invites applications from interested firms and randomly selects the winning firm. This method has been utilized in smaller US computerized markets since this method is seen by the administrative office as a medium to distribute licenses rapidly without inviting any solid, time squandering legitimate battles. This method of spectrum allocation has its own pros and cons. Talking about positive aspect, spectrum allocation method through lottery is faster as well as an affordable in comparison to other methods and it also has low costs. However, talking about negative side, the proficient utilization of spectrum is not a guarantee as there may be occasions where the randomly selected firm is not the best when it comes to efficient utilization of spectrum.

In the wake of dismissing the administrative process, the United States explored different avenues regarding lotteries in dispensing cell licenses during the 1980s. Lotteries pulled in numerous speculative candidates, a significant number of whom were not skilled. Such candidates sold the licenses to different firms at over-the-top costs prompting notional misfortunes. The Federal Communication Commission (FCC, USA) used the lottery method in 1980 and they nearly received 4 lakh applications and many of them did not have the technical expertise to run a cellular telephone service. RACDG partnership won the license to provide cellular telephone service in Cape Cod (USA) by lottery method and later sold its right to Southwestern Bell.

First Come First Serve (FCFS)

First come first serve (FCFS) is a method to allocate spectrum licenses wherein spectrum license is given to a firm whichever comes first. It has the same random characteristics and disadvantages as a lottery-like selection of technically incompetent firms, loss of government revenue, *etc*. It has the same advantage of quick allocation of licenses. This method of granting spectrum licenses is one of the most conventional and orthodox method of granting spectrum particularly when the spectrum to be allocated and regulated is new and unused. This was fundamentally applicable concerning the analogue systems (1G) and was also used by different members of European Union for the first time in 2007. The FCFS strategy was also used in Bangladesh and is still being used in Bhutan.

Auctions

In the auction method, the spectrum is distributed by offering among the contending candidates. Spectrum is dispensed to the candidate who offers the highest price contrasted with other candidates. Auctions were first used by the New Zealand government in 1990. Since then, it has been used in various other countries like USA, India, Colombia, Australia, the UK, Hungary, and Argentina. India too has adopted auctions in its early phases and used it as an effective tool for spectrum allocation. Unlike the administrative process, an auction can provide a speedy method of spectrum allocation by eliminating the lengthy process of invitation and evaluation of applications. It ensures the selection of technically competent firm and spectrum licenses will go to the firm which values it most. It generates the highest possible revenue to the government by creating competition in bidding. The efficient firm increases the value of the license by intensive and efficient use of spectrum and also reduces the loss due to delay in commencement of telecommunication services. Among the different method for spectrum allotment, auctions have picked up popularity because of speedy allotment. Such competitive bidding is the best methods for allotting licenses for use of spectrum and avoids months or years of administrative or other postponements.

The rules, regulation and structure of the auction directly affects the cost of spectrum allocation on both sides *i.e.*, on the side of the government as well as the service providers. High reserve prices can maintain high costs and deprive the medium-sized and small organizations. Bidding rules likewise have a considerable effect in the reasonableness of spectrum and the subsequent expenses for consumers. A well-designed auction can also achieve various policy goals because of its flexibility. If the government wants to assign licenses to some targeted group of companies, they can do so by allowing only targeted firms to participate in the auction. To curb the monopoly and encourage competition in a particular region, the government, as is being done in India and USA, can assign licenses to more than one firm using the auction method. An auction can also ensure universal access of telecom services by keeping the price of spectrum constant and spectrum will be awarded to a firm which can provide cellular services across the country (including entire backward rural area) in the fastest time. Argentina adopted this type of auction to solve its universal access problem where the competition was not on spectrum price but on the coverage area of service.

Most of the literature suggests that auction is the best method for spectrum allocation. The same can be proved using the example of various countries. Most of the countries started with various other method but later on, they all converged to auction method. The USA started with the administrative

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process to allocate telecommunication license and then moved to a lottery in 1980. But because of their disadvantages, USA switched to auction in 1993. Similarly, Canada started with the administrative process then moved to the lottery and finally switched to auction. Federal Communication Commission (FCC) found that cost of spectrum allocation (telecommunication license) is six times higher in the administrative process than in an auction.

Auction too has its own disadvantages as well. Many critics argue that auction leads to loss of the government's discretionary power in the allocation of telecommunication licenses because anybody can get a license by bidding high. In this regard, it is observed that a pre-planned and well-designed auction can achieve the desired result even though the government does not have any control on spectrum allocation once the auction starts. Given the above discussion, it is clear that auction can be of multiple types. A government can design the rule and structure of the auction as per its requirements. The various types of the auction are as under:

a) **Dutch auction (descending price auction): '**Dutch auction' is also known as the 'descending price auction'. The seller sets an exorbitant cost of the article at first and brings down it ceaselessly. In this method, a bidder who communicates his readiness to purchase the item first, is declared as the winner of the auction and the spectrum is given to him at that price itself. One of the issues with the descending price auction is that the seller must have decent information on the upper bound on the estimations of the bidders. Otherwise, the seller may lose expected income from the auction.

b) English or Japanese auction (ascending price auction): The 'ascending price auction' is the ascending partner of the Dutch auction. There are two generally utilized variations of this configuration. The main variation is called the **English auction** where the vender begins the auction at a low cost (potentially zero or seller's reserve price). The bidder who needs to win the article builds the cost thereby increasing the price of the article. The auction closes when there is no cost increment, and the last bidder gets the article by paying the offered sum. In another variation, called the **Japanese auction**, the vender begins the bartering at a low cost (potentially zero or seller's reserve price). Bidders express their readiness to purchase the article at each cost. In the event, the number of bidders who need to purchase the article at the current cost is multiple, at that point the dealer expands the cost by a pre-decided sum, called the 'offer addition'. In other words, the price is continuously increased in small proportions by the vender. The auction stops when there is one bidder who wants to purchase the item and is declared as the winner of auction and after paying the displayed price at that point of time. Ordinarily, there are auction rules which require every bidder to communicate his ability to purchase the item at each cost in the bartering, and once a bidder disapproves of purchase the article at a value, he is no longer permitted to take an interest in the auction.

c) **Simultaneous Ascending Auction (SAA) also known as Simultaneous Multiple-Round Ascending Auction (SMRA):** In the SAA, the bidders at the same time quote offers, generally posting their offers through the web. The most noteworthy offer in each round is disclosed after the fulfillment of the concerned round without naming the bidder to evade potential outcomes of bid-rigging arrangement among the bidders. Setting the most noteworthy offer given by bidders in a specific round as the requisite cost required to proceed for the next following round, the auction proceeds till the number of licenses requested by enduring bidders equals the number of licenses available to be purchased.

d) Simultaneous Clock Auction (SCA)

In the event of SCA, there is a clock which denotes the consistent increment in the cost of the items available to be purchased. The bidders watch the costs on the clock and choose when to venture out. The auction is finished when the interest of remaining bidders equals the accessible number of licenses available for auction. In clock auctions, the bidders have less degree of control; the final cost is what the vendor quote offers and the bidders simply have to show their interest to purchase those objects at the given price. Thus, the likelihood of revenue loss coming from collusions among bidders is quite low for such auctions.

e) Combinatorial auctions

In the combinatorial auctions, the articles are sold as a total bundle or as a mix of various bundles. These auctions can initiate bidders to offer higher in presence of complementary nature, positive collaboration or super-additive qualities (for example having the items together produces a higher incentive to the bidder than the whole of the qualities got from having the articles separately). This is because when there is a super-additive incentive for each bidder, there is likelihood that all the articles are bought together by the same bidder.

Spectrum Allocation Methods in India

Over the past few years, there has been a lot of discussion on spectrum scams, interference of spectrum, shortages of spectrums and merger of

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companies to get more spectrum *etc*.[5]. There are many authorities in India which work collectively in the field of spectrum regulation and management in India. However, on the recommendations of the Telecom Regulatory Authority of India (TRAI) on pricing and spectrum allocations, the Department of Telecommunications (DoT) is in-charge authority of spectrum licensing[6], whereas, the Standing Advisory Committee on Radio Frequency Allocation (SACFA) is responsible for decision making in spectrum frequency allocations[7].

Telecommunication sector was largely state controlled and regulated before 1991. It was only after the policies and changes brought during the 1991-92, that transformed India in an open and market-driven economy. As indicated by the Indian Telegraphs Act, 1985, the Department of Telecommunication under the Ministry of Communications was to be the sole authority working in the telecom services and had a monopoly in the telecom segment. There were certain measures and reforms that were presented in 1991, which were subsequently backed by the reformative period of change through the presentation of the National Telecommunications Policy (NTP) in 1994, but the requirement of able organization was still not fulfilled. Therefore, in January 1997, the Telecom Regulatory Authority of India (TRAI) came into existence solely for regulation and dispute settlement forum by an act of Parliament.

India started allocating spectrum licenses through auctions in 1991 which did not prove to be successful at all. In India, the Department of Telecommunications (DoT) was the authority which conducted the auctions of spectrum licenses. The entire country was divided into 20 circles categorized as A, B, C depending on their revenue potential, for service provision. The 1991 auction rules and structure forced the potential Indian service providers to seek foreign partnership, since it was felt that no Indian provider had adequate financial resources and technical knowledge. The adopted auction format was first price sealed-bid. The DoT designated Global System for Mobile Communications as India's accepted cellular technology. India started the second process of allocating the spectrum to the telecom operators in 1994.

So far, the Government of India has used two methods of spectrum allocation. One is spectrum allocation through auctions and other is 'first come first serve' allocation method. Although, the 'first come first serve' allocation process was used only once during the 2008 spectrum allocation. India has experienced a lot of ups and downs in the allocations of spectrum over the years. In 2003, Government introduced a license named 'Unified Access Services' (UAS), which was made compulsory for the telecom operators to operate in any of 22 circles valid for 20 years through which the telecom operators were allotted frequencies for a fixed period for that particular circle.[8] Although after the introduction of new telecom policy in 2011, operators had to pay for spectrum separately while renewing their licenses[9]. In 2008, instead of auctioning, the government of India allocated 100 MHz bands to various international firms on 'first come first serve' basis and allowed them to start their businesses in India. In 2010, 2100 MHz band of the 3G spectrum were auctioned and Tata Docomo became the first private telecom operator in the country to start 3G services.[10] Delhi Circle ended up being paying the highest price of Rs.4,505/- million per block among all circles during 2013 spectrum auction. In 2014 spectrum auction, Reliance Jio won the bid in 14 circles across the country in 1800 MHz frequency which was the only company in the country possessing 4G license[11]. For the first time, the government initiated the sale of 5G spectrum ranging over 3000 MHz band frequency in 2017 spectrum auction[12].

[5] Reardon, M. (2012, August 12). *Wireless spectrum: What it is, and why you should care*.https://www.cnet.com/news/wireless-spectrum-what-it-is-and-why-you-should-care/

[6] APC report (2012, May). *Spectrum for development India*.https://www.apc.org/sites/default/files/countries/factsheet%20india_eng.pdf

[7] Ibid.

[8]ibid.

[9]ibid.

[10] PTI (2010, April 9). 3G spectrum auction begins smoothly, top telecom operators in fray. *The Times of India*.https://timesofindia.indiatimes.com/business/india-business/3G-spectrum-auction-begins-smoothly-top-telecom-operators-in-fray/articleshow/5776917.cms

[11] 2G spectrum auction nets □61,162 crore: 10 things to know. *NDTV*.https://www.ndtv.com/business/2g-spectrum-auction-nets-rs-61-162-crore-10-things-to-know-380575

[12] Doval, P. (2017, March 10). Govt to auction 5G spectrum in frequencies above 3k MHz. *The Times of India*. https://timesofindia.indiatimes.com/business/india-

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The enormous increment in demand of wireless services has increased the requirements of radio spectrum accessibility. Radio spectrum alludes to the pieces of electromagnetic frequencies that are accessible for wireless transmissions. In other words, radio spectrum is a part of electromagnetic spectrum with frequencies ranging from 30 Hz to 300 GHz (radio waves) and is primarily used in telecommunication services. Various pieces of the spectrum are utilized for various innovations and applications. A spectrum band is a little segment of the spectrum wherein channels are utilized for telecommunication services. The Indian government is focused in its approach to utilize these radio spectrum and other smaller spectrum bands to improve budgetary access, improving data services, and bringing profitability up in the economy. It has, therefore, launched significant leading programs like 'Digital India' and 'Smart Cities' which essentially rely upon media communications foundation. While auction accessibility is a worldwide test looked by all economies, it is an especially extreme issue in India. Given the vital function of the broadcast communications area in India's future, understanding these difficulties is essential for financial development and cultural incorporation.

Spectrum management policies in India have advanced towards market-based approaches. Since 2010, the Department of Telecommunication has exceptionally applied the auction-based strategy for spectrum allocation. Over the six auctions held during the period 2010 to 2016, the government has auctioned just sub-sets of the all-out frequencies and the average reserve price in each ensuing auction has seen an upward. Considering the experience of India in spectrum allocation, the competent authority should design the spectrum allocation method after taking into consideration all the commercial and social aspects of the economy.

Global Spectrum Allocation Experience

The major challenge for the government across the globe nowadays is to determine – how spectrum management can be done keeping in mind the best possible advantage to the economy as well as to the society. The methodology for spectrum allocation began to change from 1989 because of the phased improvements in financial and strategic side. This induced many governments to use auction for spectrum allocation many times. Talking about the pioneer countries that adopted 'auction' as a method of spectrum allocation, New Zealand led the bandwagon, followed by the United States of America and several other developing economies, including India. These nations started preferring auction as the method for spectrum allocation. In view of above discussion, the following paragraphs will discuss the experiences of the other nations regarding spectrum allocation methods.

United States of America

The US Congress approved the spectrum allocation through auctions in 1993. The auction format which was used was similar to the simultaneous multiple rounds ascending auctions (SMRA). It is noteworthy to mention that just 6 per cent of the US citizens were using cell phones at that time. Today, 97.2 per cent of the US mobiles have the choice to pick between at least three service providers and 80.4 per cent consumers pick among at least five suppliers. This shows that the FCC has been fruitful in accomplishing its goal of guaranteeing rivalry in the telecom market. By and large, the US telecom auction is appraised as an example of overcoming adversity.

A central policy objective in the United States is socioeconomic development, including employment and economic growth. In general, we have seen that the framework of spectrum management in the USA is constrained by the embedded values prioritizing defence usage over commercial telecommunications. In general, it is the security of the country that takes the top priority in every nation throughout the globe. However, given the importance and economic benefits accrued thereof due to commercial mobile communications, the different layers of the institutional framework have been altered in varying degrees in different nations to accommodate the demand for spectrum.

New Zealand

Before 1987, the New Zealand government kept following a virtual imposing monopoly model in the arrangement and guideline of telecommunications services. The executives of the radio spectrum until 1987 were dealt with by the Post Office. At that point in 1987, New Zealand passed the Telecommunications Act, which opened up New Zealand's media communications markets, intending to improve the proficiency with which new

business/govt-to-auction-5g-spectrum-in-frequencies-above-3k-mhz/articleshow/57564796.cms

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Volume 5, Issue 2, Mar.-Apr., 2025, pp: 883-894 ISSN: 3048-6874
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administrations were given to general society. The principal spectrum auction in New Zealand occurred in 1990. The New Zealand government approved the Simultaneous second-price sealed-bid auction design for each license.

Germany

The 3G auction in Germany started on July 31, 2000, and went on until August 17, 2000, comprising more than 173 rounds of bidding. During this phase of auctions, it was seen that about 12 of the total bidders enlisted to partake, while five pulled back before initiation and one was denied permission to take part in the auction by the regulator. The auction was planned using the simultaneous multiple rounds. The ascending auctions design started with cautious bidding, however wound up with an all-out income offer of around Euro 50 billion. Sometimes bidding went up by 90 times of the initial bid values. The new firms failed to enter the German telecommunication market through the auction process. The 3G auctions negated to alter the market structure, which was continued by 4 market operators. The German design resulted in more competition and potentially higher revenue. In Germany, the regulators constantly put up a modest reserve price for radio spectrum which was sufficient enough to prevent any objectionable entry and guaranteed that winners pay a particular amount in the event of foregoing. Opportunity cost of spectrum *i.e.*, the value of the next best alternative use of spectrum at equilibrium (demand of spectrum is equal to supply). For some operators, eminently those in Germany, income isn't a need – their emphasis is on the more extended term advantages to purchasers and the more extensive economy through advancing mobile administrations and develop a computerized society. Nonetheless, for other people, income might be a significant criterion for certain financial reasons and to determine the extent of reasonable returns to the citizens. They are much more concerned about realizing welfare gains for consumers than they are about whether they could have extracted more money from the industry in selling the spectrum.

Australia

Given Australia's geology, atmosphere and population distribution, wireless network assumes a basic function in connecting its outskirts to its main metropolitan population by giving high quality and timely access to basic and value-added administration services that are important for the regular existence of a developed economy. The first spectrum auction was conducted in 1994. In Australia, as in other nations, most of the spectrum isn't assigned using an auction or other price-based allocations, but is allocated through "over the counter" method on a 'first-come first-serve' basis. 'First come first serve' spectrum allocation method is thus the most preferred and widely used method for allocation of spectrum in Australia. FCFS allocation is likewise useful as a method for guaranteeing admittance to spectrum even for lesser developed business firms. The ACA has a perspective that the use of the spectrum is usually more suitably made by operators of communication frameworks rather than by regulators. The ACA thinks about that, when all is said and done, the spectrum will be used most effectively where it is dispensed to the entities who esteem it most profoundly. Allocations made in the commercial centre are probably going to be better at guaranteeing that spectrum is designated to its most elevated interest, and more productive, use. Such allocations are likewise prone to be more attractive in comparison with allocation done through discretionary choices by controllers as to the best use for a band.[13]

Pricing of the Spectrum

Management of the electromagnetic spectrum is the most important question for few decades now. It not only includes the allocation of the spectrum but also includes the valuation of the spectrum. Price of a commodity completely depends upon its demand and supply or in other words scarcity. Spectrum is a scarce natural resource but it is very useful in the modern era and hence it bears significant economic value. A valuation can be done from two points of view: buyer (service provider) and the seller (government). The service provider only thinks about accounting profits while the government takes into consideration all types of positive externalities. In an auction, the authority to determine the price of the spectrum is given to bidders (service provider) and in some cases government solely determines the price (FCFS, lottery, administrative prices *etc*.). Sometimes, the government uses past auction values as a base to determine the current value of the spectrum if latest data is available of a successful auction. If the price of the spectrum is very

[13] International Telecommunication Union (n. d.). *Spectrum management for a converging world: case study on Australia*. https://www.itu.int/osg/spu/ni/spectrum/aust-rsm.pdf

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high compared to its actual value, then the spectrum will remain unused. Telecom is a dynamic sector, there is a huge possibility of the emergence of new technology, services and application which had not been predicted at the time of valuation and it can have a significant impact on the efficiency of spectrum pricing. The innovation of new technology adds to the uncertainty in the future which both the regulator and government should take into consideration while deciding spectrum price.

Regarding the pricing of the spectrum by the government, it has been noticed that in general, it is opined that government should maximize its revenue from the spectrum allocation which may be used to provide other social services. However, many researchers believe that higher spectrum cost to the service provider will reflect in their tariff which may further harm the potential consumer of telecommunication services in terms of higher tariff and deprive them to avail the telecom services. On the other hand, reasonable and fair spectrum pricing will enhance social and economic welfare.

Broadly we have two approaches to value spectrum one is cash flow approach and second is opportunity cost approach. In cash flow approach (Kathuria, 2012), price setter tries to trace a value of spectrum based on the present value of net cash inflow over license tenure. Net cash inflow is the difference between cash inflow and cash outflow. Cash inflow refers to total revenue and cash outflow includes various cost license fees, spectrum charges, network cost, administration cost, marketing cost and personal cost. The determination of revenue and cost are either based on some realistic assumptions or past data. According to a report for OFTA (2009), the opportunity cost of spectrum refers to the value of the next best alternative use of spectrum at equilibrium (demand of spectrum is equal to supply). In other words, it is an equilibrium price and sometimes we call it administered incentive price (AIP). Auction is one of the best methods to achieve such kind of balance.

According to Houpis (2012), at the time of spectrum valuation, one should take into consideration various points such as determination of boundaries of the band, congestion in the band, potential user etc. Price setter needs to determine the boundaries of spectrum over which spectrum has same value otherwise they can't determine the uniform price of the band. If the actual or economic value of one part of the band varies from another part then price in this band which is efficient in one part of the band may not be efficient in other parts of the band. Congestion of the band refers to enough demand of spectrum by potential user and a band is congested if the entire spectrum is used by its potential user at minimum price. In a congested band, the government can charge high prices whereas in a non-congested band they can't. Potential users are proxy for the value of the spectrum which determines the price of spectrum as a high demand will automatically result in increasing price.

In general, the valuation of the spectrum has the following wide objectives and targets:

a) Spectrum should be used productively, financially, rationally and ideally.
b) Transparent process of designation of the frequency spectrum for use by assistance and making it accessible to various users under explicit conditions advancing reasonable competition.
c) Maximizing the monetary advantages to the nation from the use of the spectrum asset.
d) Ensuring the user's profit by the use of the spectrum asset
e) Encouraging spectrum sharing and overhauling old frameworks toward innovations
f) Providing income to the legislature or the spectrum controller.
g) Ensure Administratively easy to oversee
h) Promote social and social advantages

However, considering the government's goals and objectives, the spectrum pricing shall be in such a way that addresses the government priority/objective in the telecommunication sectors. Determination of the price of spectrum is generally based on the pricing objective, assessment of availability and demand, estimation of costs, and options for pricing mechanism to achieve the highest economic efficiency. While making such a decision, apart from monetary consideration, the government also takes into consideration other positive externalities associated with the use spectrum. Hence, as per the government's objectives, the pricing mechanism should:

a) stimulate efficiency in spectrum use,
b) promote the development of new technologies,
c) ensure customer satisfaction in terms of price and quality.

The government will likely have social and cultural objectives related to spectrum use. These objectives include:

a) Developing and extending telecommunications services.
b) Supporting industrial development, e.g., job creation, foreign investment.
c) Funding education e.g., Tele-education and Health e.g., tele-health.
d) Supporting cultural development e.g., broadcasting.

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Volume 5, Issue 2, Mar.-Apr., 2025, pp: 883-894 ISSN: 3048-6874
www.ijhssm.org

The task of determination of prices of spectrum is one of the important factors for effective use of spectrum. As an indispensable natural and regular asset, the price of spectrum ought to be adequate to guarantee that it is esteemed and maximum use to its best potential. The maximum benefits from the spectrum should be obtained for furthering the economic growth and development of the country, keeping in mind the consumer's interest. The expenses related to overseeing and controlling radio frequencies ought to be recouped from the individuals who get profit from the spectrum. This ought to apply to all users of the spectrum- both public and private. Important social and cultural objectives can be progressed by the use of the spectrum, and spectrum pricing ought to encourage the accomplishment of government's social and cultural objectives. Despite these targets, the income objective of government has a significant impact on the setting of spectrum price by the controller. As best as conceivable, these income targets ought to line up with the destinations of:

a) Ideal spectrum proficiency,
b) Accomplishing social and economic development objectives,
c) Spectrum users paying for spectrum asset usage, and
d) Recouping spectrum costs.

There are distinctive spectrum evaluating strategies. Some of the significant strategies are explained hereunder. One can use the procedures for the finalization of the spectrum valuing according to the requirement:

Recovery of an administrative cost model for pricing: This model is based on the assessment of the subsidizing cost which is needed to recoup the yearly expenses brought about by the administrative organization in dealing with spectrum asset. A significant hindrance of this methodology is that the expenses intended to recuperate managerial expenses are not attached to the financial estimation of the spectrum used, and may not encourage spectrum proficiency.

System performance-based pricing: The price could be estimated after taking into consideration various separate components over which the value of the spectrum depends. For example, the measure of spectrum used, the number of channels or connections used the level of blockage, the effectiveness of radio hardware, transmitter power/inclusion zone, geological area, etc. The essential rule is to recognize various specialized boundaries to gauge the spectrum volume used.

Administrative Incentive Prices: AIP is a strategy where a spectrum controller endeavours to estimate the prices that may develop in a market setting. The prices are set at a level to support productive use. Here, licenses are issued using the administrative method (*i.e.*, usually FCFS). Under this method, the service provider has an obligation to pay spectrum fee on regular basis. It induces the service providers to return the unused spectrum instead of paying the fee and use the spectrum more efficiently.

In the process of reaching the reasonable spectrum charge, the auction starts with a reserve price which gives starting prices in an auction. However, reserved prices do not correctly give an idea of worth which may be accomplished by an auction. There is an absolute level of susceptibility over the normal estimation of the spectrum price because this is controlled by bidders' expectation and estimation for business sectors and guideline throughout the following 15-20 years. Reserve prices ought to be set in a way so that they are beneath the normal worth. Otherwise, potential bidders might be dissuaded from entering the auction and there is a danger spectrum that it might be left unsold. If the spectrum is left unsold huge national and customer benefits will be lost. Ordinarily, productivity is the essential target for a spectrum auction. There are likewise secondary targets such as rivalry, straightforwardness and market improvement, and a tertiary goal of raising income for the government. Effectiveness implies that all the spectrum is sold and are allocated out to those operators that esteem it the most. Effective spectrum allocation can deliver enormous advantages to consumers and society in terms of a new and better quality of services. These advantages are exceptionally huge in contrast to incomes raised from spectrum auctions. The reserve price is the base sum at which the government will sell the spectrum. Whenever reserve prices are set at a non-trifling level, it may discourage collusion among bidders and in this way advance rivalry in the auction. Reserve prices ought to be set underneath the normal estimation of the spectrum to possible bidders, else they may prevent bidders from entering the auction or potentially decrease request from those that do partake in the auction. The higher the reserve price, the more prominent the danger of spectrum being left unsold. Unsold spectrum is an unwanted auction result because of the loss of monetary advantages from spectrum being left inert. Consequently, setting reserve prices must be done carefully keeping in mind certain risk factors. Reserve prices therefore must be set keeping in mind the general auction trends, specific productivity, rivalry, straightforwardness, market improvement and government incomes, *etc*.

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The future development of mobile communications is exceptionally uncertain especially given the quick movement of innovation and the impact of strategic choices for future spectrum and segment guideline. Bidders may have various desires concerning these arrangement factors just as various business plans and desires regarding innovation improvement and economic situations, all of which will influence their valuations. The degree of reserve price depends upon the compromises between various auction goals as discussed previously. The proportion of reserve prices in a given auction relies significantly upon the degree of rivalry for licenses available for distribution.

On the other hand, spectrum usage fees are charged to recover a spectrum asset lease by the government and to guarantee that consumers of spectrum use the asset on a proficient premise. In the case of non-utilization of the spectrum, the potential spectrum user (service provider) returns the unused spectrum for reuse. Specific focuses for spectrum utilization differ significantly across different areas. There is a contention for making uniform spectrum utilization charges fixed over an area to maintain a strategic distance from speculative disincentives. Nonetheless, considering several best local practices certain elements such as shortage, quality, congestions and incentives should be considered for determining spectrum usage fees.

India's way to deal with the spectrum has changed altogether throughout the long term and therefore even the fundamental standards of spectrum evaluating are as yet not settled. The development of India's spectrum charging has been as per the following:

e) Initially, in the significant metro zones, a spectrum fee was dependent on a fixed fee;

f) From 1999 a fixed upfront fee for spectrum was combined with continuous spectrum utilization charges as a percentage of revenue generated by telecom service providers.

g) In 2010, the percentage of income charged for annual spectrum use were self-assertively raised.

h) Auctions were held in 2012 and 2013 of the portions of the 1800 MHz spectrum that was given in 2008 then dropped by the Supreme Court. These auctions failed to sell a greater part of the spectrum because of misleadingly high reserve prices (set based on the last prices in the 2010 3G auction).

i) In February 2014, an auction was held for spectrum in significant metro zones. This auction saw spectrum sold at prices a few times the global average.

j) The Indian Government additionally presented keeping in mind the reasonable and maximum utilization of spectrum, a fixed spectrum usage charge equal to 5% of revenue, which was again struck by unpredictability by the Feb 2014 spectrum auction.

The October 2016 auction highlighted a prominent amount of spectrum to be sold and licenses to be granted. Had that whole spectrum been sold, it would have contributed enormously in finishing the unrealistic spectrum shortage in India. Rather, the auction floundered, with only 41% of the wireless transmissions accessible sold and the auction raising just $9.8bn, against a reserve price of $84bn. Bidding was intense and centered around high band frequencies, while 700 MHz and 900 MHz got no bids. The Indian market has extraordinary potential; however, until service provider gets the opportunity to procure considerable spectrum possessions at reasonable prices, the entry of cutting-edge information organizations will stay hindered.

Hence, a competent authority should adopt a guideline on spectrum evaluation following the spectrum pricing objective, principles, methodologies, approaches and criteria. It is prescribed to utilize spectrum estimating as a device to advance successful and proficient service provider, making the best possible judicious, logical and financial use of the spectrum with sufficient accessibility of spectrum to each level of efficient service providing firms, along with an aim to advance innovation and maintain impartiality in its approach. Higher spectrum prices perform a major role in slowing the rollout of cutting-edge technology organizations.

It is to be understood that a costlier spectrum will have a huge impact on decreasing an organizations quality which is more often than not experienced by customers in both developed and developing nations. Higher spectrum prices are related to higher purchaser prices in developing nations; however, further exploration is expected to affirm whether the impact is strong enough or not to confirm the above-stated conclusion. Other arrangement factors assume a noteworthy function in slowing network organization rollout (for example decreased inclusion) and diminishing the nature of the 3G and 4G network. Specifically, the early arrival of the spectrum and an adequate amount of licensed spectrum are both discovered to be essential drivers of consumer welfare. The essential target accordingly, therefore, is to assign spectrum only to those Operators who will have the option to extricate most of the incentives from this scarce and limited asset to support society overall.

Setting reserve prices forcefully or at levels that are too high is one motivation behind why

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auctions can convey wasteful results since it sabotages the very foundation for which the auction was to be conducted *i.e.*, ascertainment of price. Accordingly, the valuable spectrum may go unsold or be sold at such significant levels that require service providers to rethink their speculation designs or apply higher levies to recoup costs.

Governments have time and again tried to advance development and rivalry by sometimes reserving spectrum for a particular participant or by setting asides certain portion of the spectrum for another participant. While such arrangements might be planned considering the correct targets, they may likewise have unintended outcomes if they are ineffectively planned or actualized and bring about higher spectrum prices, in this way hurting customers. Artificial spectrum shortage is a continuous reason for exorbitant costs at auction. This can be an aftereffect of controllers keeping spectrum away from the market, saving it for new participants or verticals, to limit spectrum gracefully and subsequently drive-up request. The need ought to be on delivering adequate measures regarding spectrum allocation and pricing, in order to satisfy customer needs with respect to fast availability of services. The discoveries from this discussion show that making extra spectrum accessible drives a huge effect in conveying great benefit to the nation.

II. Conclusion

The telecom spectrum is the backbone of ICTs services and plays a significant role in terms of bridging the digital divide and digitization of the telecom sector which in turn benefits the economic growth of a country and thereby laying the foundation for further development. Further, the telecom spectrum is a scarce natural asset whose misallocation is probably going to adversely affect an economy. It is accordingly critical for a nation to guarantee effective distribution of telecom spectrum at reasonable pricing. Spectrum allocation and regulation is done primarily for the maximum utilization of public property so that larger public interest is taken care of. As all the governments have their agenda and goal, which may not be same across the world. Hence, a government should pick either the most efficient method of spectrum allocation or design a mix of multiple spectrum allocation methods which can help to extract the maximum benefit following their own goal. The possible spectrum allocation methods are the decentralized method, administrative process, beauty contest, lottery, first come first serve and auction. Within auction, there are multiple methods such as Dutch auction, English or Japanese auction, simultaneous ascending auction, simultaneous clock auction and combinatorial auction. Talking about India's experience concerning about spectrum allocation method, India majorly adopted the auction method for spectrum allocation and sometimes used first come first serve and administrative methods. The valuation of the spectrum is the most important part and can be done from two points of views: the buyer (service provider) and the seller (government). The service provider only thinks about accounting profit while the government takes into consideration all types of positive externalities. In an auction, the authority to determine the price of the spectrum is given to bidders (service provider) and in some cases government solely determines the price (FCFS, lottery, administrative prices *etc.*). Sometimes, the government uses past auction values as a base to determine the current value of the spectrum if the latest data of a successful auction is available. If the price of the spectrum is very high compared to its actual value, then the spectrum will remain unused. Telecom is a dynamic sector, there is a huge possibility of the emergence of new technology, services and application which had not been predicted at the time of valuation and it can have a significant impact on the efficiency of spectrum pricing. The innovation of new technology adds to the uncertainty in the future which both the regulator and government should take into consideration while deciding spectrum price.

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