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# Economical Methods in Spectrum Re-Allocation

Pavel Mamchenkov, ITU Expert

# Economical Methods at Different Stages of Spectrum Management

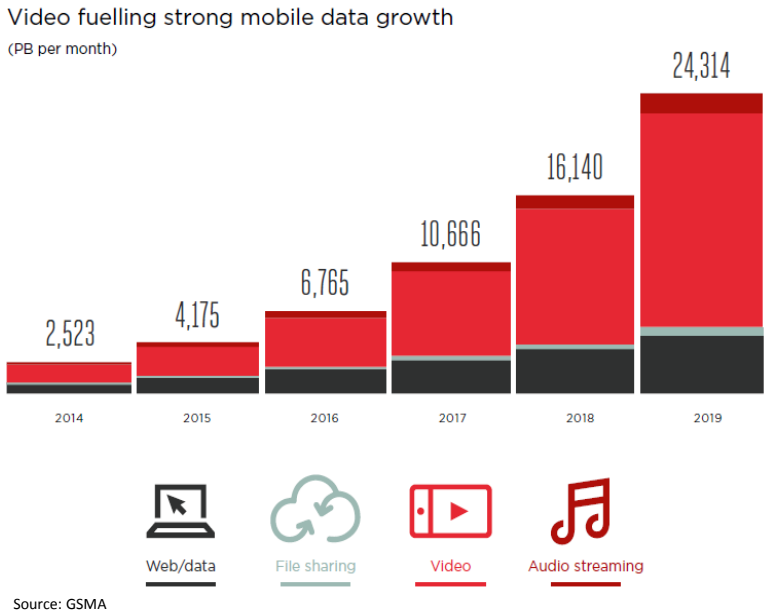
## Economical Methods Within Spectrum Life-Cycle

| Primary Issuing (initial licencing) | Post-Issuance Operation (through the period of licence validity) | Re-issuance of Resources (re-allocation) |
|---|---|---|
| **Spectrum Auctions** | **Spectrum Pricing and Trading** | **Spectrum Incentive Auctions** |
| Auction ensures that any newly released spectrum into the market is acquired by those who value it most.<br>Primary issuance of licences based on market signals reflects more accurately the value of spectrum and lead to more efficient spectrum utilization. | Genuine spectrum markets are creating when ownership and use of spectrum can change in the course of licence's operation.<br>**Spectrum Trading** involves the transfer of spectrum usage rights between interested parties (government, public or private users).<br>**Spectrum Pricing** is powerful mean to achieve a range of spectrum management objectives – efficient usage, innovation and competition. | Incentive Auctions is a market-driven mechanism of re-allocation where regulator plays the role of auctioneer in two-sided bidding process and finds equilibrium in supply and demand.<br>**Sellers (incumbents)** are showing the price for their spectrum intended to be sold - supply.<br>**Buyers (newcomers)** are showing the price at which they are willing to acquire spectrum proposed by incumbents - demand. |

**Economical methods should be applied through the entire spectrum life-cycle**

# The Footings of Spectrum Repurposing

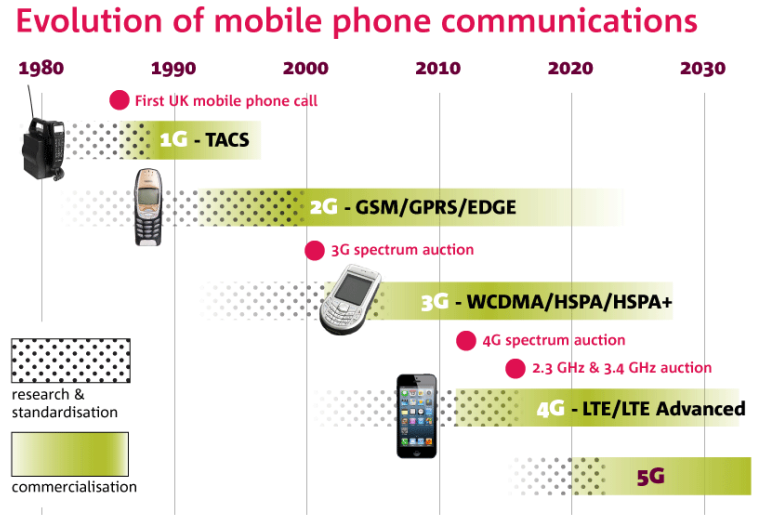
## Towards the Economy of Gigabytes…




Source: GSMA

Growing demand for data is satisfied by evolving radio technologies with greater geographic reach and capacity, advanced handsets with increased processing power, larger screens, ubiquitous social media, messaging, video streaming. Data traffic is growing exponentially 60% annually.

## Turnover of Radio Technologies…




Source: Http://tutorvoice.com/index.php/2015/10/11/generations-of-wireless-communication-technology/

The pace of change in radio technologies is speeding up. From ten years life cycle of new generation in the past, now turnover is increasing. The advent of 4G LTE happened six/seven years from the mass commercial adoption of 3G. 5G is estimated to happen four/five years from adoption of 4G.

## Revolving Spectrum Allocations…

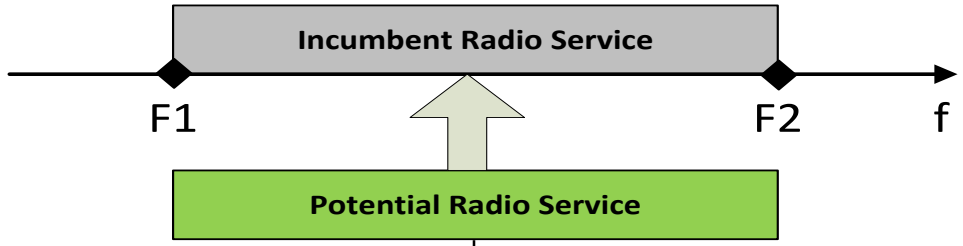
| WRC-07 candidate bands | WRC-07 identified bands | WRC-15 Candidate bands | WRC-15 Identified bands |
|---|---|---|---|
| 410 – 430 MHz | 450 – 470 MHz | 470 – 698 MHz | 694 – 790 MHz |
| 450 – 470 MHz | 698 - 806 MHz | 1350 – 1400 MHz | 1427 – 1518 MHz |
| 470 – 862 MHz | 790 – 862 MHz | 1427 – 1452 MHz | 3300 – 3700 MHz |
| 2300 – 2400 MHz | 2300 – 2400 MHz | 1452 – 1492 MHz | 4800 – 4990 MHz |
| 2700 – 2900 MHz | 3400 – 3600 MHz | 1492 – 1518 MHz | |
| 3400 – 3600 MHz | | 1518 – 1525 MHz | |
| 3600 – 3800 MHz | | 1695 – 1710 MHz | |
| 3800 – 4200 MHz | | 2700 – 2900 MHz | |
| 4400 – 4990 MHz | | 3300 – 3400 MHz | |
| | | 3600 – 3700 MHz | |
| | | 3700 – 3800 MHz | |
| | | 3800 – 4200 MHz | |
| | | 4400 – 4500 MHz | |
| | | 4500 – 4800MHz | |
| | | 4800 – 4990 MHz | |
| | | 5350 – 5470 MHz | |
| | | 5725 – 5850 MHz | |
| | | 5925 – 6425 MHz | |

ITU is in the pervasive rush of seeking for new allocations for emerging radio technologies.

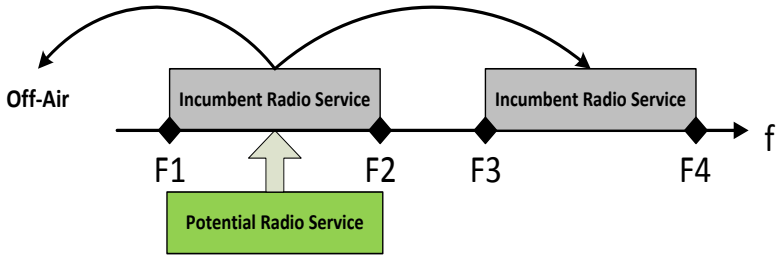
Effectively each WRC adopts a host of new spectrum bands for developing and emerging advanced radio technologies.

# Methods to Achieve Spectrum Turnover

## Target Setting

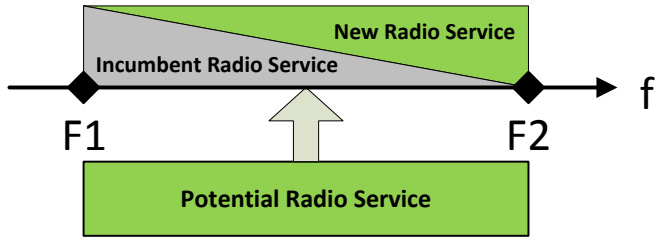



### Spectrum Redeployment



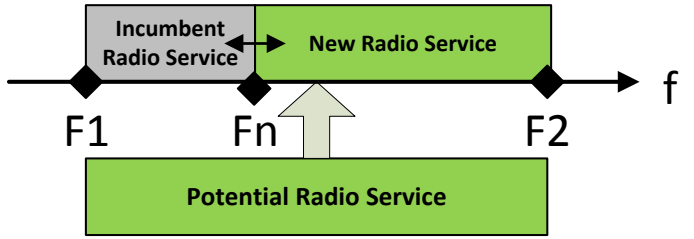

- Determination of alternative band for incumbent service.
- Determination of alternative off-air technology.
- Compensation for redeployment.
- Re-allocation fund.

### Spectrum Sharing




- Is sharing technically feasible?
- What are the technical constraints of sharing both for incumbent and potential radio services?
- For how long both services are able to coexist in the same band?

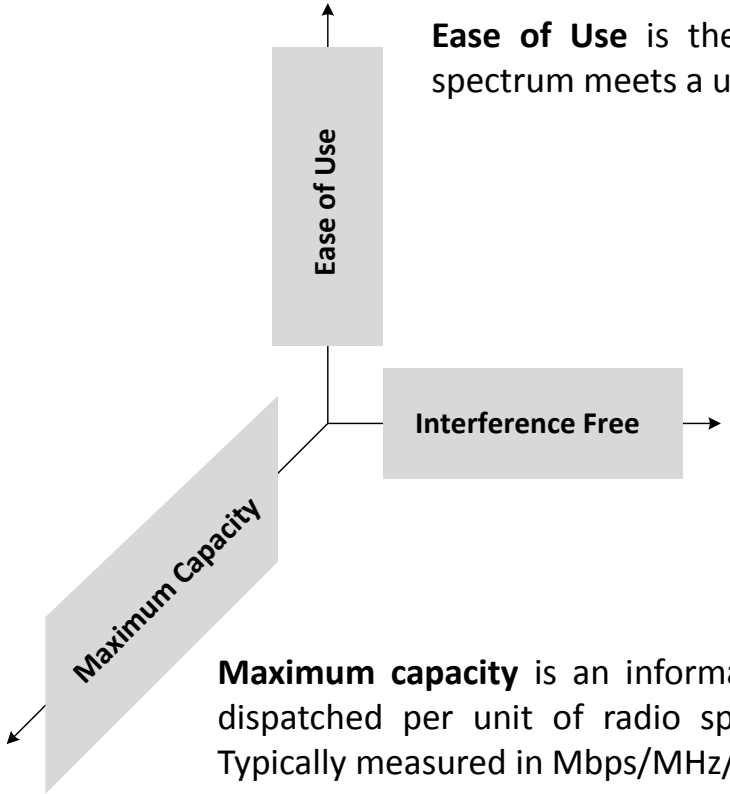
### Spectrum Band Subdivision




- Assessment of spectrum efficiency of the incumbent service.
- Inventory and optimization of frequency plan for incumbent service.
- Assessment of total spectrum value for both incumbent and potential services.
- Finding optimal proportion of sub-bands.

# Two Components of Spectrum Efficiency

## Technical Efficiency of Spectrum

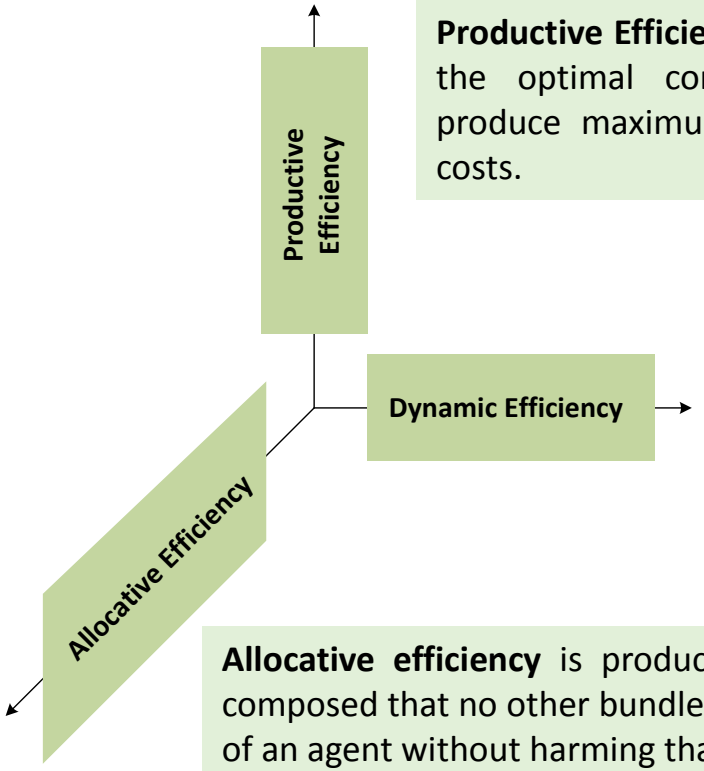



**Ease of Use** is the extent to which the use of spectrum meets a user's specific needs.

**Interference free** is an avoidance of critical degradation of quality of operation due to mutual influence of different emissions.

**Maximum capacity** is an information throughput that can be dispatched per unit of radio spectrum per unit of location. Typically measured in Mbps/MHz/ $km^2$

## Economic Efficiency of Spectrum




**Productive Efficiency** is supply of services with the optimal combination of resources to produce maximum output for the minimum costs.

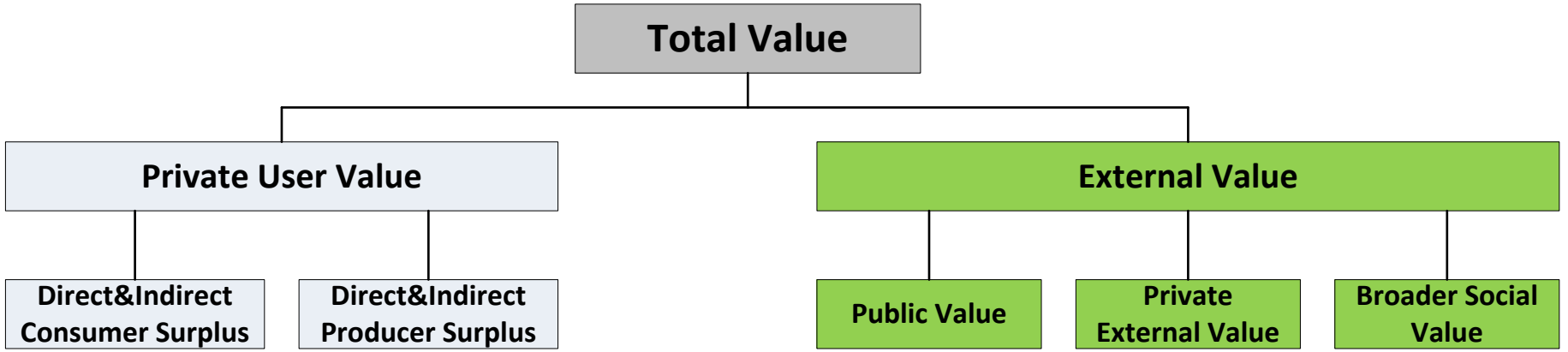
**Dynamic efficiency is** using the resource in a way enabling long-term productivity improvements through innovation and R&D.

**Allocative efficiency** is producing a bundle of services so composed that no other bundle could improve the well-being of an agent without harming that of another agent. Allocative efficiency relies on the Pareto criteria, that is, being able (or not) to improve the well-being of one economic agent without restricting that of another agent.

**Maximizing technical efficiency does not always maximizes total benefits from spectrum for the society**

# Pivotal Components of Total Value of Spectrum for Society

**The value of spectrum for society is defined by benefits for consumers, producers and citizens from spectrum-utilizing services**




**Private User Value** is the benefit to individuals from consumption of the services, less the costs of producing the services.

Private User Value is equal to the sum of consumer and producer surplus.

**Direct benefits** are benefits for service consumers and producers generated from the direct consumption and provision of radio services.

**Indirect benefits** are generated due to unintended effects of direct service on other product markets thus resulting in further indirect increase of producers and customers surplus.

**External value** is the additional benefits to society not reflected in the value of the service to consumers/producers.

**Public value** is the benefit that society derives from consuming public goods based on “non-excludability” and “non-rivalry” (such as defense).

**Private External Value** is the net private value to individuals that do not use services but are affected by positive or negative externalities.

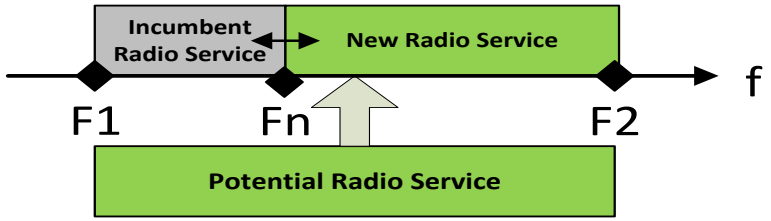
**Broader Social Value** is the benefit for citizens from the contribution of spectrum to social goods incl. social capital, political freedoms, national culture, equality etc. irrespective of incomes.

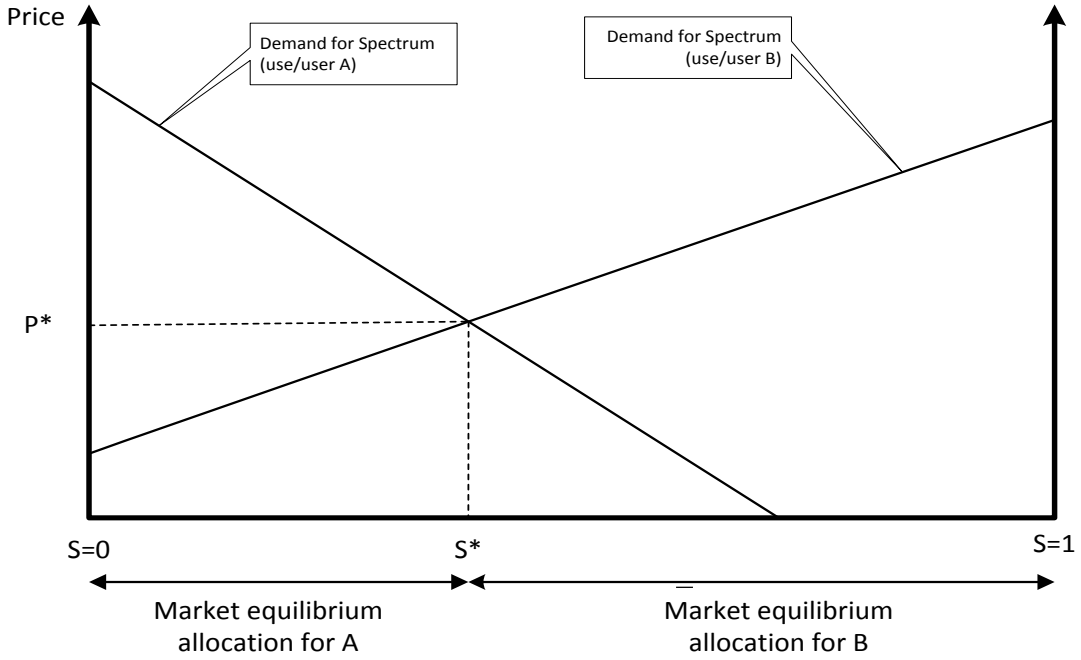
**Can be validly expressed in the monetary terms**

**Non-market valuation methods can be applied**

# Market View on Efficient Allocation of Limited Resources

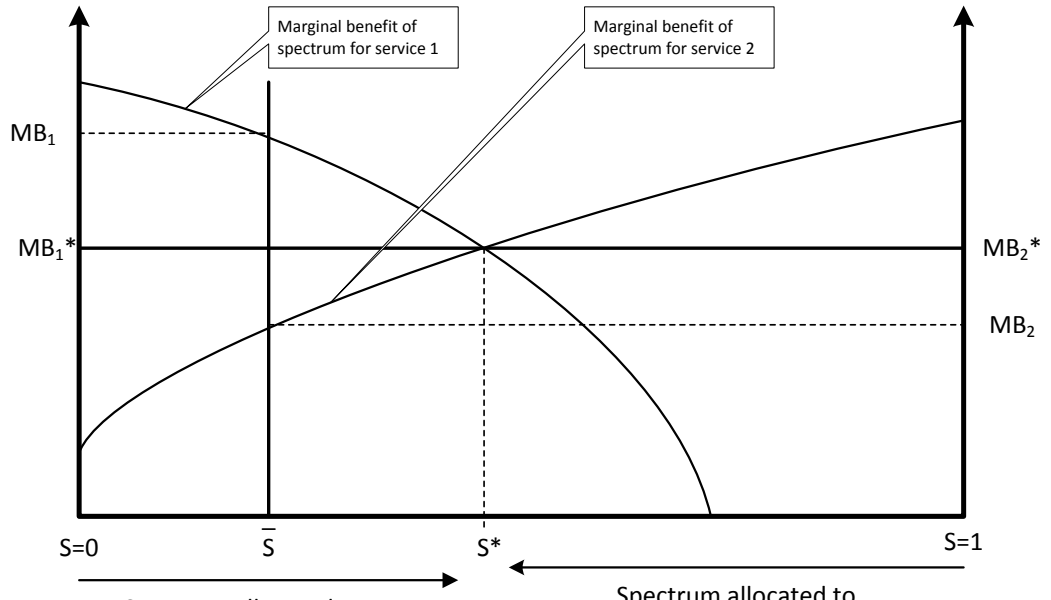
## Subdivision with Spectrum Trading (Demand)




Source: Martin Cave, Spectrum Management, Cambridge University Press, 2015

## Subdivision with Spectrum Trading (Marginal Benefit)




MB – marginal benefit of service

MB* – marginal benefit at point of efficiency

$\bar{S}$ - inefficient spectrum allocations

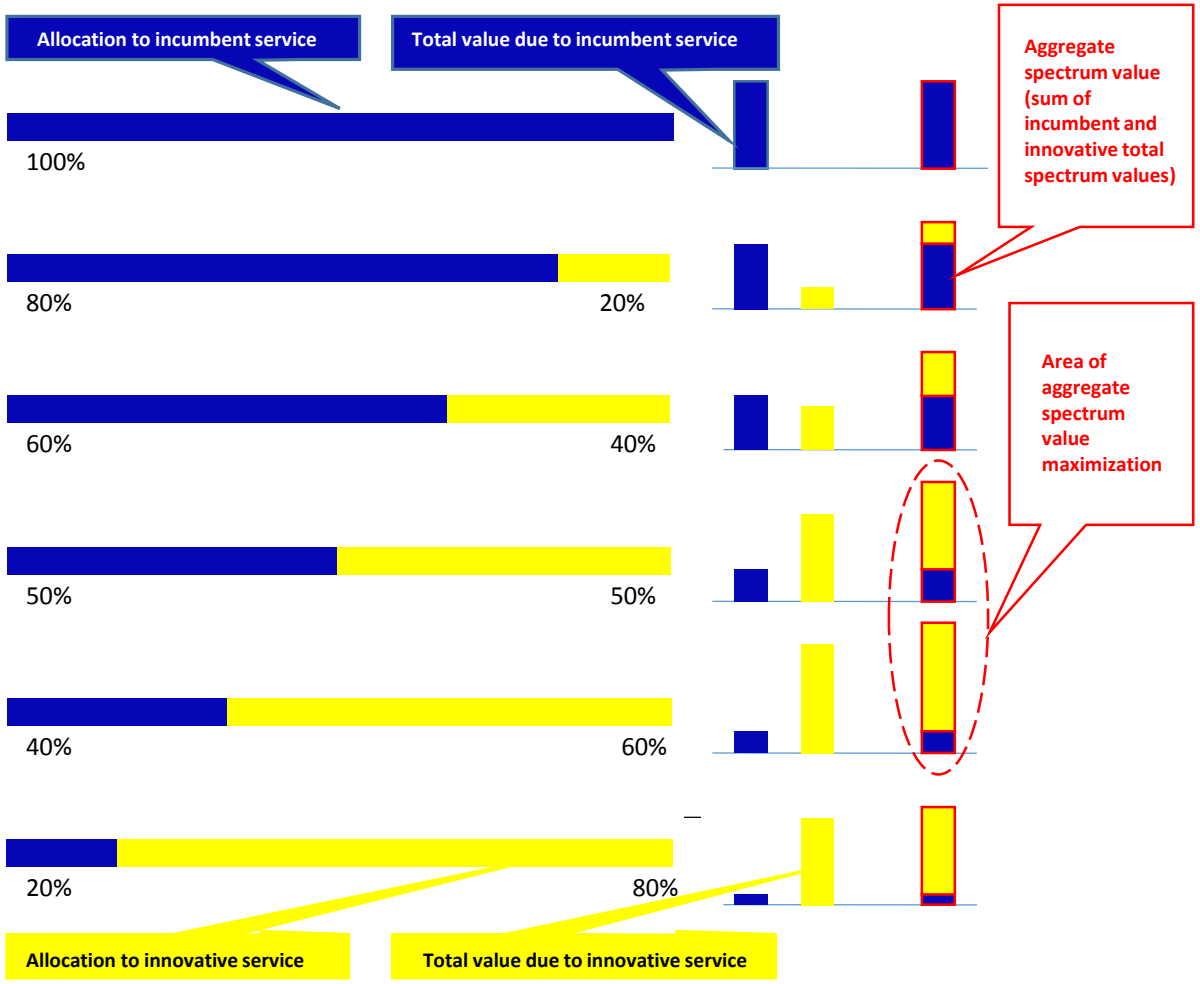
S* - efficient spectrum allocations

Source: Martin Cave, Spectrum Management, Cambridge University Press, 2015

**The core challenge is to determine optimal ratio of spectrum resources allocated to incumbents and newcomers in the way to maximize the total spectrum value for society. Market methods are highly eligible.**

# How to Obtain Efficient Band Subdivision

## How it works in practice…




## How is it estimated…

**Dynamic programming** (*dynamic optimization*) is a method for solving a complex problem by breaking it down into a collection of simpler sub-problems, solving each of those sub-problems just once, and storing their solutions. Algorithm examines the previously solved sub-problems and combines their solutions to give the best solution for the given problem for the next steps.

The task is to maximize target function ***Y(t)*** – economic benefit

$$Y(t) = max \sum_{k=0}^{n} y_k(x_k, t)$$

where

***n*** – number of radio services in the given spectrum band;

$y_k$ – economic benefit from using k-radio service within the bandwidth $x_k$;

$x_k$ – spectrum bandwidth allocated for k-radio service;

***t*** – time, bandwidth allocated to services is variable in time.

**The most efficient subdivision is achieved with the maximization of aggregate total value of spectrum subbands (economic benefit) for the society.**

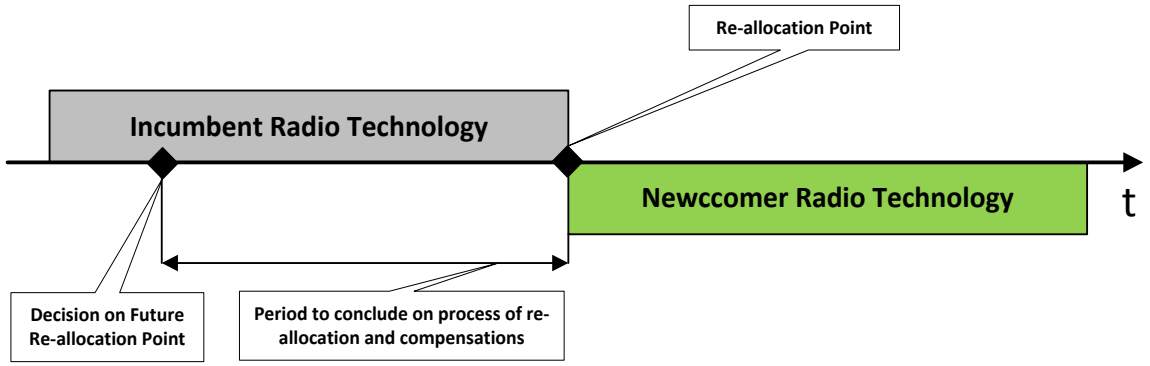
# Best Practices with Spectrum Re-Allocation

# Types of Re-allocation and Timelines

## Re-allocation Types

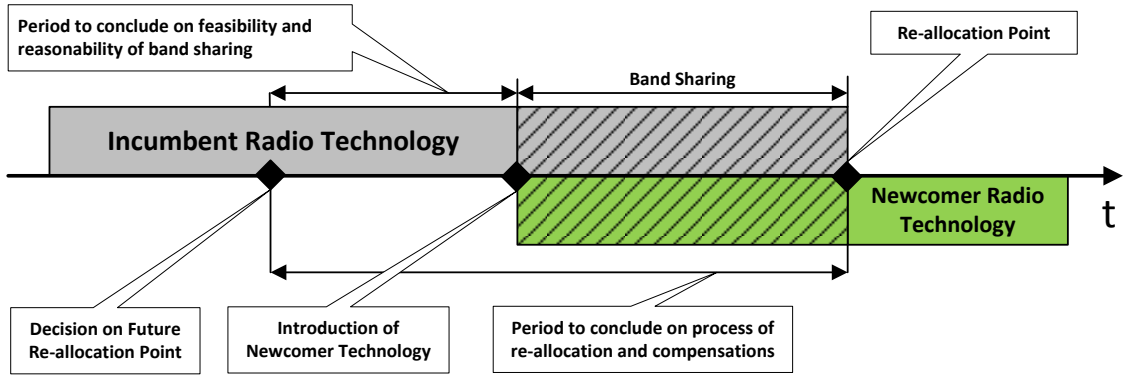
| Between Private Users | Between Public and Private Users | Between Public Users |
|---|---|---|
| Market methods are preferred to decide on optimal and efficient allocations of limited resources among users at competitive markets based on:<br>▪ Spectrum trading<br>▪ Spectrum pricing<br>In a loose sense – Coase theorem and Pareto criterion.<br>Incentive auction – innovative tool to facilitate spectrum turnover. | Economic methods should be applied to deal with compensations. Regulator estimates the cost of spectrum re-allocation.<br>Re-allocation costs could be agreed as the reserve price for an auction. | Typically command-and-control methods.<br>More arguable with introduction of market methods into the area of spectrum allocations in public sector. |

### Option 1. Re-allocation timeline, no sharing.




It is an incredible fortune for a regulator to intuit the correct point of time for re-allocation. The raft of activities should be arranged in between the decision on and practical start of re-allocation.

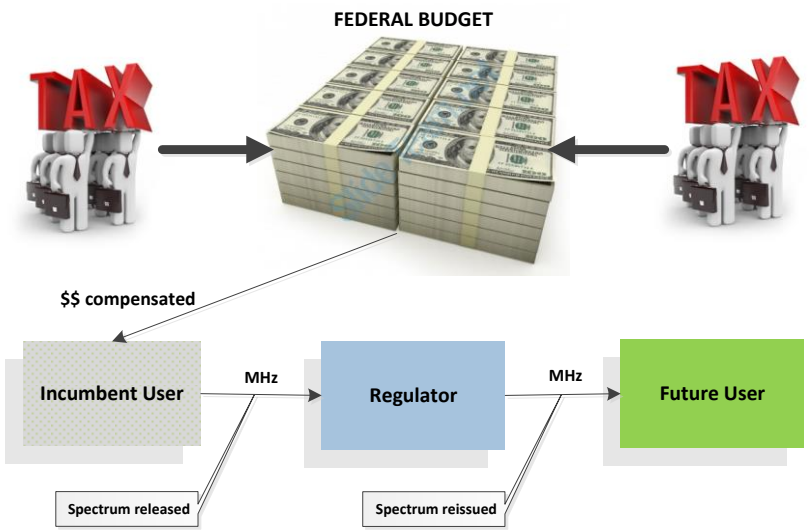
### Option 2. Re-allocation timeline, spectrum sharing.




At large extent band sharing assists in fastest possible introduction of newcomer technologies. But it complicates the spectrum management and should not become an endless process.

# Landmarks in Re-allocation Financing

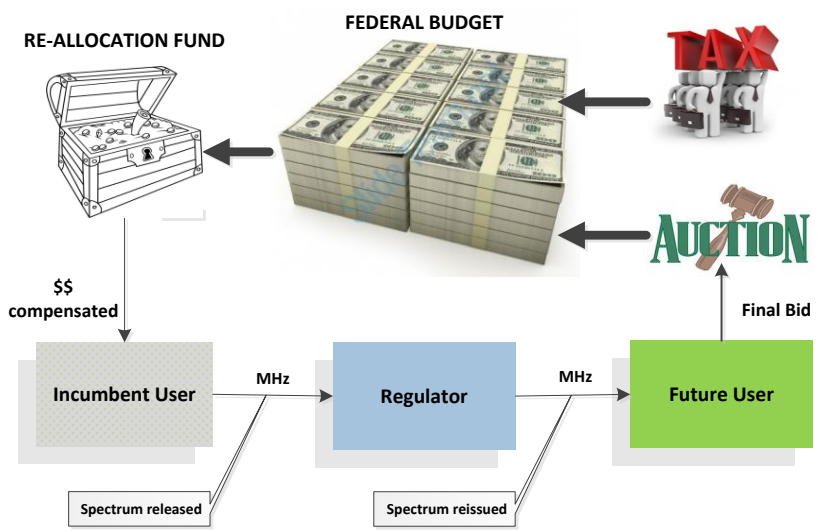
## Re-allocation Through Federal Budget




**Pros**: Typically the compensation funded by federal budget is connoted with a sort of governmental guarantees.

**Cons**: Non-spectrum users – ordinary taxpayers – are subsidizing spectrum related initiatives.

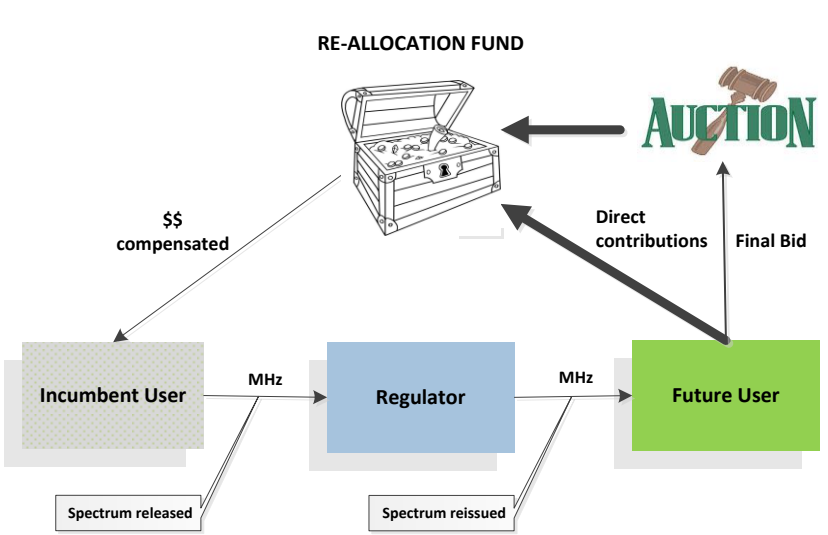
## Re-allocation Fund Through Budget




**Pros**: In essence is similar to bank saving account. Can be financed through spectrum pricing at the primary stage of spectrum issuing (auctions).

**Cons**: Still might utilize subsidizing from non-spectrum users.

## Directly Through Re-allocation Fund

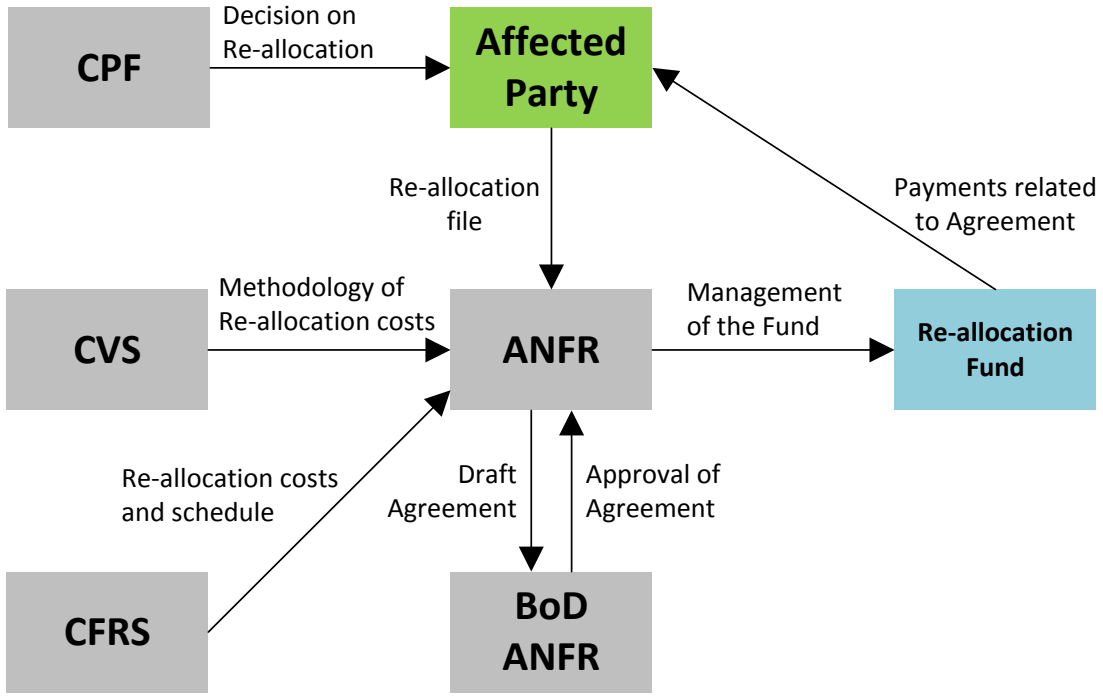



**Pros**: Re-allocation costs are covered directly by those interested in new allocations. Financial sources from auctions and spectrum fees.

**Cons**: Requires comprehensive mechanism of Fund's administration.

# Spectrum Re-allocation Fund in France

## Re-allocation Fund Management




**CPF** - Commission pour la planification des fréquences
**ANFR** - Agence nationale des fréquences
**CFRS** - Commission du fonds de réaménagement du spectre

**CVS** - Commission de valorisation du spectre
**BoD** - Board of Directors

## Practical Results

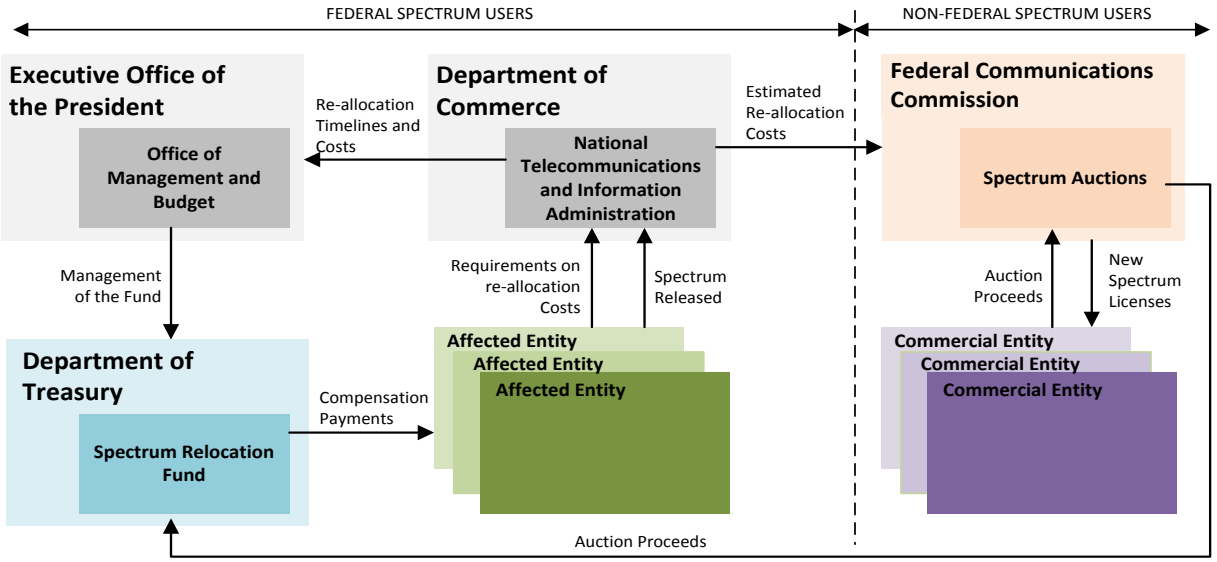
| Systems | Spectrum Amount | Transferred from |
|---|---|---|
| GSM900 | 50 MHz | Defense |
| GSM1800 | 150 MHz | Defense |
| UMTS2100 | 140 MHz | Defense (partly) |
| WiFi2400 | 83 MHz | Defense |
| WiFi5 GHz | 450 MHz | Defense, Meteo, Space |
| LTE2600 | 190 MHz | Defense |
| LTE800 | 40 MHz | Defense, Broadcasting |

The Fund is established by Law and managed by ANFR. The money is used for required changes, bills are provided to ANFR. Every six months the newcomer refunds ANFR based on the amount of spectrum owned or on actual amount spend. If the newcomer is not known (auction has not taken place yet) ANFR takes expenditures from the ANFR accumulated funds.

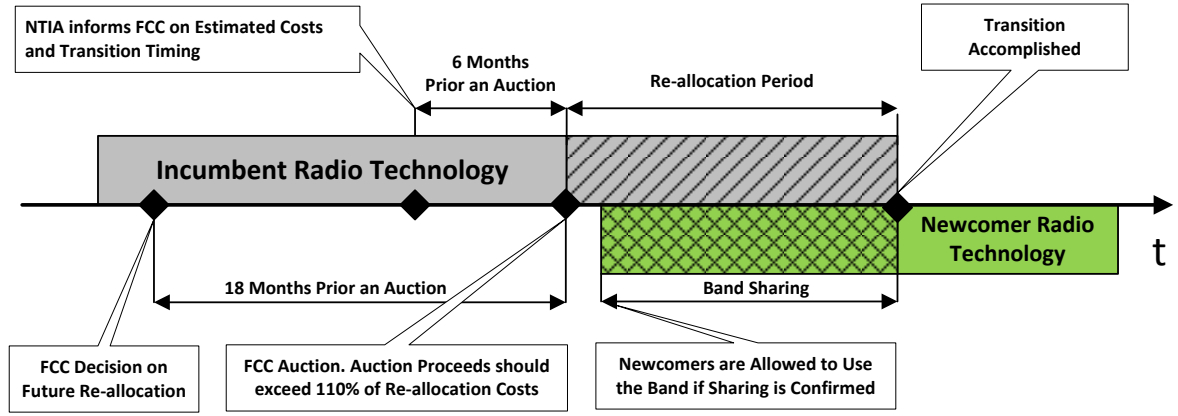
A “convention” or contract is agreed between the three parties involved (existing user, new user and ANFR). This document sets out the modality for the move, financial implications and how ANFR will monitor and control this process.

# Spectrum Re-allocation Fund in the USA

## Re-allocation Fund Management




## Practical Results




## Primary Legislation on Re-allocation

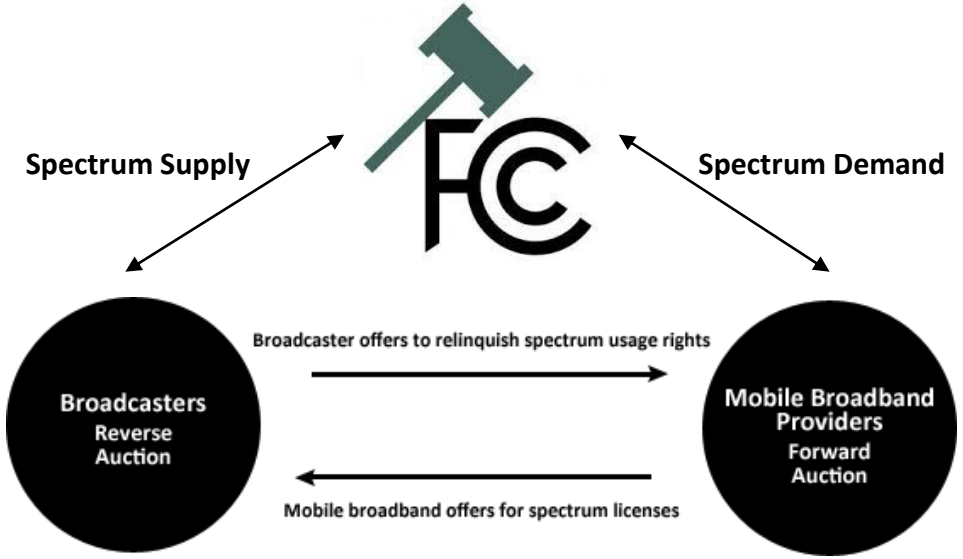
| | |
|---|---|
| Omnibus Budget Reconciliation Act, 1993 | Identification of bands which meet certain criteria of re-allocation. Initial provisions on the process. |
| Commercial Spectrum Enhancement Act, 2004 | Specifies provisions on the process of reallocation from governmental to commercial users. Establishes Spectrum Relocation Fund (SRF). |
| Middle Class Tax Relief and Job Creation Act, 2012 | Extends reimbursement to spectrum sharing scheme. Requires agencies to submit transition plans for interagency management review of costs and timelines |

1. FCC shall notify NTIA at least 18 months prior to the commencement of any auction of frequencies subject to re-allocation.
2. NTIA at least 6 months prior to an auction on behalf of the affected Federal entities and after review by the Office of Management and Budget, shall notify FCC of estimated relocation costs and timelines.
3. NTIA shall provide a Federal entity involved with information on alternative frequencies to which their radio operations could be relocated for purposes of calculating the estimated relocation costs and timelines.
4. FCC shall not conclude any auction of re-allocated frequencies if the total proceeds are less than **110 percent** of the total estimated relocation costs.
5. FCC may grant a new license for the use of frequencies under transition prior to the termination of Federal entity's authorization subject that the licensee cannot cause harmful interference to such Federal entity.

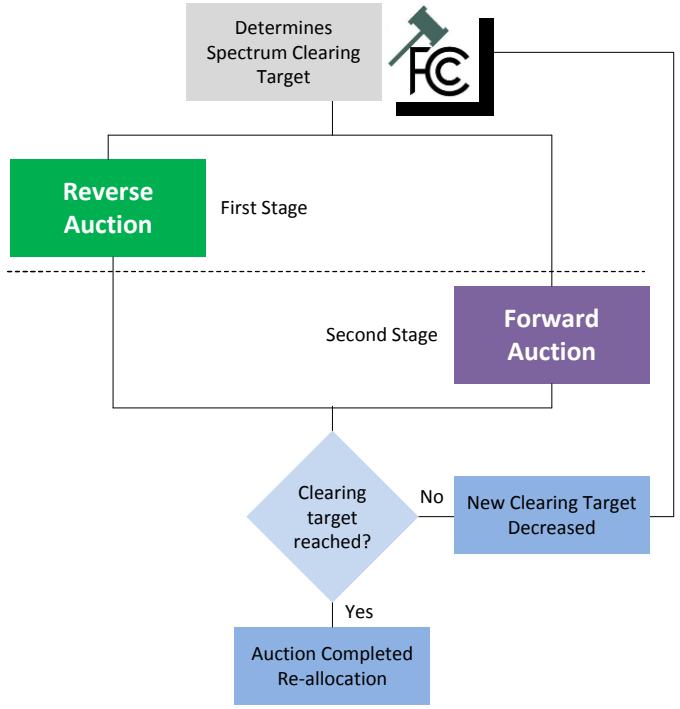
# Incentive Auctions – Ingenious Market-Based Re-allocation Instrument

## Concept of Incentive Auction

The FCC is serving as a matchmaker in 600 MHz incentive auction, going back and forth between broadcasters and bidders to settle on a price that strikes a balance between spectrum supply and demand




## Auction Algorithm and Costs Distribution




### Reverse auction

determines the price at which broadcasters will voluntarily relinquish their spectrum usage rights.

### Forward auction

determines the price companies are willing to pay for flexible use wireless licenses in former TV bands.

### Final Stage Cost Components

Auction proceeds are expended on three components:

1. Winning bidders' payments required for broadcasters
2. FCC's relevant administrative costs around $226 million
3. $1,75 billion – relocation costs for broadcasters

**Incentive auction leaves market to decide on bandwidth to be released and prices to be paid for spectrum turnover**

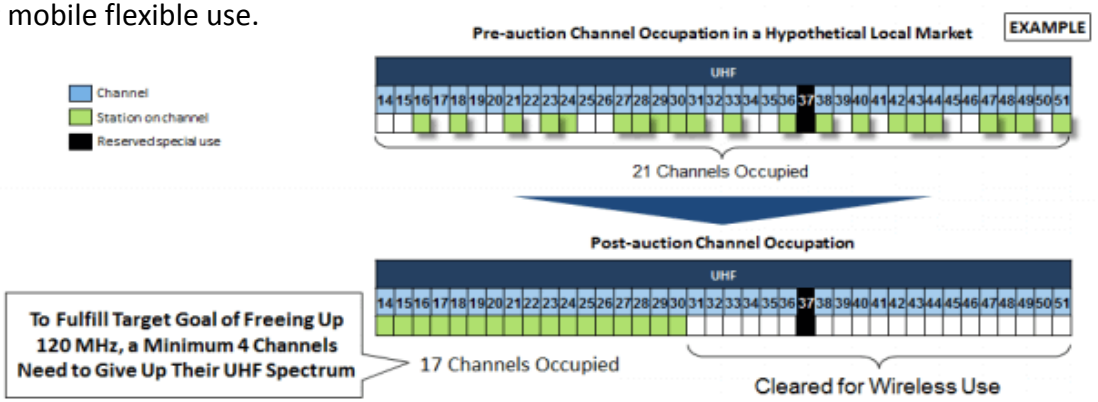
# How Incentive Auction Works

## Options for Band Plans and Preliminary Results


Source: FCC

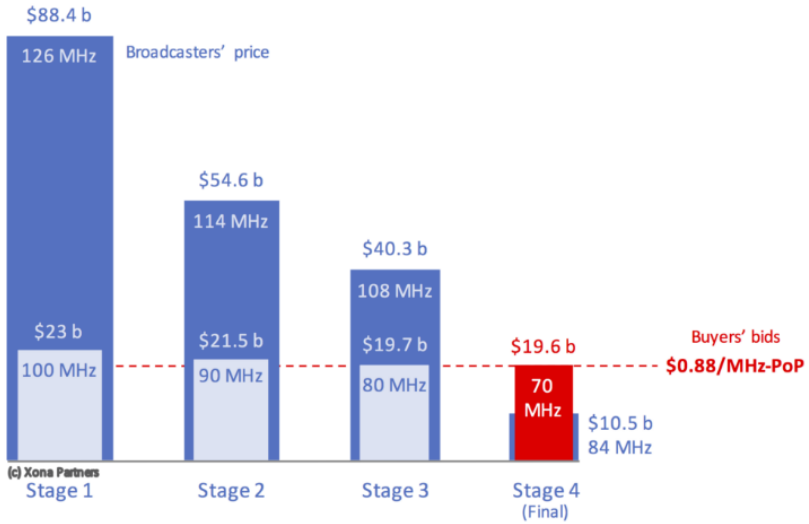
## Broadcasting Repacking as the Premise

The lynchpin joining the reverse and the forward auctions is the "repacking" process. Repacking involves reorganizing and assigning channels to the remaining broadcast television stations in order to create contiguous blocks of cleared spectrum suitable for mobile flexible use.




Source: FCC

Wireless service providers will pay $19.63 billion for 70 MHz of spectrum, or an average of $0.88/MHz-PoP. The average price for the top 40 PEAs (Partial Economic Area) is $1.25/MHz PoP that is required to close the bidding. Broadcasters will receive $10.05 billion. The US treasury will receive about 7 billion while $2 billion is for auction expenses.




Source: FCC

# Non-Technocratic View on Spectrum Re-allocation. Conclusion.

**With the experience gained in the last several years it is quite obvious that the technocratic approach with spectrum re-allocation is no longer all-encompassing.**

- In conducting strategic policy regulator should be emphasized with its duties to guarantee further interests of society including consumers, social and public needs, service providers, industry and to secure the optimal use of spectrum.

- The main incentive of administrations is to re-allocate spectrum in a way that maximizes the total value to society from its future use.

- The social-economic aspects of spectrum re-allocation are based on the fundamental concept of social welfare of spectrum resources usage. It is agreed that spectrum is used with the highest efficiency under the condition that the total amount of value for society created by its usage is maximized.

- The key objective is to guarantee the balance between retaining enough spectrum to provide the services of the incumbent users and releasing as much as possible for potential users while maximizing total spectrum value from the optimal reallocation of the whole band.

**Spectrum re-allocation is the potentiality to obtain additional benefits to society arising from the optimal distribution of spectrum to innovative services taking due account of incumbent uses.**


# Thank You