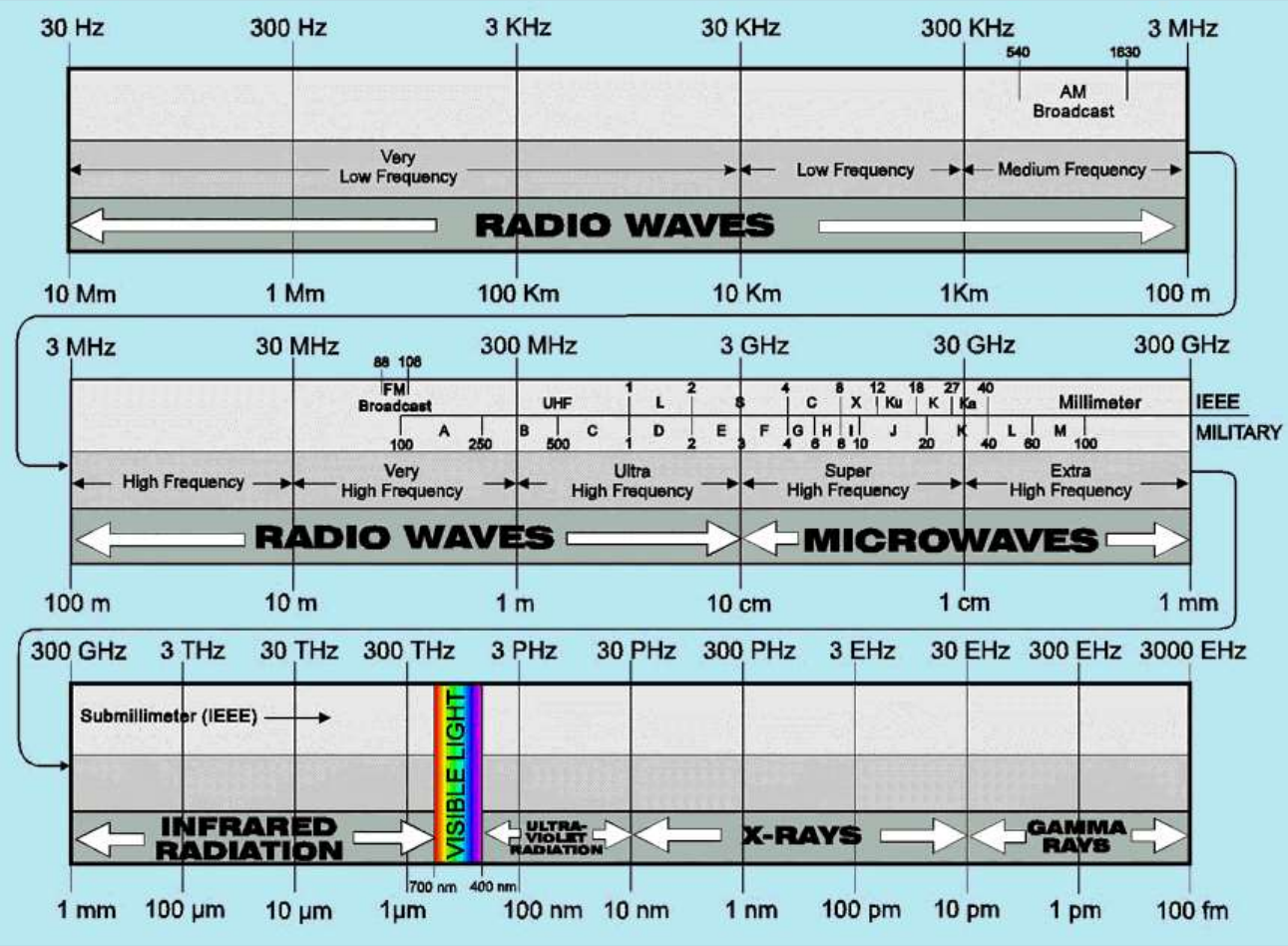
Economic of Spectrum as Resource

Workshop on
Economic Aspects of Spectrum Management

21 – 23 November 2016
Tehran, Iran

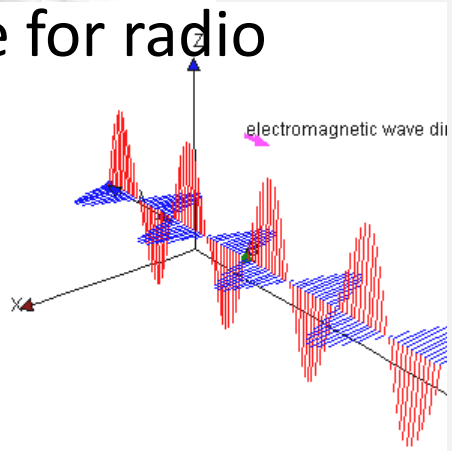
Dr. Azim Frad
DG of Radio Licensing and Planning
Communications Regulatory Authority (CRA), MICT

Electromagnetic Waves Spectrum

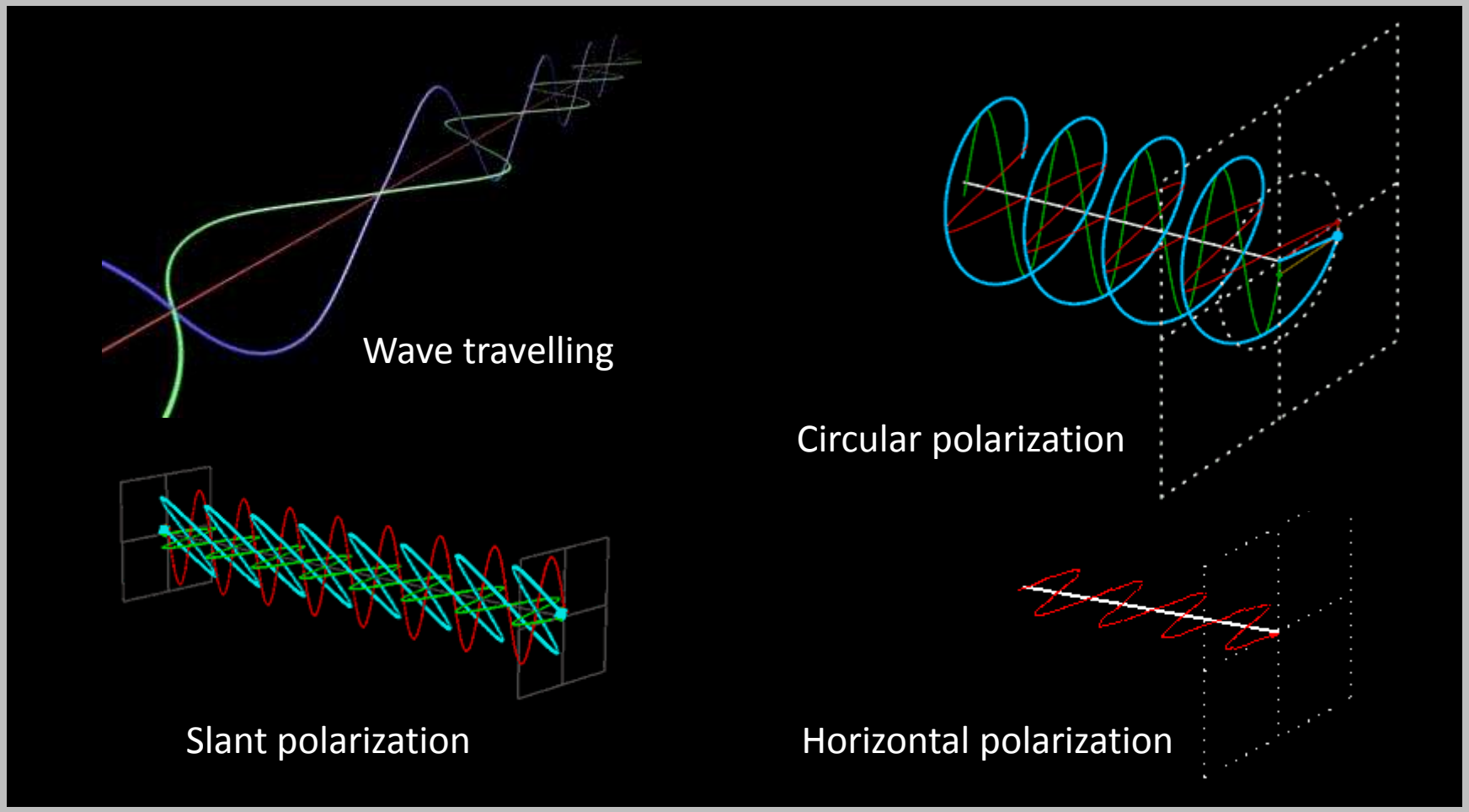


Spectrum is a Natural Resource

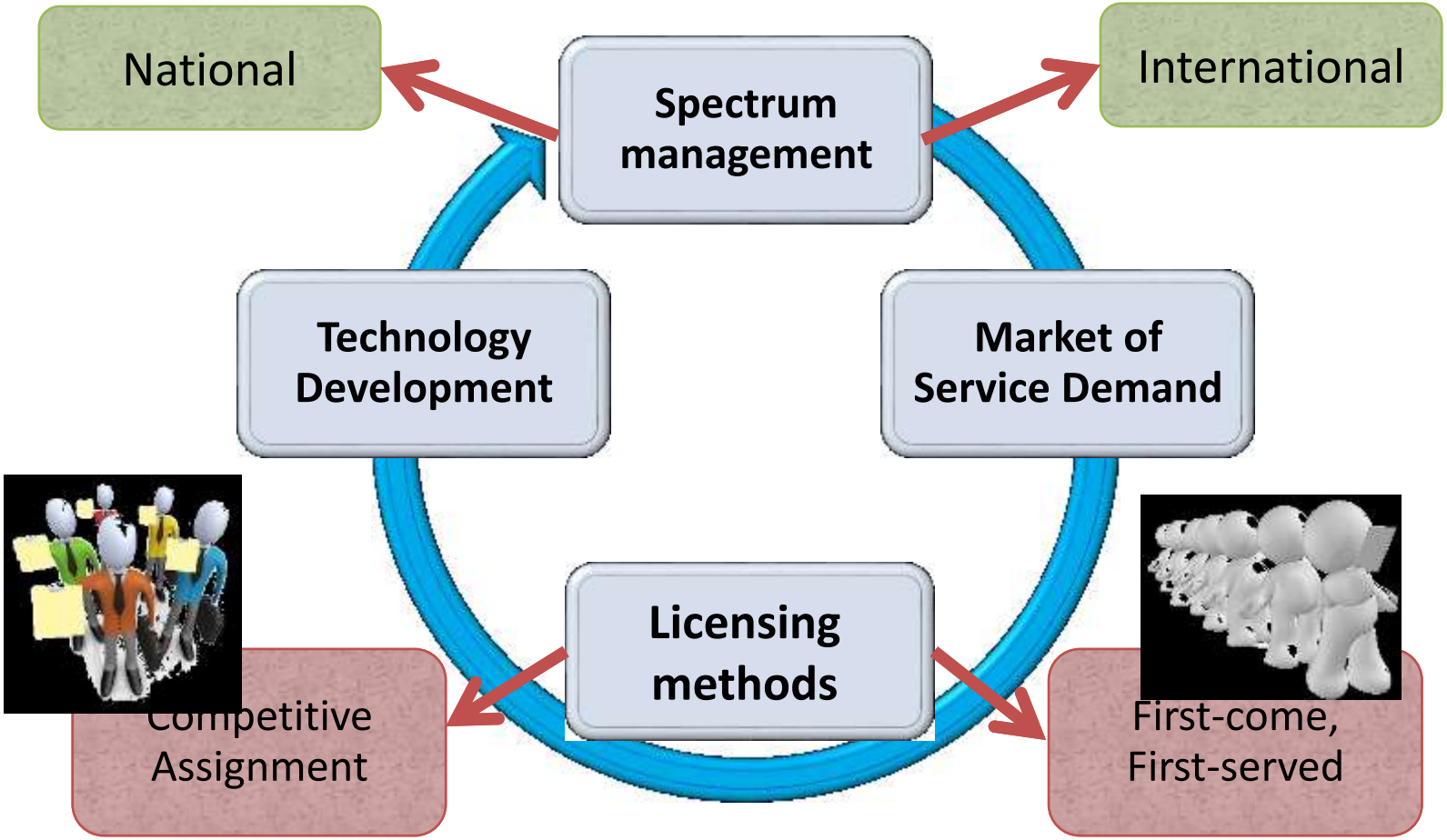
- Definition: Radio frequency (RF) spectrum is the continues range electromagnetic wave frequency
- Theoretically EM waves travels straight with the speed of light in free space once generated by source
- The **orthogonality** of EM waves having different frequencies and polarizations as well as reusing possibility in different directions and locations made RF spectrum as a valuable natural resource for radio communications
- Efficient use of spectrum needs **complex wireless technology** and coordinated professional management



Visualization of EM Waves



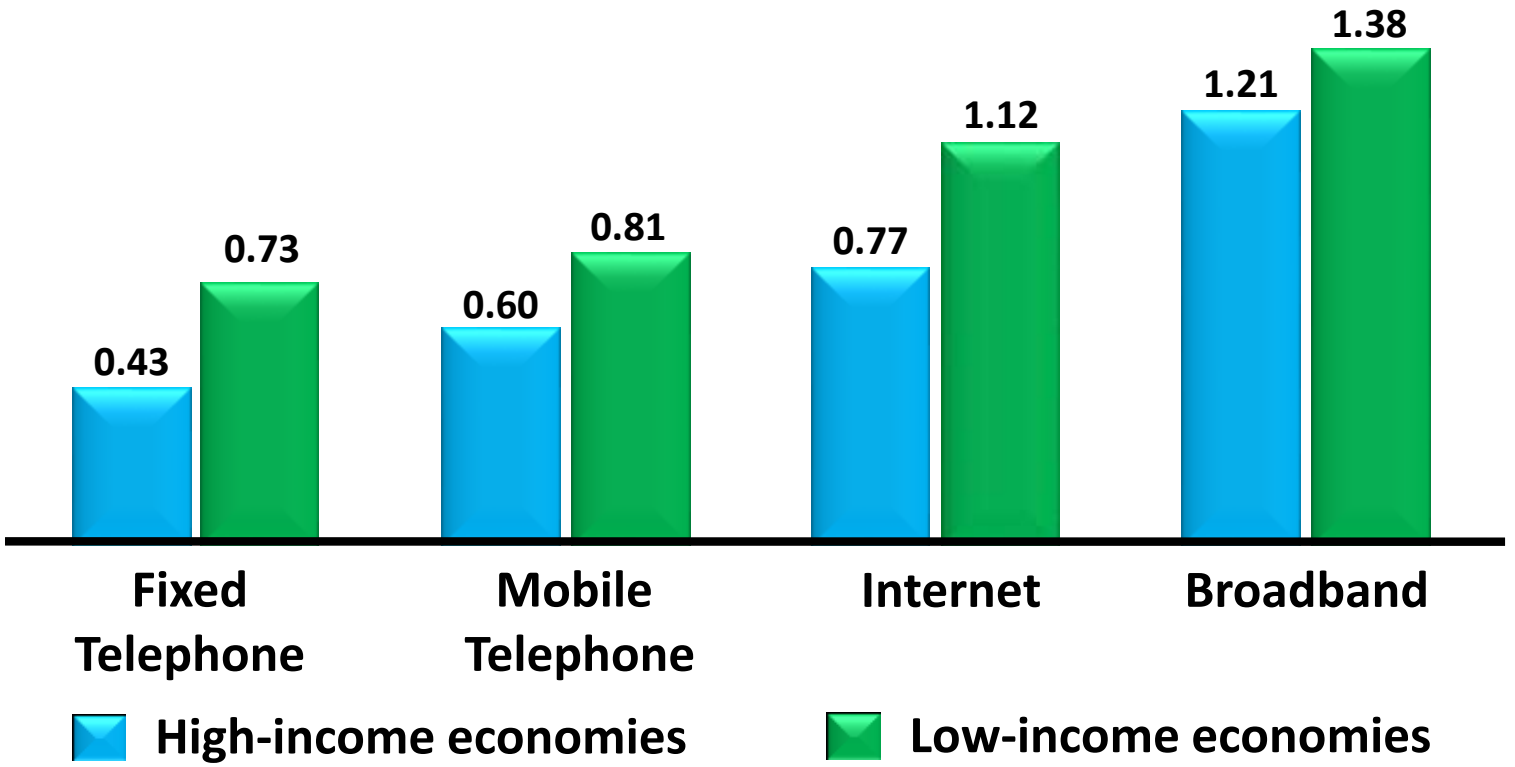
Elements
Underpinning Wireless Technologies



Radio Frequency Spectrum

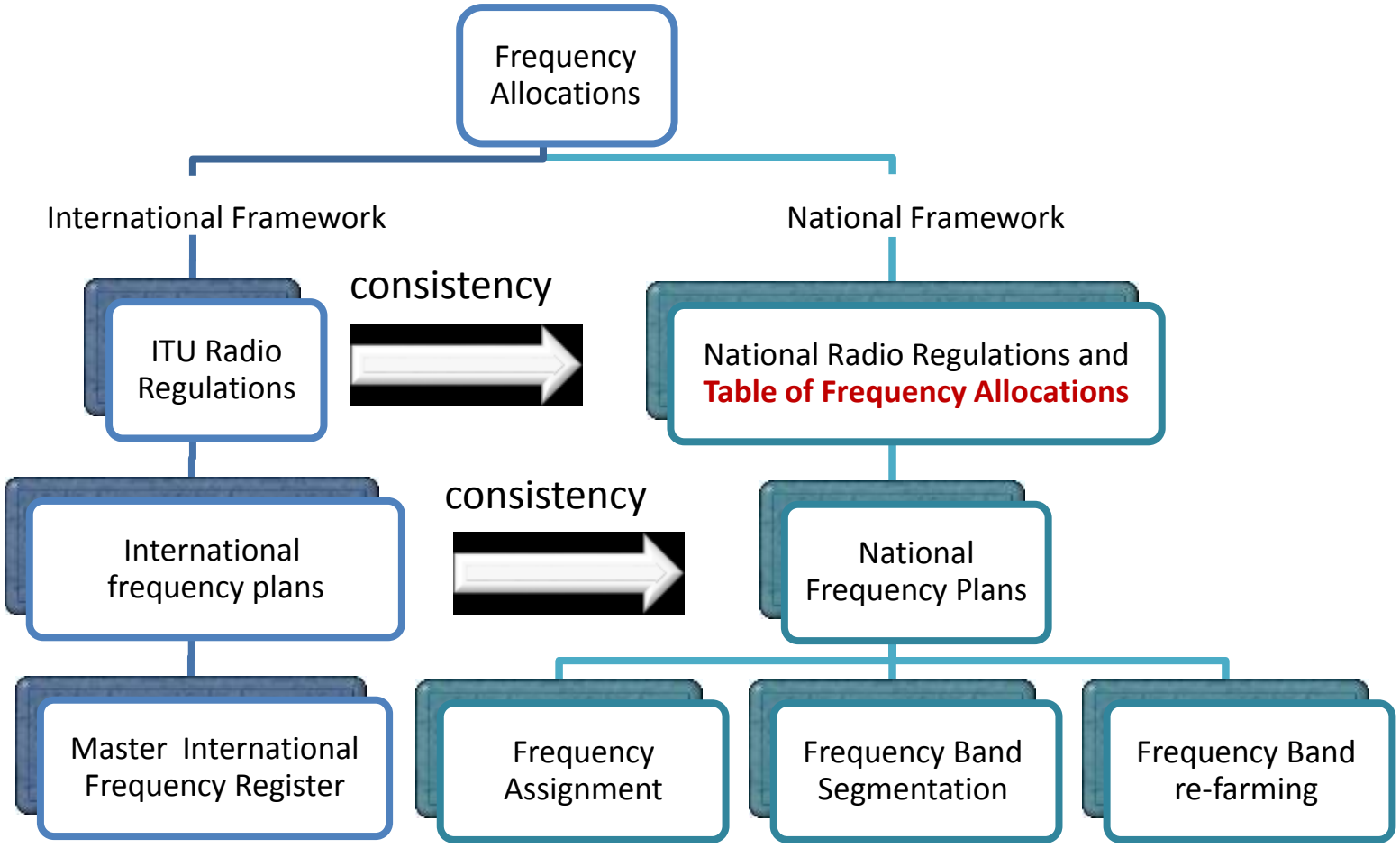
It has no actual value
if was not evacuated in-time and
was not planned properly

GDP Growth for 10% Penetration Increasing of Each of Following



Source: World band, Qiang 2008

Understanding Hierarchy of Frequency Allocations



History of International Frequency Allocations

- The 1906 Berlin conference produced the **International Radiotelegraph Convention** with an annex containing the **first regulations** in this field, in 15 pages.
- The 1927 Washington D.C. Radiotelegraph conference **allocated frequency bands** to the various radio services (fixed, maritime and aeronautical mobile, broadcasting, amateur, and experimental). This conference has also established the International Radio Consultative Committee **(CCIR)**

RÈGLEMENT DE SERVICE.

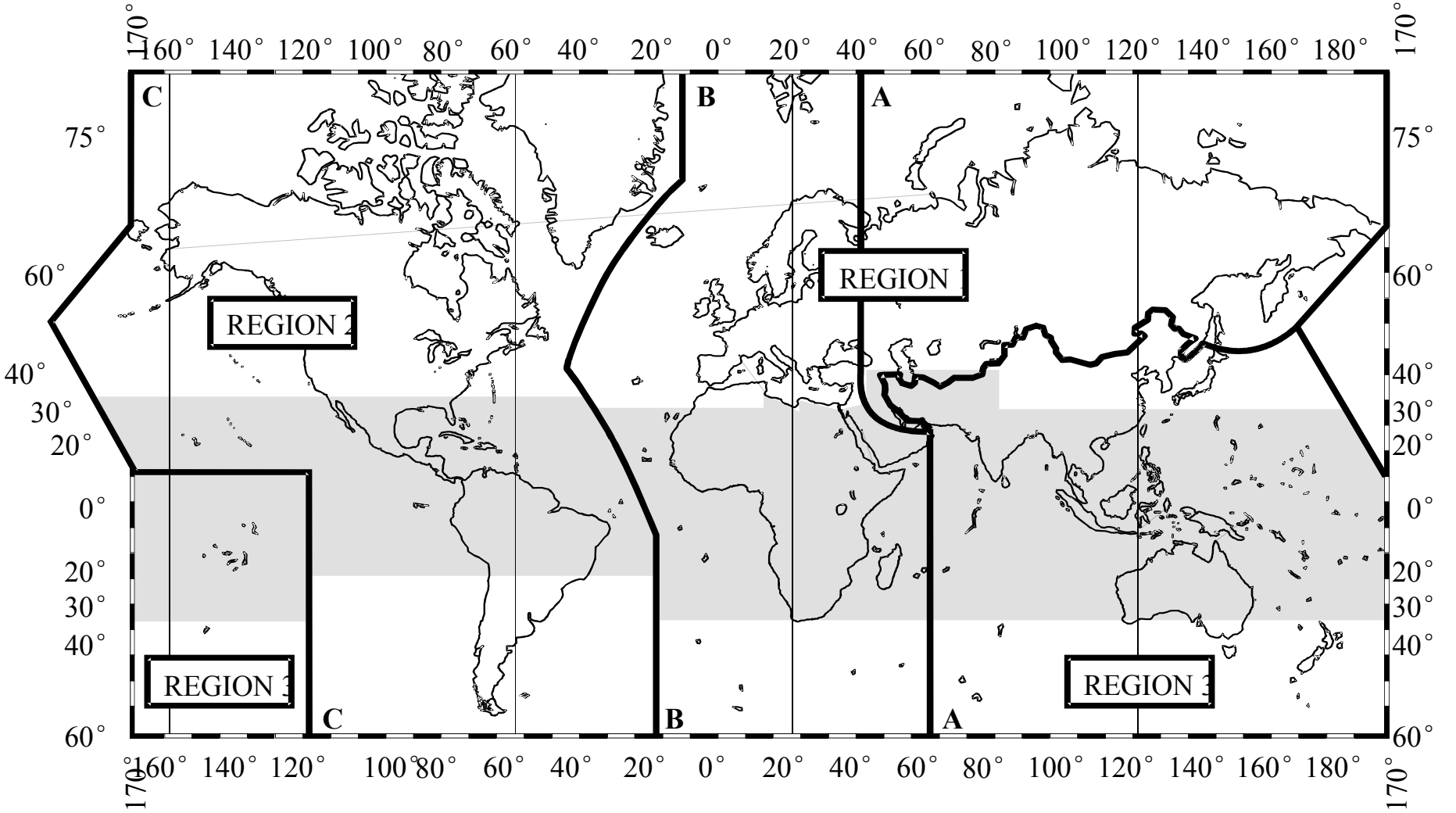
ANNEXE À LA

CONVENTION RADIOTÉLÉGRAPHIQUE INTERNATIONALE.

Table des Matières.

- In 1932 Madrid conference, the new name **ITU** adopted and then in 1947 the newly establishment UN, recognized ITU as the **specialized agency** for telecommunications
- In 1963, ITU held an Extraordinary Administrative Conference for space communications, which **allocated** frequencies to the various services.

ITU-R Frequency Allocation Regions



International Frequency Allocations, Today

- 2016 edition Radio Regulations Article 5 consists o four sections which in section IV provides table of frequency allocations in 152 pages, starting from 8.3 kHz to 275 GHz with more than 650 table footnotes

890-1 300 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
890-942 FIXED MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322 Radiolocation	**890-902** FIXED MOBILE except aeronautical mobile 5.317A Radiolocation 5.3185.325	**890-942** FIXED MOBILE 5.317A BROADCASTING Radiolocation
	902-928 FIXED Amateur Mobile except aeronautical mobile 5.325A Radiolocation 5.1505.3255.326	

Regions
Frequency band
Primary Services
Secondary Services
Frequency band Footnotes
Service Footnotes in Given Frequency band

Key Understandings in FAT

Shared Allocations	• Many frequency bands allocated to services in shared basis • Co-located use of spectrum by most services is impossible
Secondary Services	• Transceivers under secondary services need to have interference reduction and mitigation capability
Non-radio services applications	• ISM equipments and SRD Devices are using spectrum under almost no-services
Homogeneous allocations	• Frequency bands with non-homogeneous global or regional allocations is of less interest for commercial use

Convergence Influences in N-FAT

Convergence could indirectly manage frequency resource allocation to the interfering radio services

TERRESTRIAL

CURRENTLY CONVERGING

- Wireless Fixed and mobile broadband
- Broadcasting/multicasting/ unicasting gets possible through fixed and mobile networks

IN FUTURE

- Wireless backhaul and access parts
- Point-to-point and point-to-area
- Mobile and Radionavigation

SPACE

FSS, MSS and BSS are gradually converging

Terminals Convergence

Implication of ICT Convergence on Spectrum Allocation

Full services coverage will soon be possible due to:

- Pervasive network technologies of digitalization
- Internet protocols
- Availability of traditional fixed services while in motion and vice versa

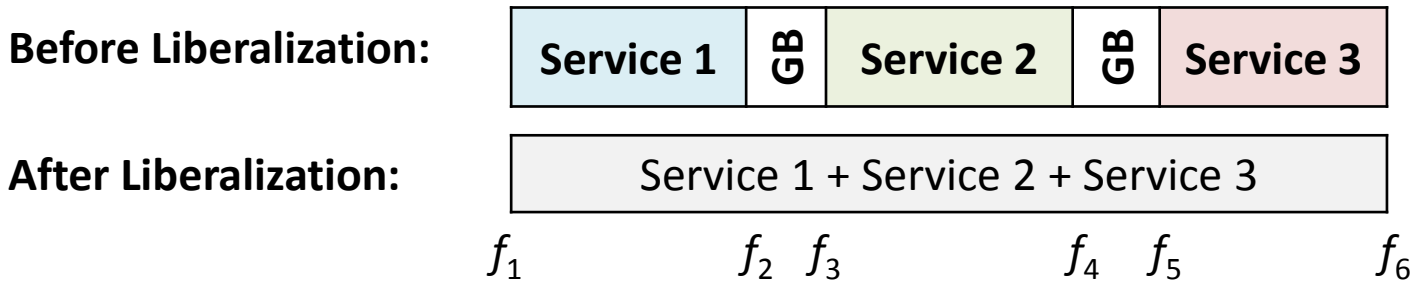
Convergence of fixed, mobile and television are already introduced in market

fore on real world,
inction between
hnologies and services in
llocation and assignment of
frequencies will no longer
appropriate

Do not remove currently
nd future converging
rvices from N-FAT.
nple (page 103 of RR Vol.1)

Advantages of Open Licensing for Converging Services

- Guard-bands between allocated frequency bands to converged services are no longer necessary

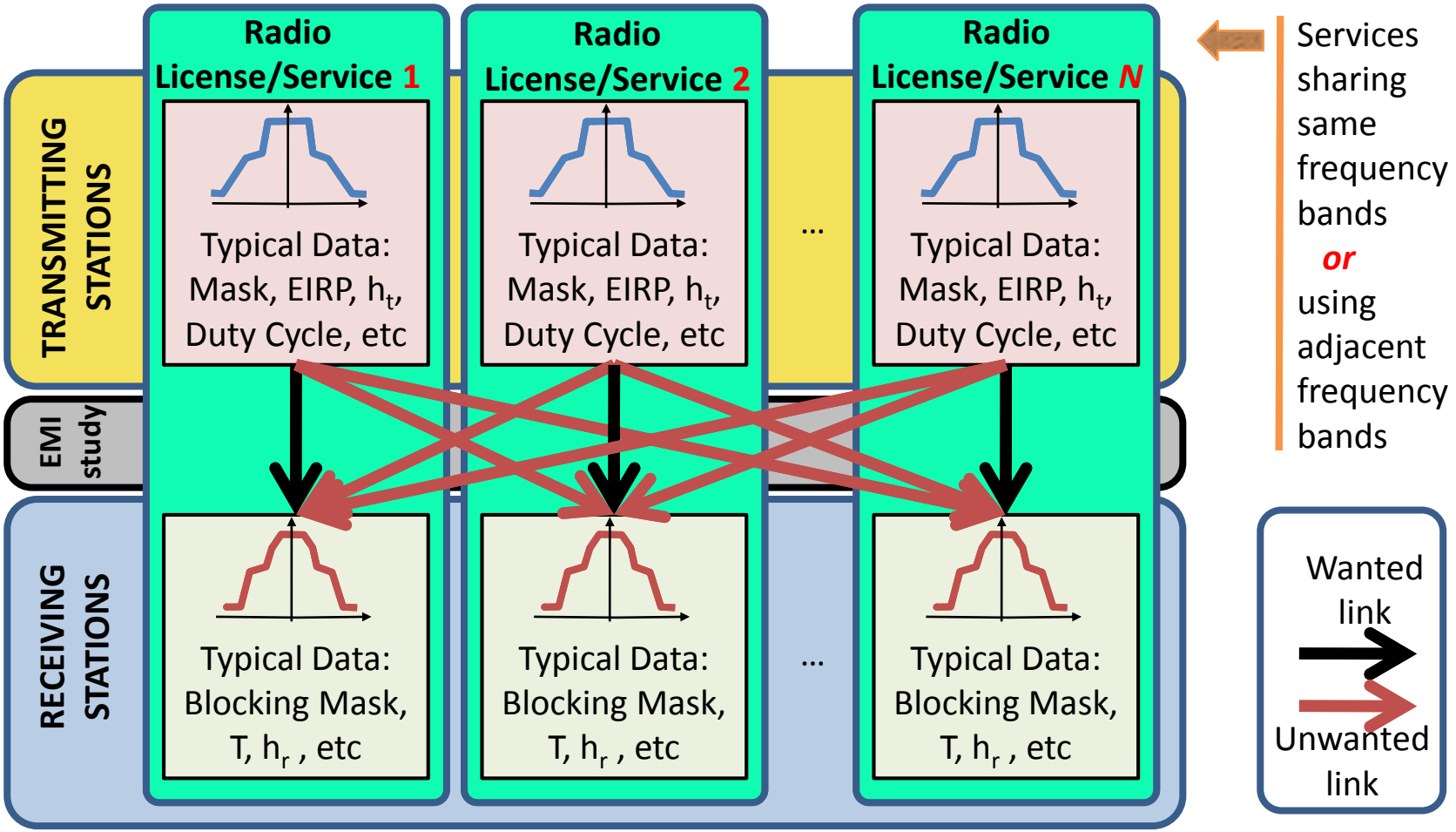


- Reduce time consuming administrative works to assess requests of **license usage** and **technology change**
- Brings greater competition into spectrum markets
- Speed up implementation of innovative services and increase spectrum benefits

Convergence Challenges

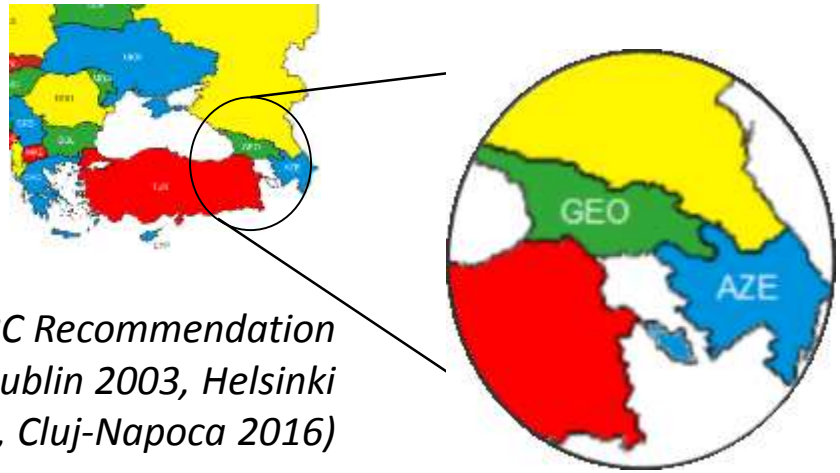
- Service-specific and technology-specific licenses (licenses need to be updated)
- Different license-fees for different services and technologies (need to be re-formulated)
- Content regulation cannot be exclusively linked to broadcasting only regulation (requires joint regulator)
- Convergence of market will lead convergence of wired and wireless regulations (joint operation of different licensees or extension of operators' license)

Use of Generic EMI Calculation to Support Frequency Allocations

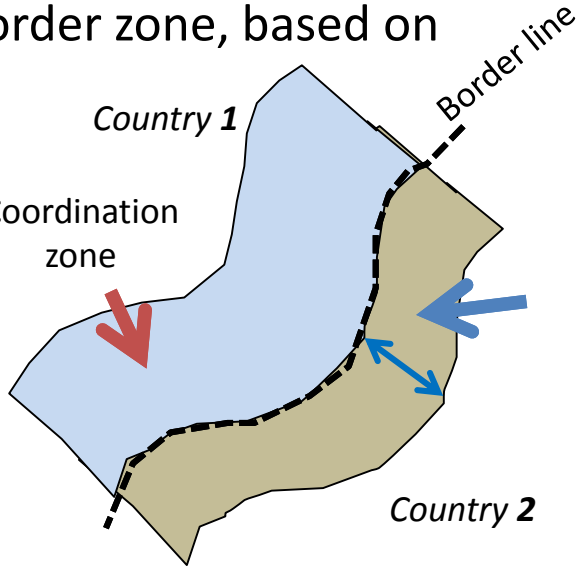


Exclusivity of Plan in Neighborhood to other Countries

- Frequency allocations of neighbor countries should have maximum consistency with each other
- Frequency band dividing among operators in border zone, based on equitable access, if no other means of diversity exist (suitable for land border and 2G bands)
- Code division if 3G and 4G are in use and similar channels used by different operators

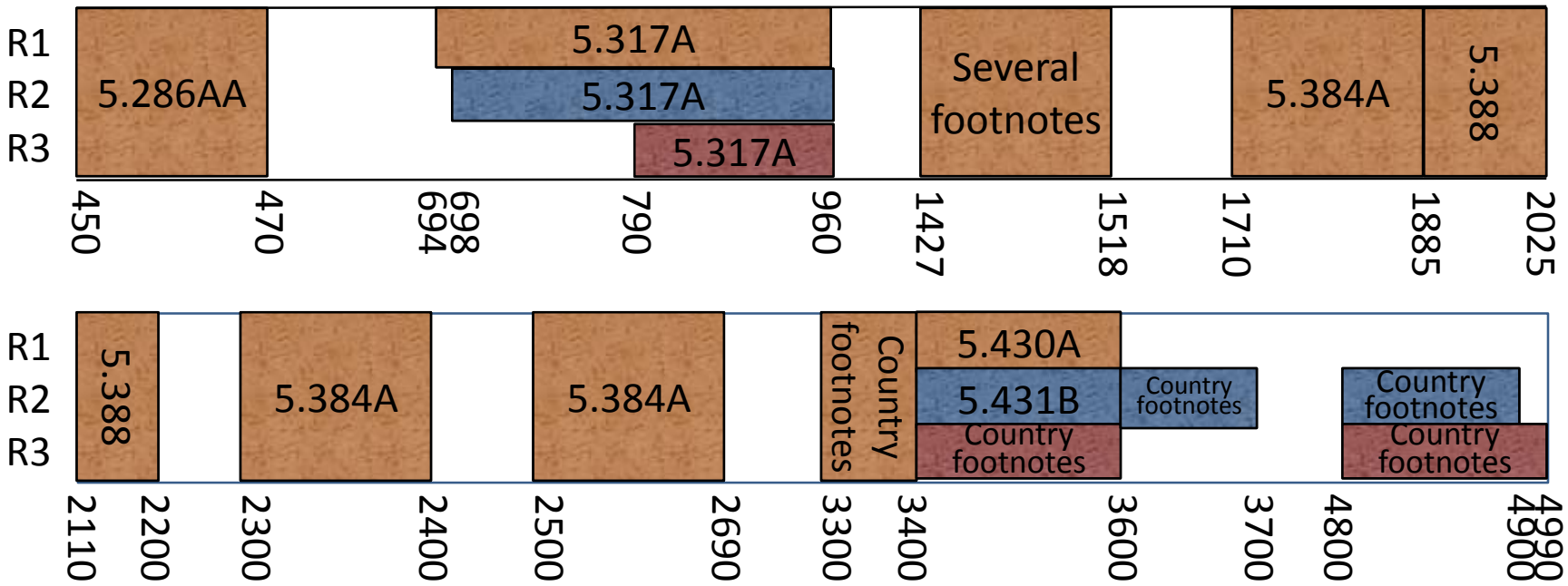


Reference: ERC Recommendation 01-01 (revised Dublin 2003, Helsinki 2007, Cluj-Napoca 2016)



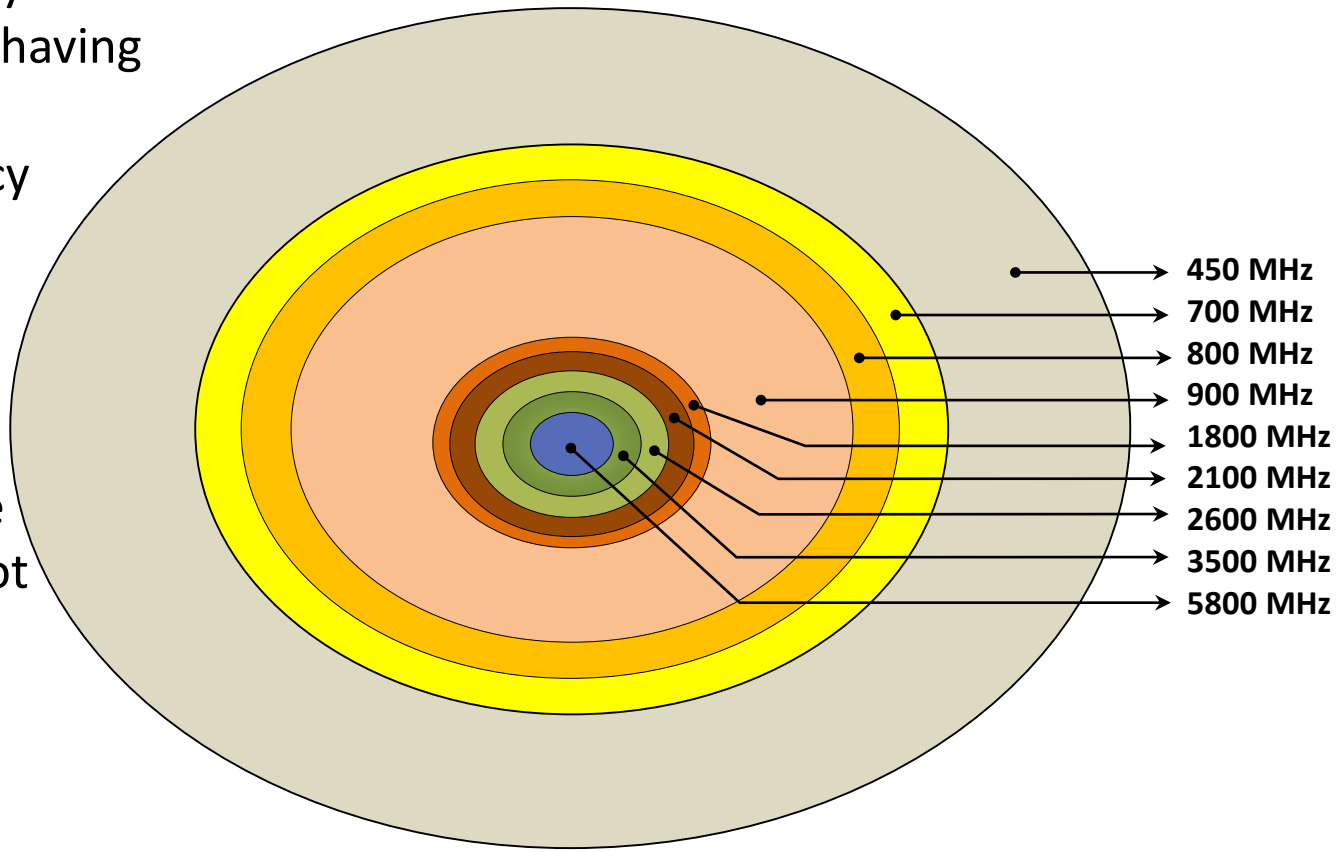
Radio Frequency Spectrum that are Currently Valuable in Market

- Frequency bands that are currently in ecosystem of wideband/broadband networks, according to ITU RR Article 5



Comparing Relative Coverage Ares in Various Frequency Bands

- Lower frequency bands are suitable for having coverage while higher frequency bands are suitable for capacity requirement
- Coverage above 3 GHz are in spot



Frequency Band Segmentation
(for Public Wireless Access)

- Segmentation is required for allocation of spectrum to operators

Number of Players	• Market Demand and Constructive Competition • Future needs of all players including non-civil users
Minimum amount of Spectrum	• Services to be delivered and associated service level • National spectrum requirement
Technical Dependence	• Guard-band requirement • Minimum technical limit for network establishment • Technology trend
Business Models	• Network –spectrum cost dependence • Equilibrium of benefit and cost

Spectrum Market

Spectrum Market

- **Main Objective of Market Creation:** Improving utilization efficiency of spectrum by improvement of the spectrum allocation and assignment method

Technical Improvement:

1. Increasing radiocommunication throughput in each channel
2. Reducing equipment and terminal costs
3. Convergence of technologies and services
4. Improving air-interface efficiency

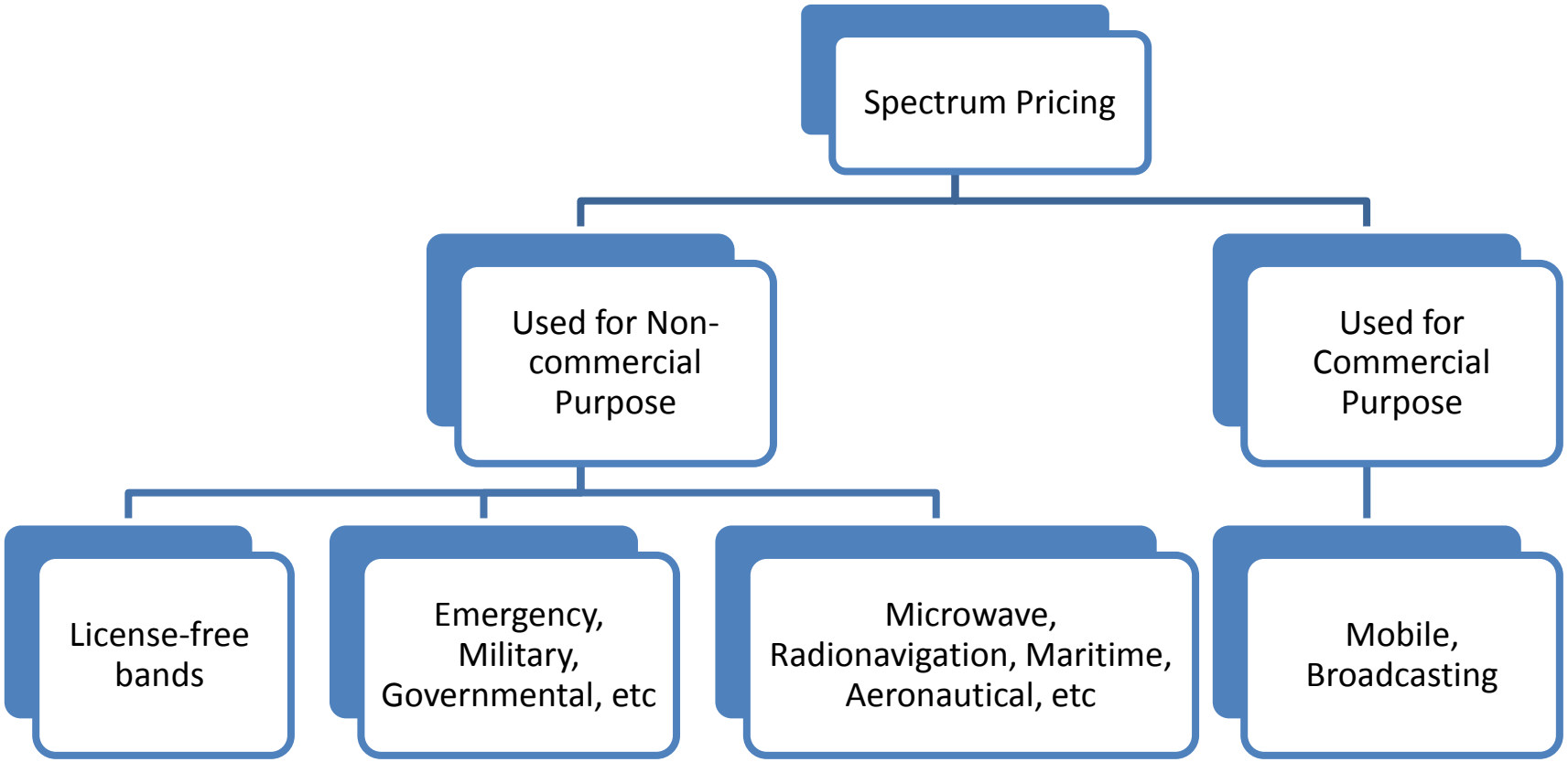
- **Players that are predominantly use spectrum:**
  - Private market sector (cell-phone operators)
  - Non-market Public (professional spectrum users, navigation, etc)
  - Non-market defense, emergency, security, broadcasting, etc

Market Force to Introduce into Spectrum Management

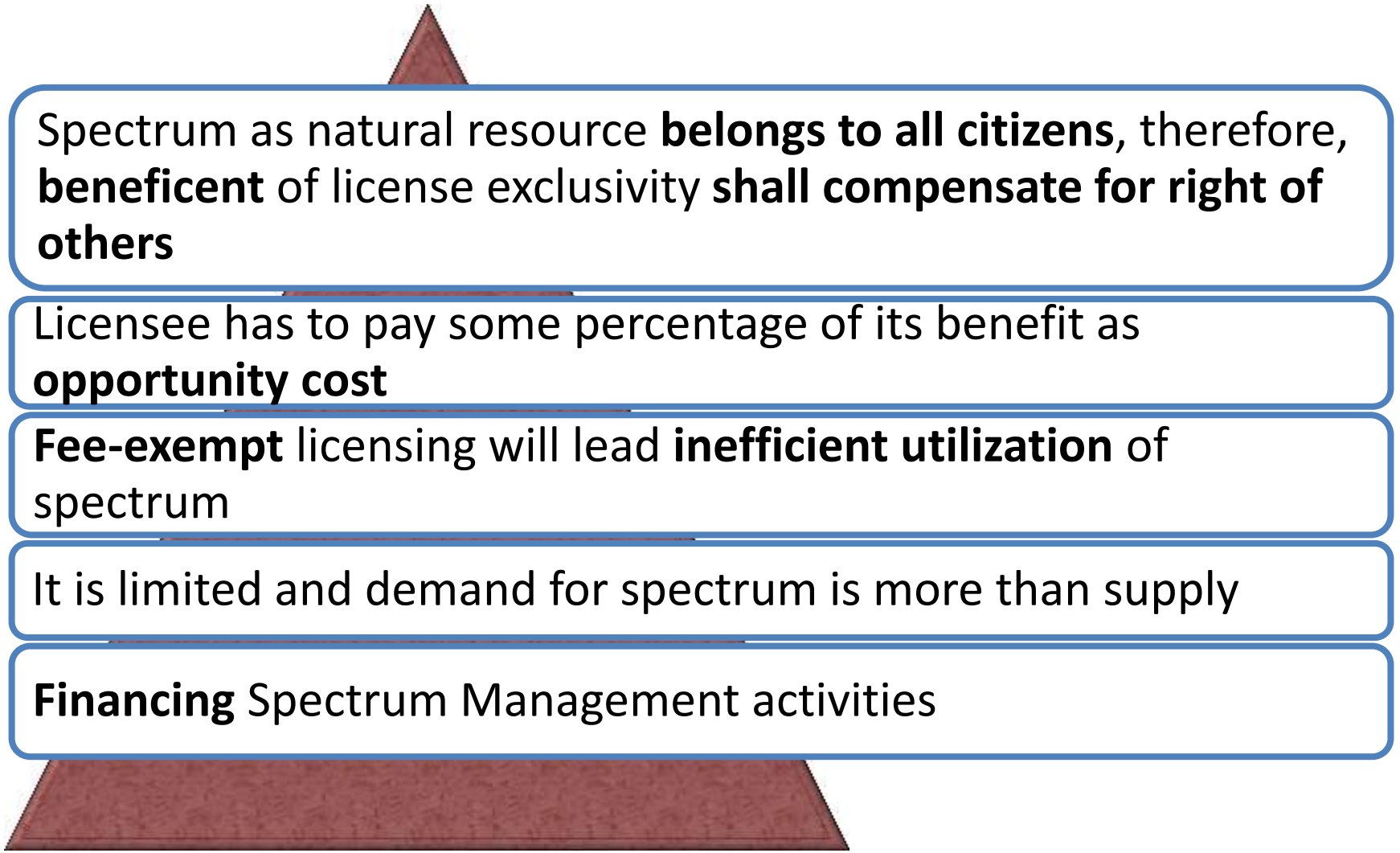
Auction	Spectrum Pricing	Secondary Trade	Liberalization
whereby spectrum block licenses are sold to the highest bidder	where owners of apparatus licenses are charged to use the radio spectrum	whereby owners of spectrum usage rights whether block or site license can sell or lease all or part of the rights associated with their licenses	whereby the owners of licenses can have their spectrum usage rights changed if they meet conditions defined by the regulator

Spectrum Pricing

Spectrum Pricing Categories

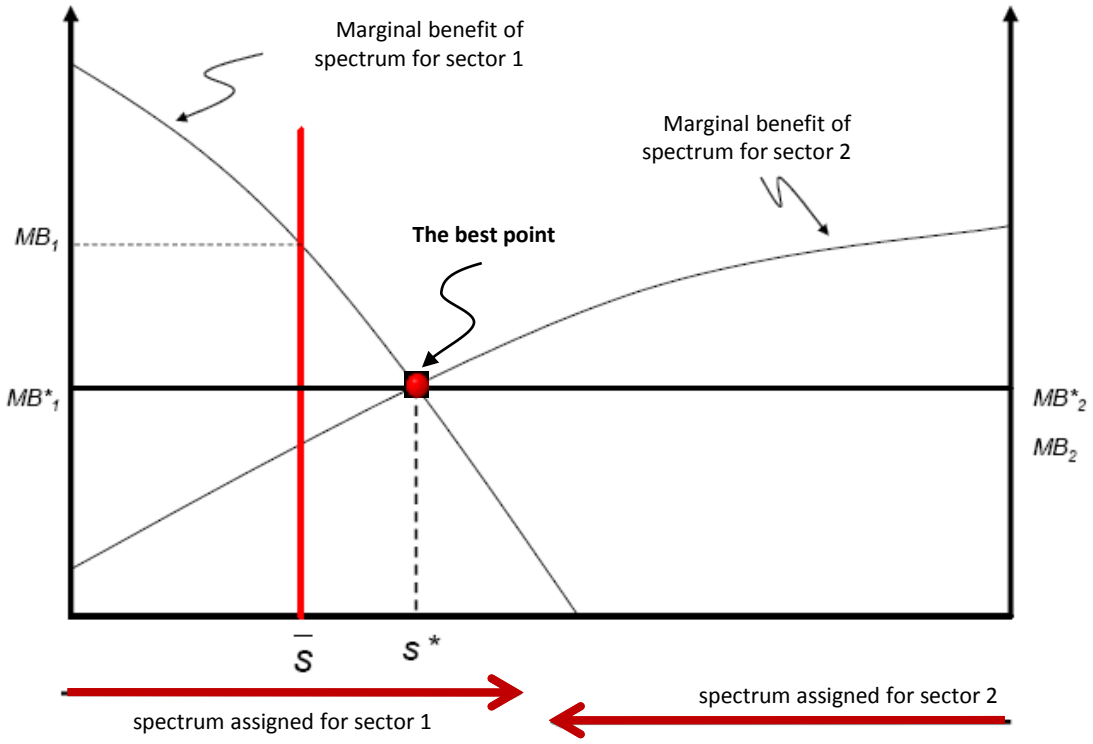


Reasons for Spectrum Pricing

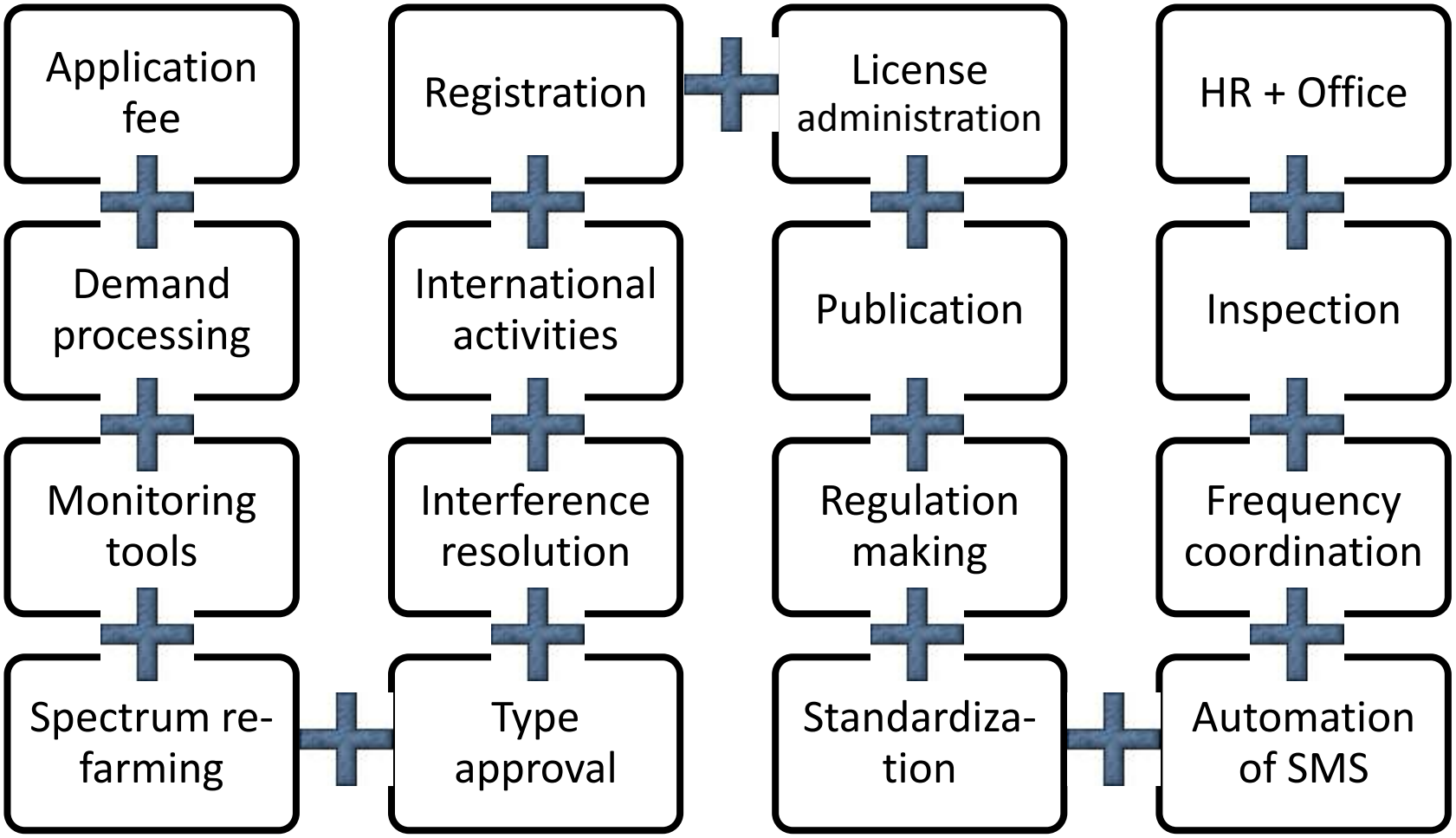


Concept of Opportunity Cost

- The best amount of spectrum price for assignment is the point that their marginal benefits of alternative sectors intersects (point s^*).
- An opportunity cost fee tries to simulate the market value of the spectrum. This process may require financial analysis, estimations of demand or market studies to achieve a valuation, and considerable expertise.

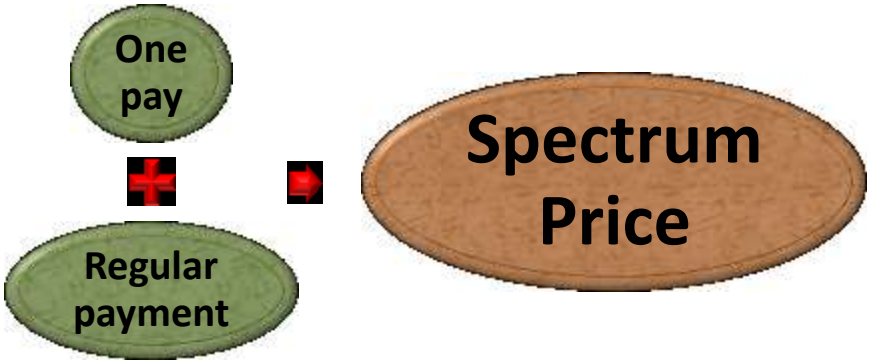


Financing Spectrum Management activities



Formulation of Traditional Method

- The formulation gives the minimum payable fee, suitable for frequency bands having no commercial interest



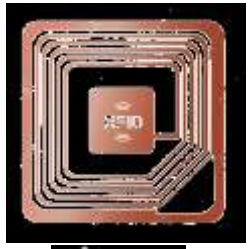
Disadvantage of traditional method:

- It in general does not reflect the value of the spectrum and as a result can generate false incentives to the licensees with respect to the amount of spectrum they want to acquire or use.

Some
Users of Non-Commercial Spectrum

Something not to Charge for Spectrum Use

- Internationally assigned emergency frequencies
- Radio devices permitted to be used by all citizens under class license
- Selective-calling channels
- Short range devices
- Radiocommunication devices standardized by international agencies of UN, e.g. IMO, ICAO, UN itself, etc
- Embassies subject to reciprocal decision
- Pilot project, radio devices for exhibition, under ground radiocommunications, R&D labs
- What regulator decides for government, military, security etc



Parameters for Traditional Spectrum Pricing

Parameters	Dependence

Pricing of Frequency Bands Having Commercial Interest, In the Context of Spectrum License

Available FDD Spectrum for Broadband

3GPP Release 13: ETSI TS 125 104 V13.3.0 (2016-08)

Operating Band	UL Frequencies UE transmit, Node B receive	DL frequencies UE receive, Node B transmit	Operating Band	UL Frequencies UE transmit, Node B receive	DL frequencies UE receive, Node B transmit
I	1920 - 1980	2110 -2170	XII	699 - 716	729 - 746
II	1850 -1910	1930 -1990	XIII	777 - 787	746 - 756
III	1710-1785	1805-1880	XIV	788 - 798	758 - 768
IV	1710-1755	2110-2155	XIX	830 – 845	875 -890
V	824 - 849	869-894	XX	832 - 862	791 - 821
VI	830-840	875-885	XXI	1447.9 - 1462.9	1495.9 - 1510.9
VII	2500 - 2570	2620 - 2690	XXII	3410 – 3490	3510 – 3590
VIII	880 - 915	925 - 960	XXV	1850 -1915	1930 -1995
IX	1749.9 - 1784.9	1844.9 - 1879.9	XXVI	814-849	859-894
X	1710-1770	2110-2170	XXXII		
XI	1427.9 - 1447.9	1475.9 - 1495.9	(NOTE 1)	N/A	1452 – 1496

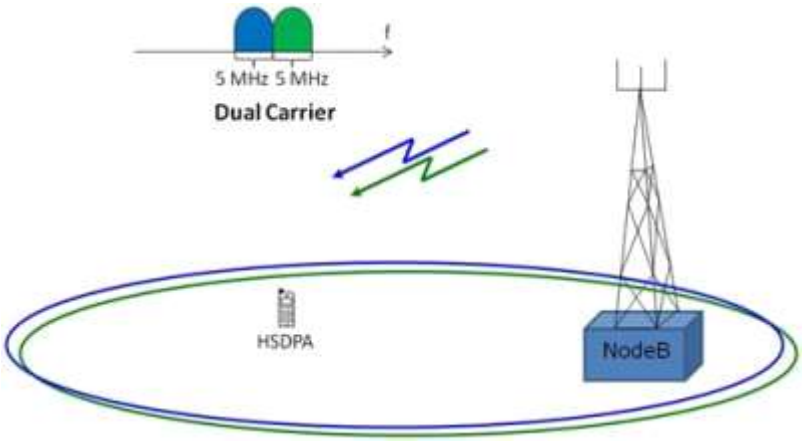
NOTE 1: Restricted to UTRA operation when dual band is configured (e.g., DB-DC-HSDPA or dual band 4C-HSDPA). The down link frequenc(ies) of this band are paired with the uplink frequenc(ies) of the other FDD band (external) of the dual band configuration.

Available FDD Spectrum for Broadband

3GPP Release 13: ETSI TS 125 104 V13.3.0 (2016-08)

DB-DC-HSDPA configurations

DB-DC-HSDPA Configuration	UL Band	DL Bands
1	I or VIII	I and VIII
2	II or IV	II and IV
3	I or V	I and V
4	I or XI	I and XI
5	II or V	II and V
6	I	I and XXXII



- DB-DC-HSUPA configurations as well as single band or dual band contiguous and non-contiguous 2, 3, 4 and 8 channel HSPDA combination are also standardized

Available TDD Spectrum for Broadband

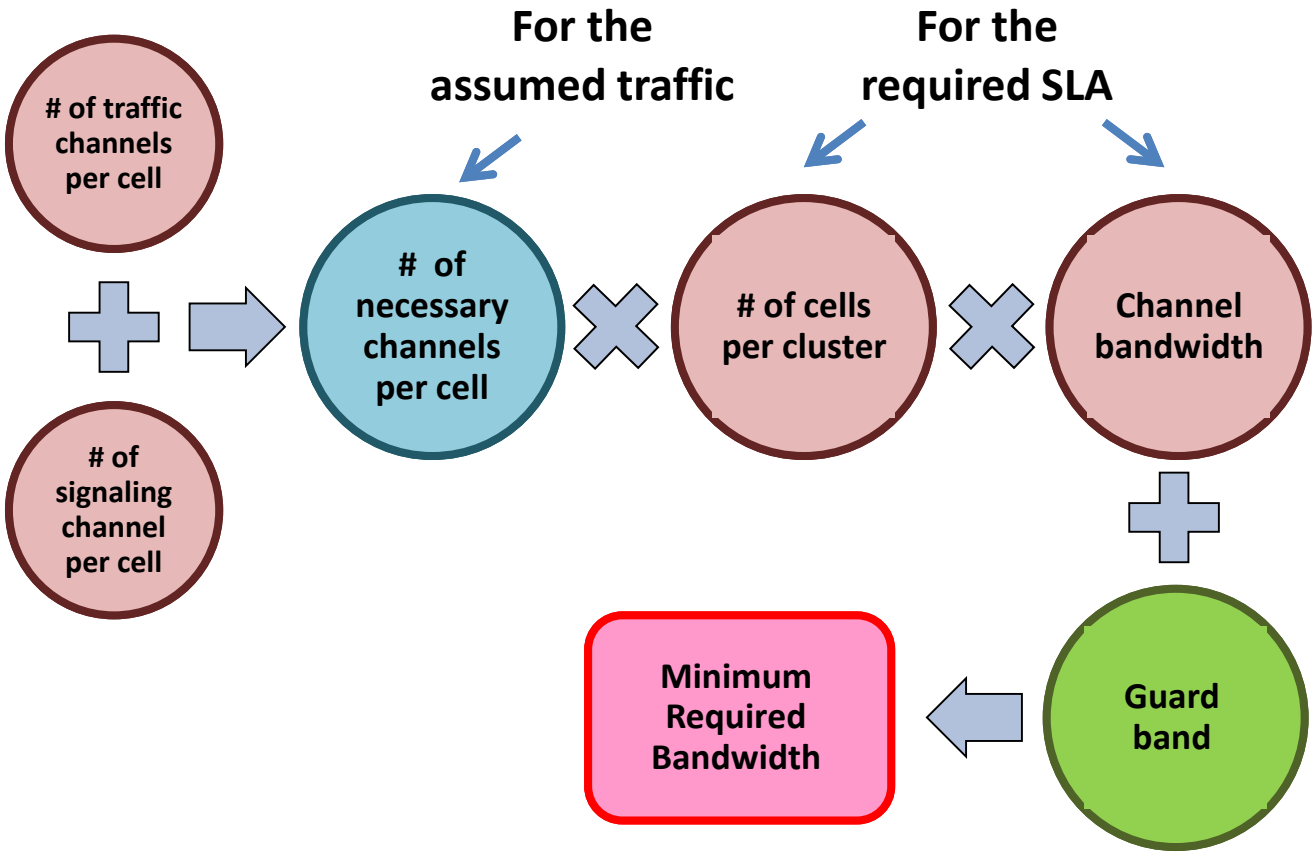
3GPP Release 13: ETSI TS 125 105 V13.1.0 (2016-05)

a) 1900 - 1920 MHz: Uplink and downlink transmission
   2010 - 2025 MHz Uplink and downlink transmission
b) 1850 - 1910 MHz Uplink and downlink transmission
   1930 - 1990 MHz Uplink and downlink transmission
c) 1910 - 1930 MHz Uplink and downlink transmission
d) 2570 - 2620 MHz Uplink and downlink transmission
e) 2300 - 2400 MHz Uplink and downlink transmission
f) 1880 - 1920 MHz: Uplink and downlink transmission

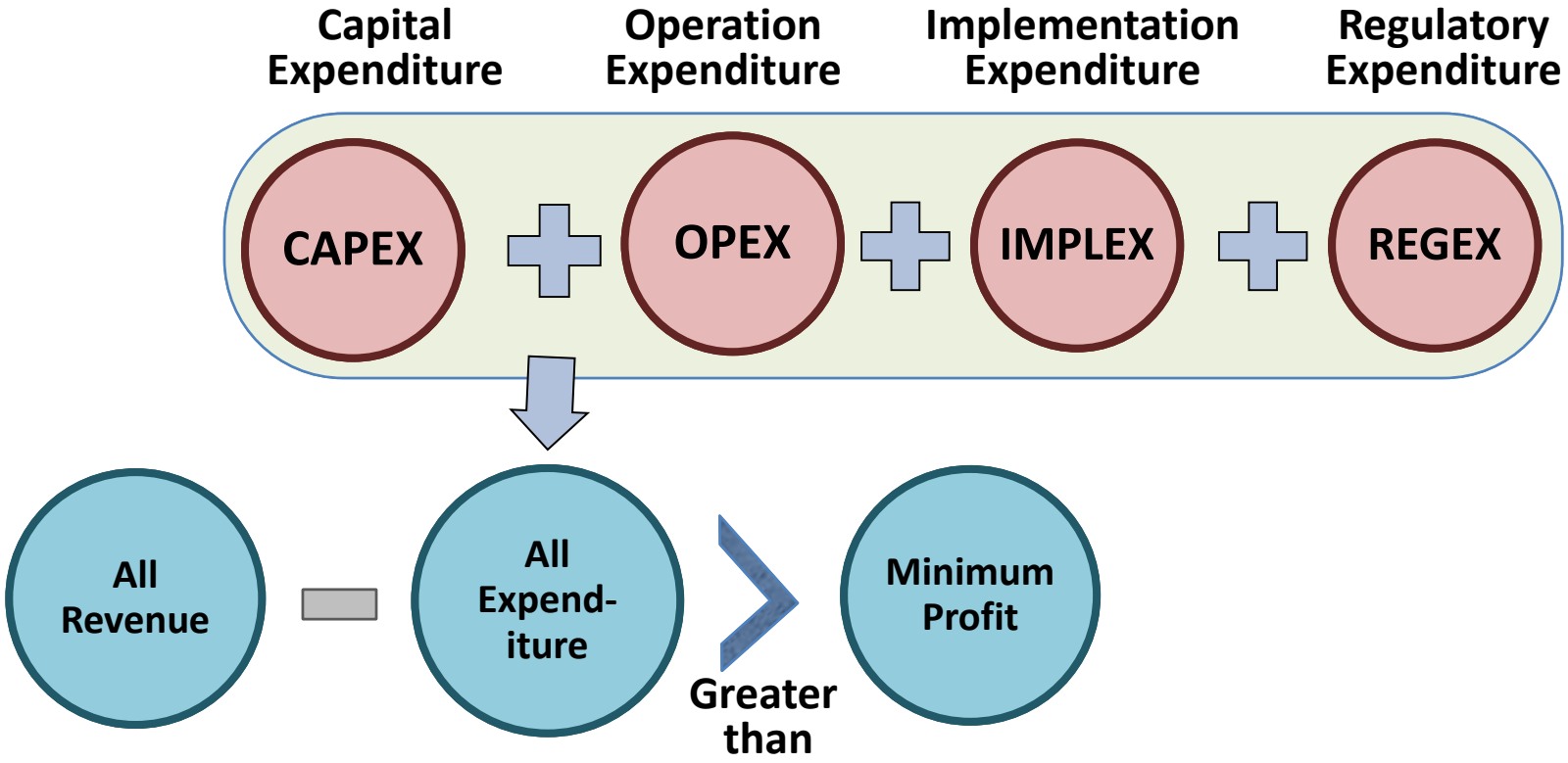
* In China, Band a only includes 2010-2025 MHz for 1.28 Mcps TDD option

- The co-existence of TDD and FDD in the same bands is still under study

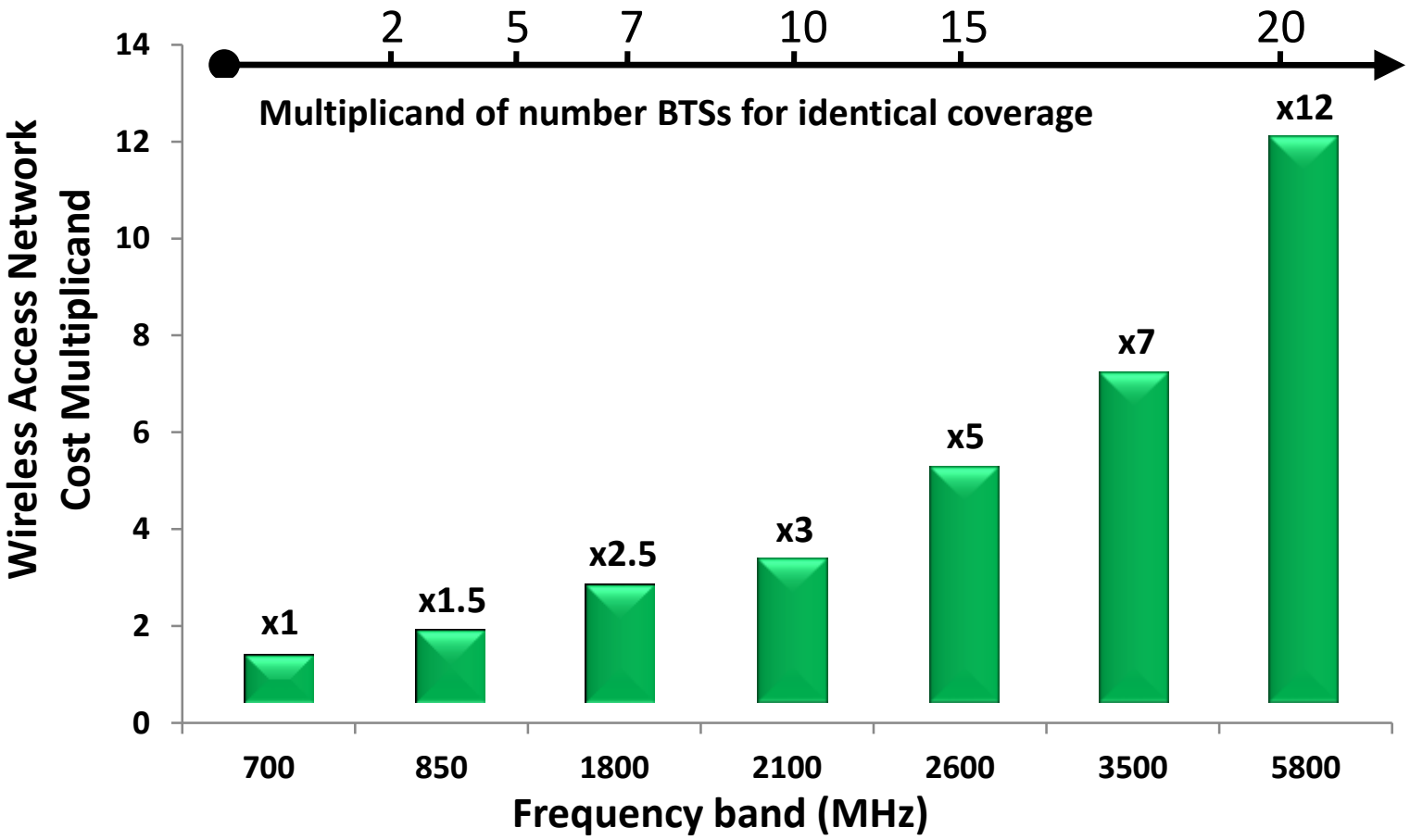
Minimum Amount of Spectrum from Technical Point of View



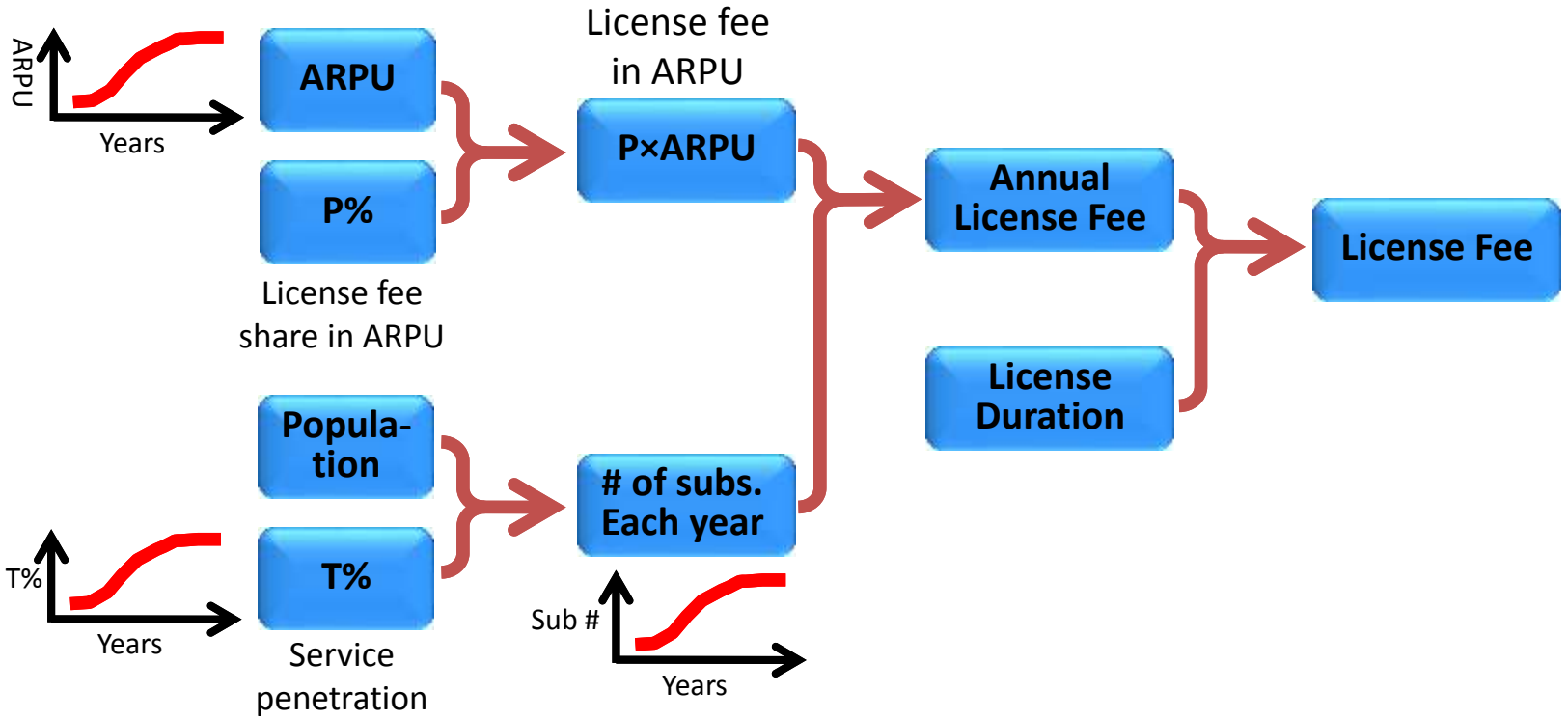
Minimum Amount of Spectrum from Economic Point of View



Frequency Band and CAPEX Dependence



Bottom-Up Approach for Calculation of License Fee



Assigning Spectrum By Auction, as a Market Mechanism

- Before auction, the market potential shall be assessed
- Particular method of auctioning also need to be selected for effective rollout of the new services
- The market condition for price auctions must be carefully established to meet the efficiency objectives, such as:
  - The amount of spectrum allocated for auction
  - The bandwidth that would be allocated for each license
  - The specific geographical coverage of each licens
  - License duration
  - Technical specifications

- Bidders also need to know possibility of using previously allocate spectrum for new services and possibility for new allocations for same service in future

Auction
Advantage and Disadvantage

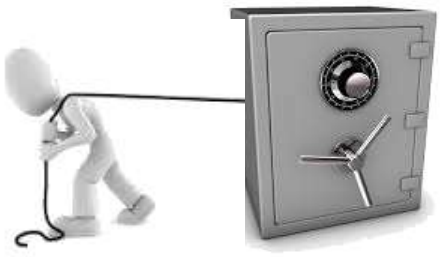
- **Advantages:**
  - Transparent and fair if laws are explicit (auctions safeguard against damaging accusations of corruption, bribery and favoritism)
  - Revenue maximization
  - Greater innovation and quicker service time-to-market because of high cost of license
  - Maximize benefits to consumers
  - Generally swift, quick and easy to administer
- **Disadvantage:**
  - Does not allow governments to impose a detailed list of criteria (including coverage, commencement dates and etc)
  - Extremely high license fees
  - Less competitors will exist in the market
  - The auction process appears to be particularly inappropriate when considering innovative technologies and new markets

Auction Types

- **“English” auction:** Auctioneer increases the price until a single bidder is left;
- **First-price sealed bid auction:** Bidders submit sealed bids and the highest wins;
- **Second-price sealed bid auction:** bidders submit sealed bids and the highest bidder wins but pays the second highest amount bid;
- **“Dutch” auction:** Auctioneer announces a high price and reduces it until a bidder shouts “mine”;
- **Simultaneous multiple round auction (SMR):** The highest bid on each lot is revealed to all bidders before the next round when bids are again accepted on all lots. The process continues until a round occurs in which no new bids are submitted on any lots.
- **Simultaneous combinatorial multiple round auction (SCMR):** this is basically same as SMR, except that they can place a unique bid on a combination of lots.
- **Combinatorial Clock Auction (CCA):** This seeks to solve invalidation of every previous bid from the bidder in SMR by making every bid in every round a binding bid (all the bids in all the rounds count), and by giving bidders one last chance to make a bid after the auction ends in the first stage.

Auction Price Challenges

- ***Disadvantage:***
  Imposing one-pay high auction price for certain usage, may hinder/delay network rollout

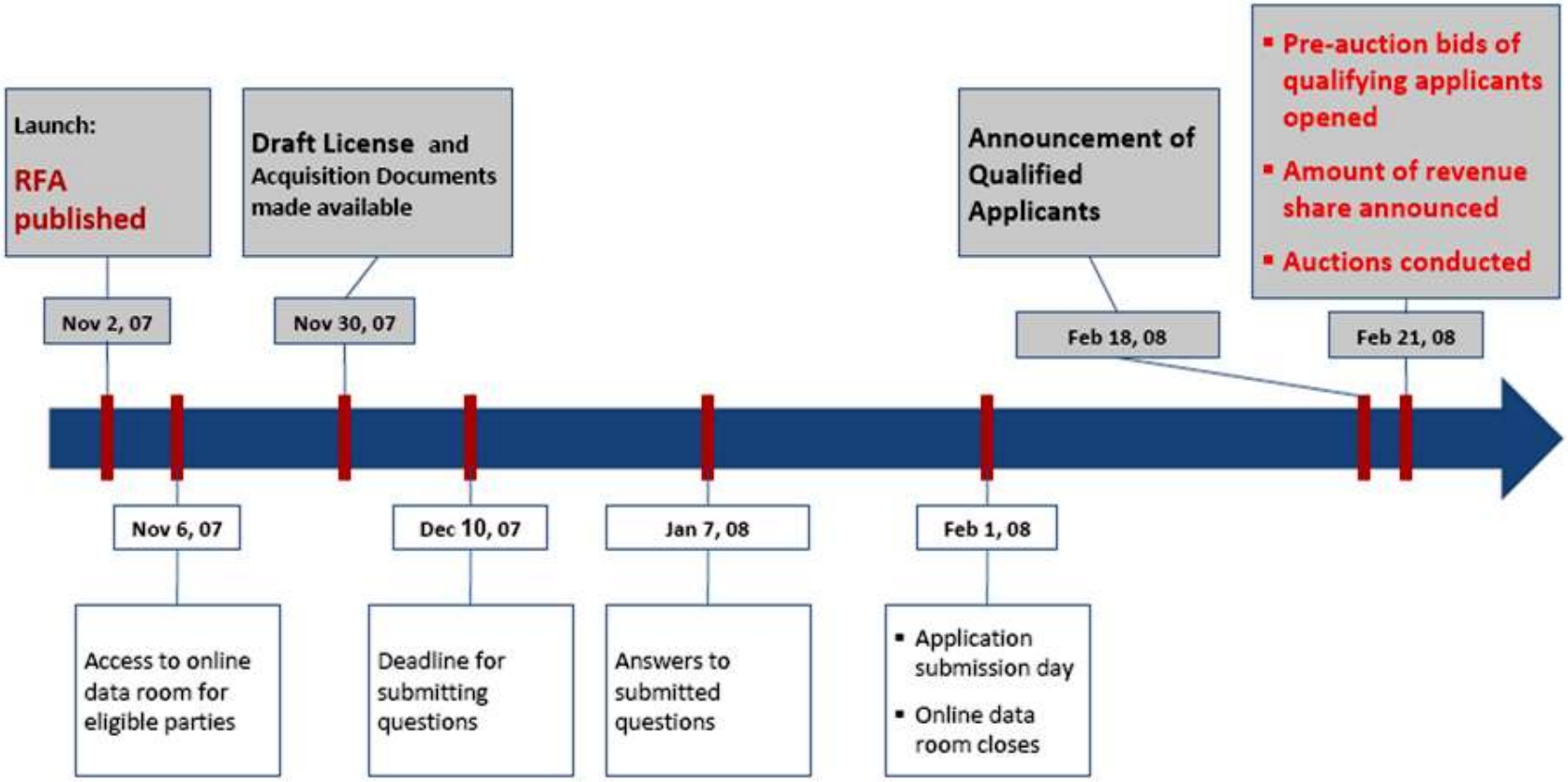


- ***Solution:***
  Instead of high auction price, some percent of auction price could be collected at license issuing and remaining as royalty payment (revenue sharing)
- The combination provides more stable governmental revenue which reduce initial cost of winners
- The method removes one big obstacle against high speed network rollout

General
Procedures for Auction and Tender

- **Procedures for auction may deal with any of the following matters:**
  (a) the types of auction;
  (b) advertising of auctions;
  (c) entry fees for prospective bidders;
  (d) reserve prices (if any);
  (e) deposits (if any) payable by successful bidders;
  (f) methods of payment for licences.
- **Procedures for tender may deal with any of the following matters:**
  (a) the types of tender;
  (b) advertising of tenders;
  (c) entry fees for prospective tenderers;
  (d) reserve prices (if any);
  (e) the method for resolving which of 2 or more equal tenders is to be successful;
  (f) deposits (if any) payable by successful tenderers;
  (g) methods of payment for licences.

Example Tender Milestone



Auction Example

(http://wireless.fcc.gov/auctions/default.htm?job=bandplans)

698-806

700 MHz Auction Results (Auction 73)				
700 MHz Block	Geographic Area	Bandwidth (MHz)	Total Provisionally Winning Bids	$'s per MHz-Pop
A	EA	12	$3,961,174,000	$1.16
B	CMA	12	$9,143,993,000	$2.67
C	REAG	22	$4,748,319,000	$0.76
E	EA	6	$1,266,892,000	$0.74
Total			$19,120,378,000	$1.29

1710-1755/2110-2155

AWS-1 Auction Results (Auction 66)				
Comparable AWS-1 Block	Geographic Area	Bandwidth (MHz)	Comparable Total Provisionally Winning Bids	$'s per MHz-Pop
C	EA	10	$1,491,238,000	$0.52
A	CMA	20	$2,268,029,200	$0.40
F	REAG	20	$4,174,486,000	$0.73
C	EA	10	$1,491,238,000	$0.52

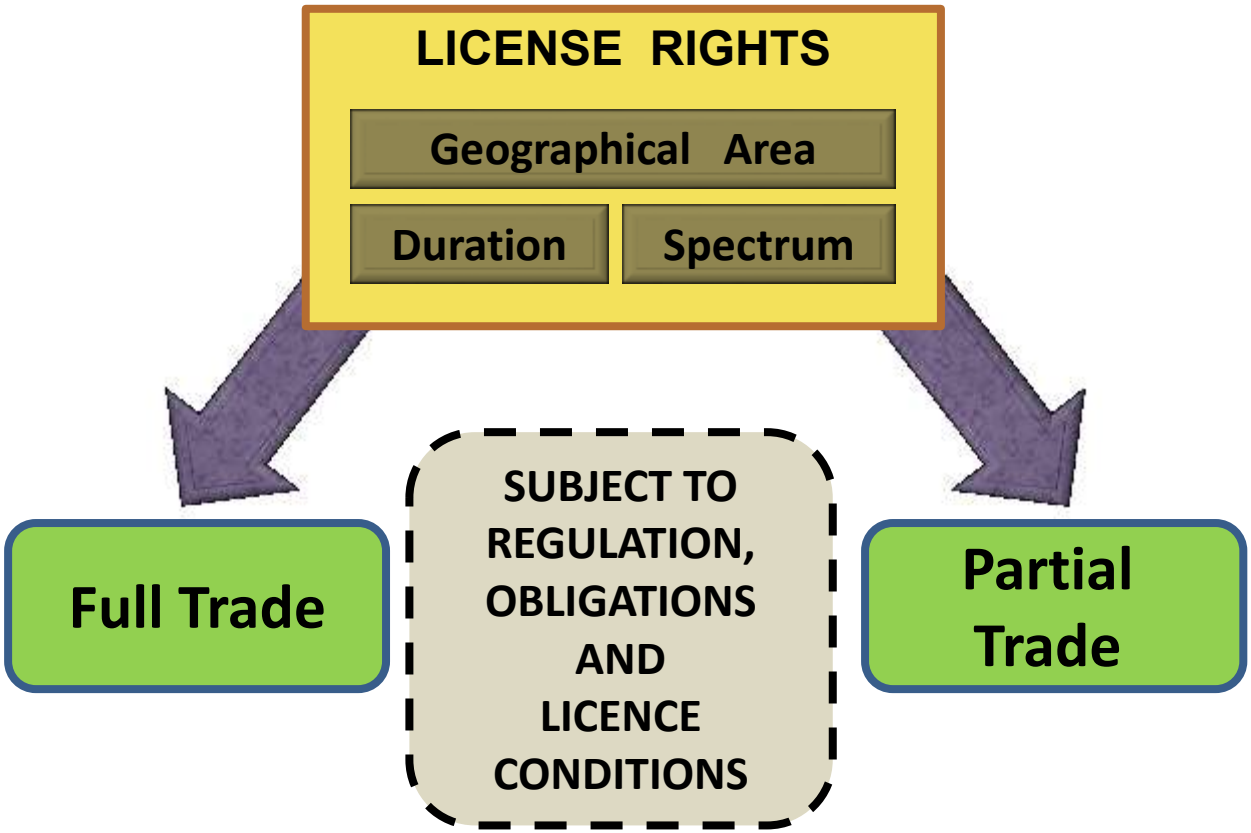
Spectrum Trading and Liberalization (Definition Only)

Frequency License Trading

- Traditional spectrum management regulation:
  the frequency must be used by licensees or returned to the licensing authority
- A few countries are exploring for allowing market trading in spectrum licenses:
  Australia, New Zealand, UK, Iran, etc

- Condition of usefulness of spectrum trading:
  If the trading value to be determined by standards of competitive market efficiently, the trading expected to improve spectrum efficiency
- If the trading values are governed by artificial scarcity, speculation, gains from holding rather than using scare resources, or anticompetitive objectives, then trading will not results desired efficiency

Spectrum Trading as a Valuable Good

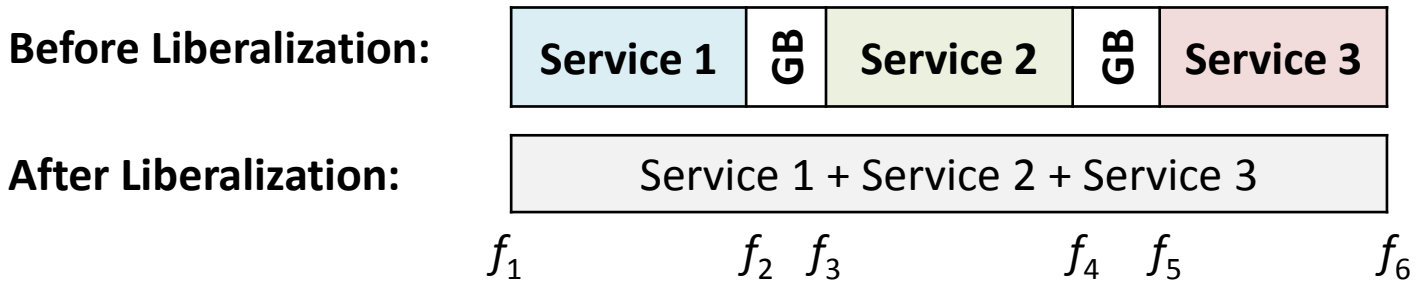


Concept of Spectrum Liberalization

- Increasing benefit of radio frequency spectrum by relaxation of restricted license to enable licensee to change technical specifications and market requirements such as:
  - Changing spectrum usage,
  - Trading spectrum,
  - Re-locating stations,
  - Changing channel bandwidth,
  - Re-shaping market,
  - etc

Advantages of Spectrum Liberalization

- Guard-bands between allocated frequency bands to converged services are no longer necessary



- Reduce time consuming administrative works to assess requests of **license usage** and **technology change**
- Brings greater competition into spectrum markets
- Speed up implementation of innovative services and increase spectrum benefits


END