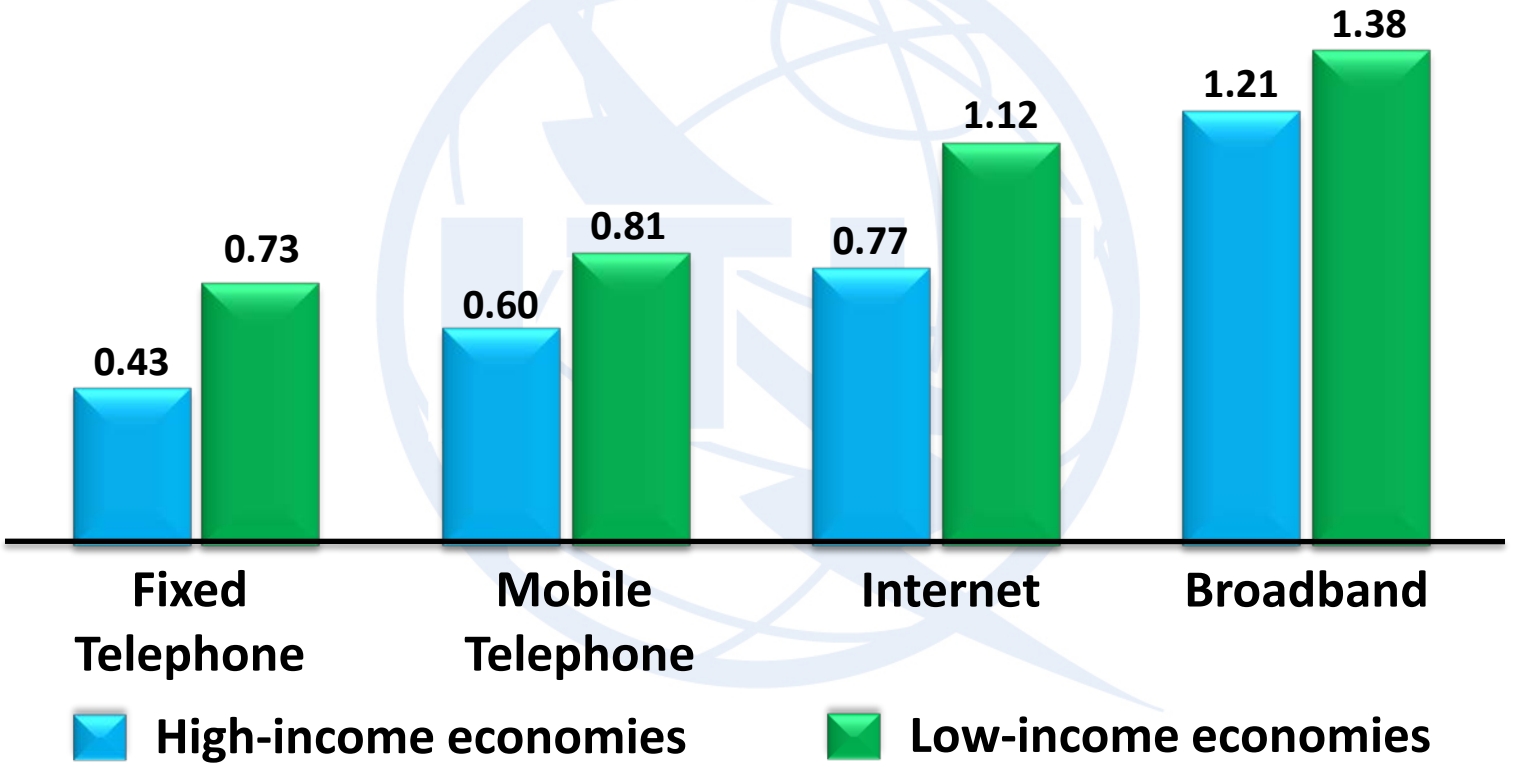
Spectrum Planning for Wireless Broadband

ITU ASP COE TRAINING ON "WIRELESS BROADBAND ROADMAP DEVELOPMENT"

06-09 August 2016

Tehran, Islamic Republic of Iran

GDP Growth for 10% Penetration Increasing of Each of Following

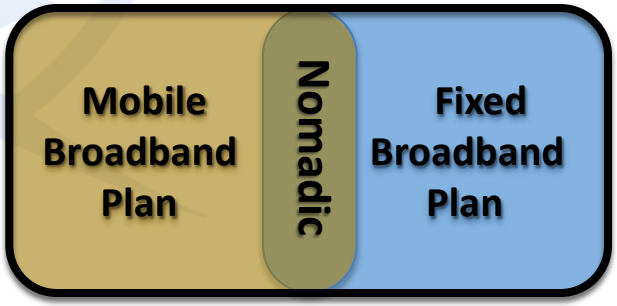


Source: World band, Qiang 2008

National Broadband Plan

- Identifies the **target speed** for different **group of stakeholders**
- Determines the **infrastructure requirement**
- Determines the **spectrum requirement**
- Determines the **budget** that should be spent by sector and government
- Provides the **roadmap** to achieve goals during the given **time frame**
- **Distribute** responsibilities among players

✓ ***Broadband achievement plan*** *need to be reviewed and revised continuously appropriate to technology change and national growth*



Concept of Spectrum Planning

- **Providing answer to the following questions:**
  - Who? Categorizes type of operator/operator selection method,
  - What? Determines the deliverable service,
  - How? Identifies rollout plan and SLA,
  - When? Determines license issuing time,
  - Where? Gives the geographical elements of license,
  - How long? Set timing frame for service delivery,
  - To whom? Provides customer range,
  - What tariff? Provides service fee,
  - Which resource allowed to use: Spectrum, number, IP, etc

What Speed is the Broadband

- "Broadband" is a relative term
- Broadband defined by ITU-T I.113: "Qualifying a service or system requiring transmission channels capable of supporting rates greater than the primary rate" referring to the primary rate which ranged from about 1.5 to 2 Mbit/s.

Second generation (2G) from 1991:

Speeds in kbit/s	*down and up*
GSM CSD	9.6
CDPD	up to 19.2
GSM GPRS (2.5G)	56–115
GSM EDGE (2.75G)	up to 237

Third generation (3G) from 2001:

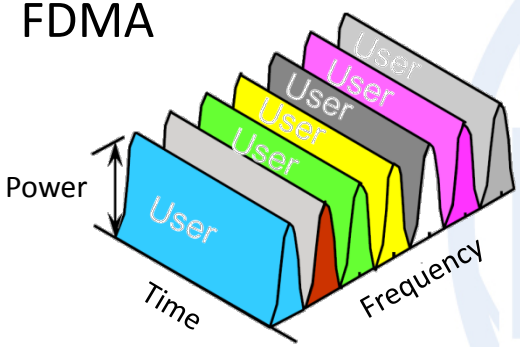
Speeds in Mbit/s	*down*	*up*
UMTS W-CDMA	0.4	
UMTS HSPA	14.4	5.8
UMTS TDD	16	
CDMA2000 1xRTT	0.3	0.15
CDMA2000 EV-DO	2.5–4.9	0.15–1.8
GSM EDGE-Evolution	1.6	0.5

Fourth generation (4G) from 2006:

Speeds in Mbit/s	*down*	*up*
HSPA+	21–672	5.8–168
Mobile WiMAX (802.16)	37–365	17–376
LTE	100–300	50–75
LTE-Advanced:		
• while moving at high speeds	100	
• while stationary or moving at low speeds	up to 1000	
MBWA (802.20)	80	

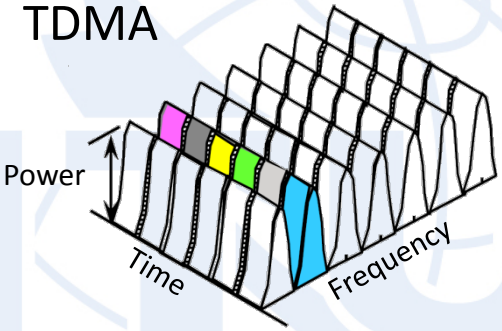
Multiple Access Technology

FDMA



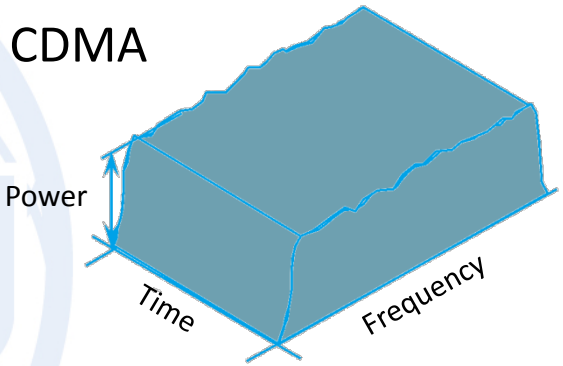
Different frequency bands are allocated to different users, for example, AMPS and TACS

TDMA



Different time slots are allocated to different users, for example, D-AMPS and GSM

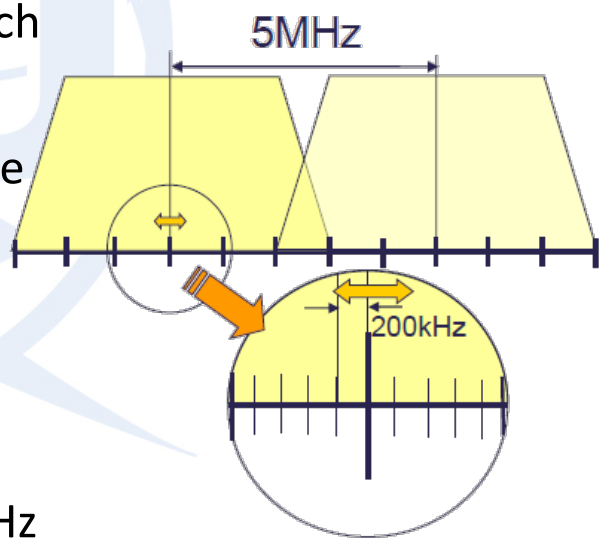
CDMA



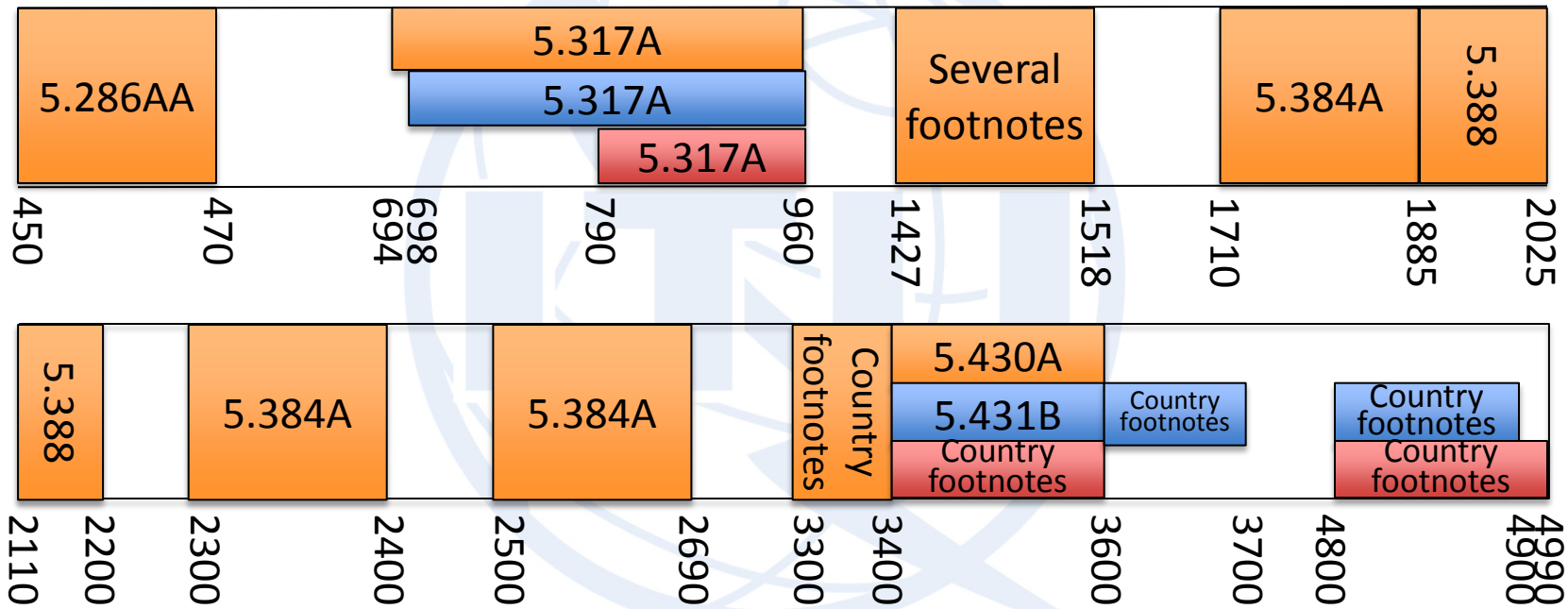
Signal of all users are assigned unique codes and transmitted over the same frequency band simultaneously, for example, WCDMA and CDMA2000

Channeling Plan

- **Channel spacing:**
- For UMTS, the nominal channel spacing is **5 MHz**, but this can be adjusted to optimize performance in a particular deployment scenario
- **Channel raster:**
- The channel raster is **200 kHz** for all bands, which means that the **centre frequency** must be an **integer multiple of 200 kHz**. Some additional channel based on 100 kHz raster is also available (see standards)
- **Channel Number**
- The carrier frequency is designated by the UTRA Absolute Radio Frequency Channel Number (UARFCN), where
- Fcenter = UARFCN * 200 KHz

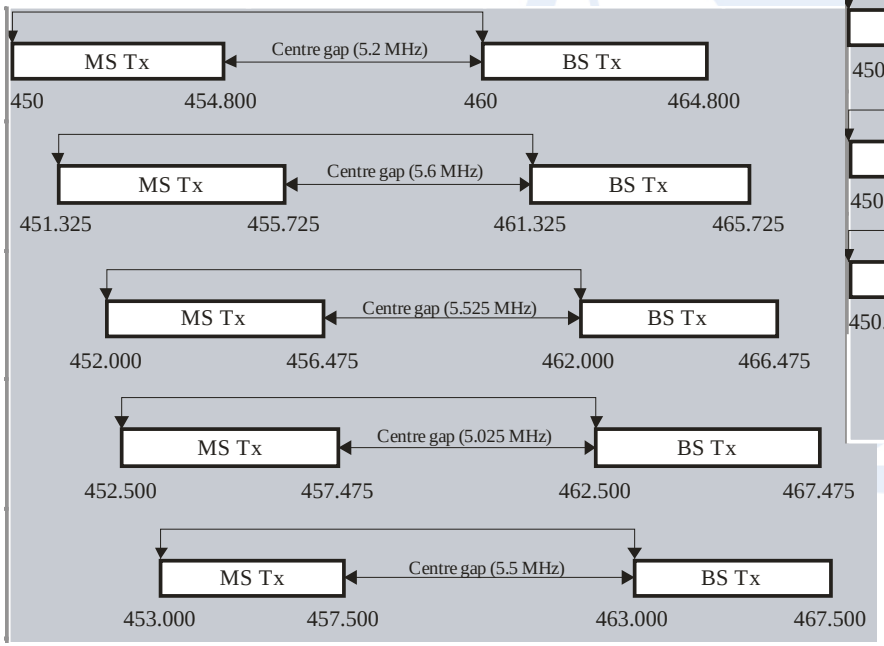


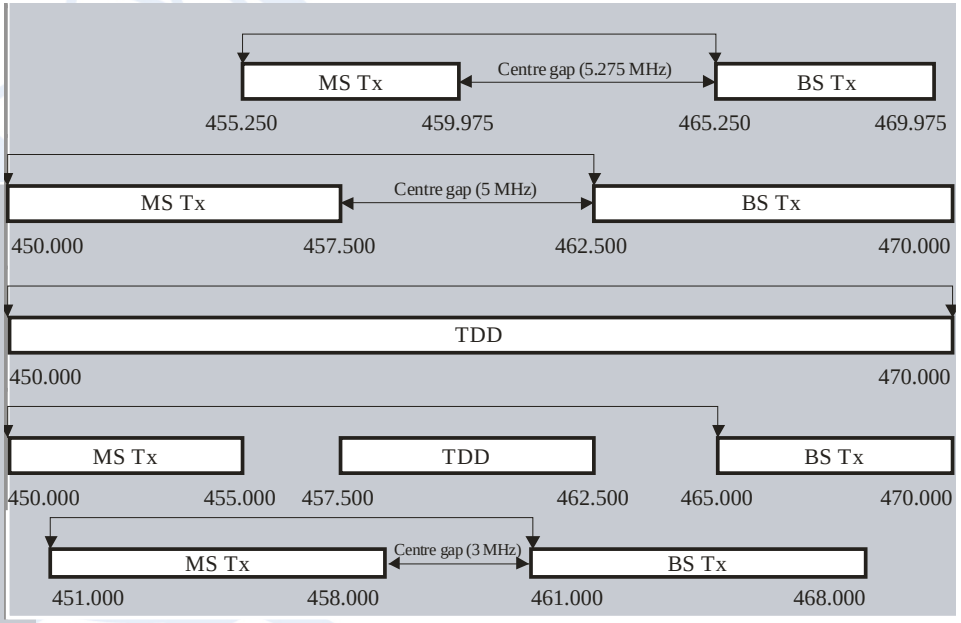
Frequency Bands Identified for Terrestrial IMT by ITU



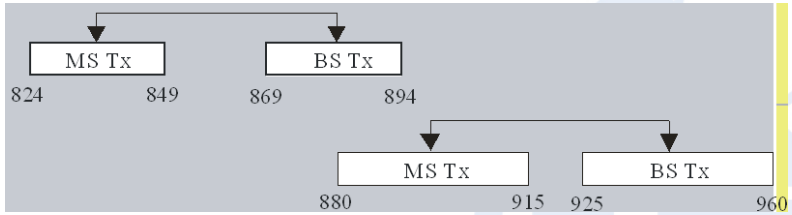
- There is also 5.388A for HAPS use as IMT BTS

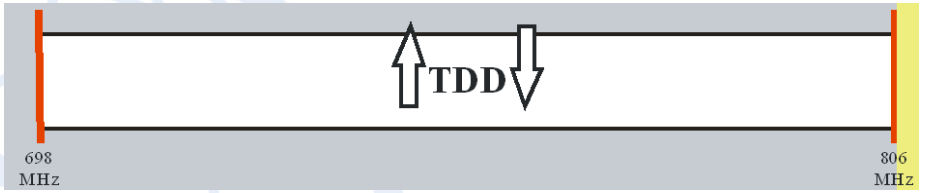
Frequency Block Arrangement by M.1036
450 MHz

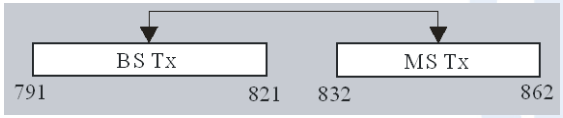


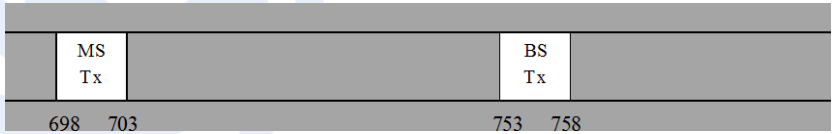


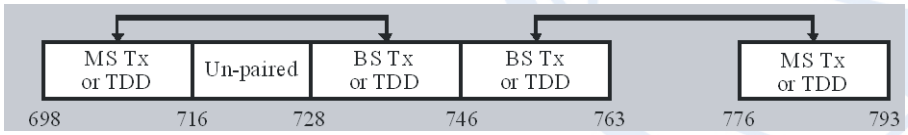
Frequency Block Arrangement by M.1036
694-960 MHz

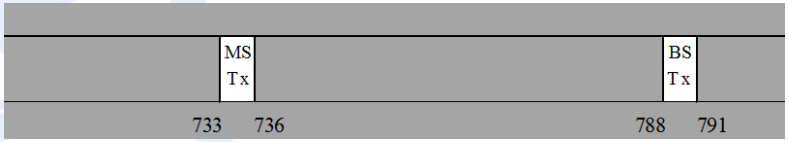


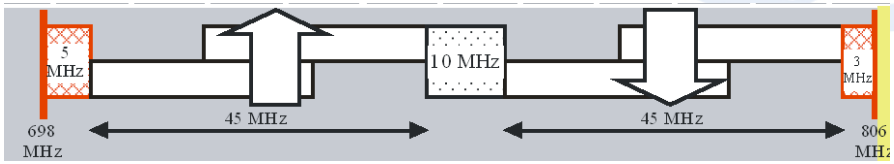


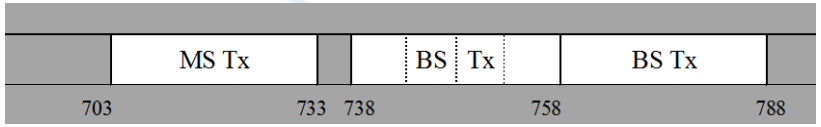




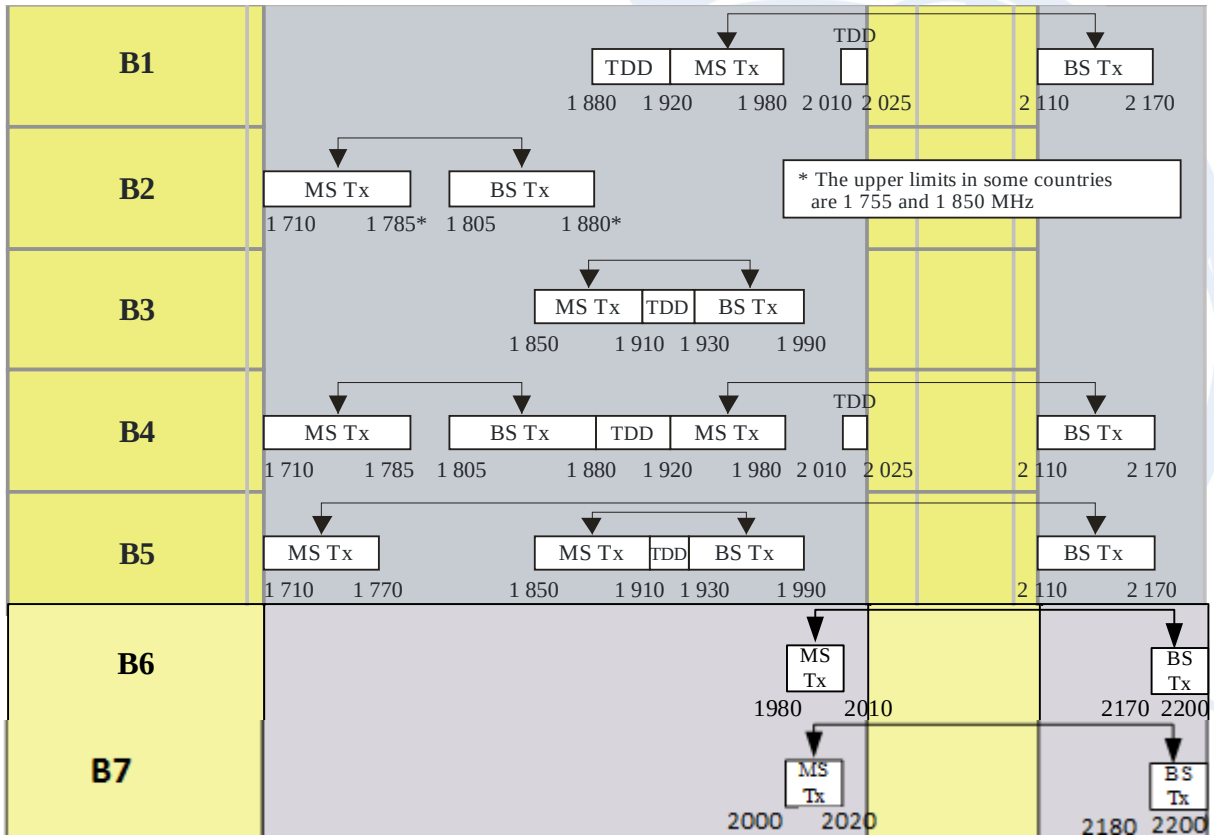


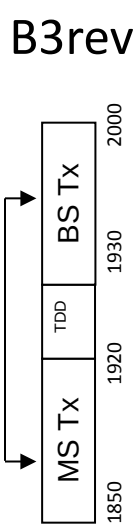


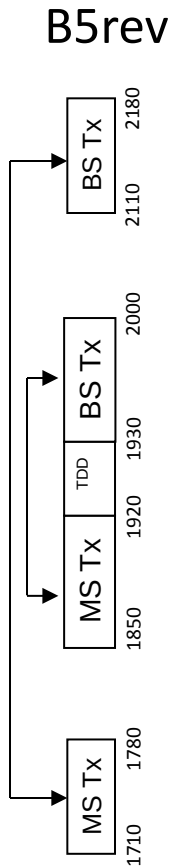




Frequency Block Arrangement by M.1036
1710-2200 MHz

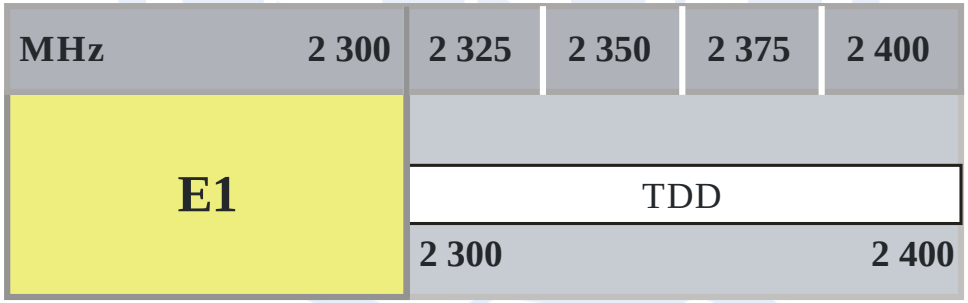




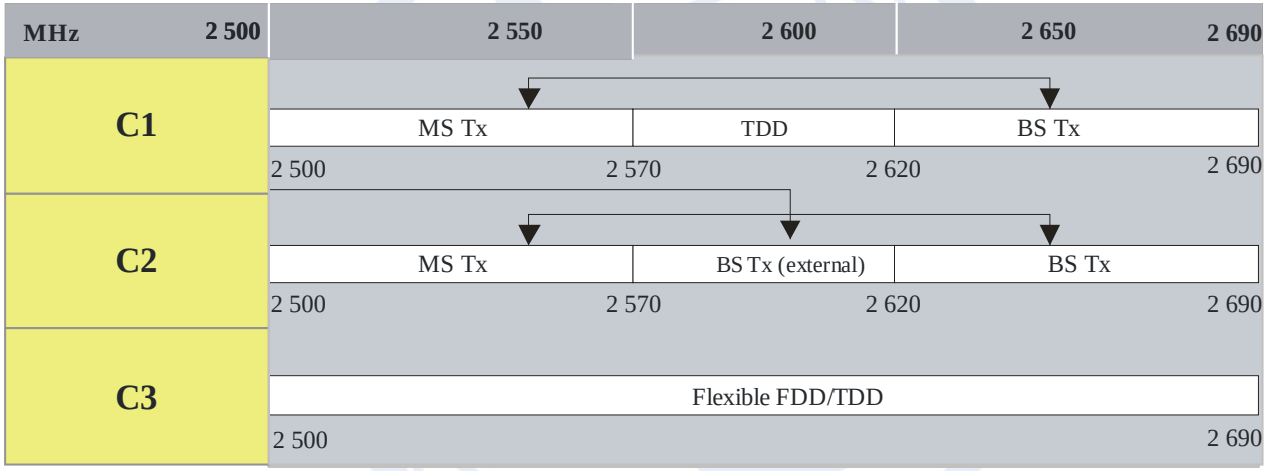


Frequency Block Arrangement by M.1036 2300-2400 MHz

- The upper edge is the beginning of 2.4 GHz ISM band

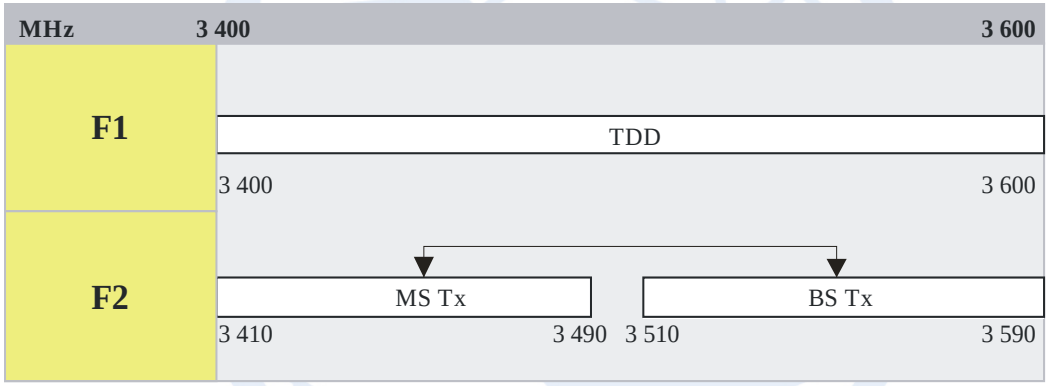


Frequency Block Arrangement by M.1036 2500-2690 MHz



- Guard-band in C1 should be in 2570-2620 MHz

Frequency Block Arrangement by M.1036
3400-3600 MHz



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

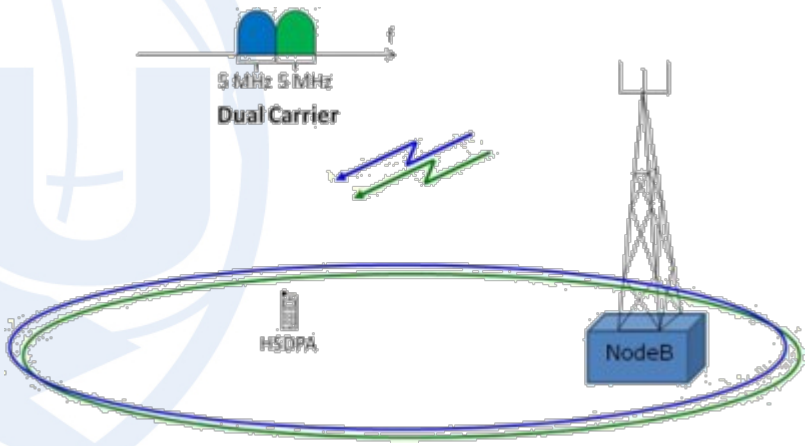
NOTE 1: Restricted to UTRA operation when dual band is configured (e.g., DB-DC-HSDPA or dual band 4C-HSDPA). The down link frequenc(ies) of this band are paired with the uplink frequenc(ies) of the other FDD band (external) of the dual band configuration.

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

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

Channel Bandwidth and Broadband Speed Relation

- An informative summary is available in: https://en.wikipedia.org/wiki/LTE_frequency_bands based on 3GPP TS 36.101
- There are variety of channel bandwidths **1.4, 3, 5, 10, 15** and **20 MHz** for single channel but the **nominal** bandwidth is **5 MHz**
- Calculation of broadband speed in LTE is explained in **3GPP TS 36.213** document for given channel bandwidth, simplified as:

Resource element = (Number of subcarriers) × (number of resource blocks) × (number of slots)

Data rate = (Number of bits in selected modulation having given coding scheme) × (throughput gain for MIMO antenna system)

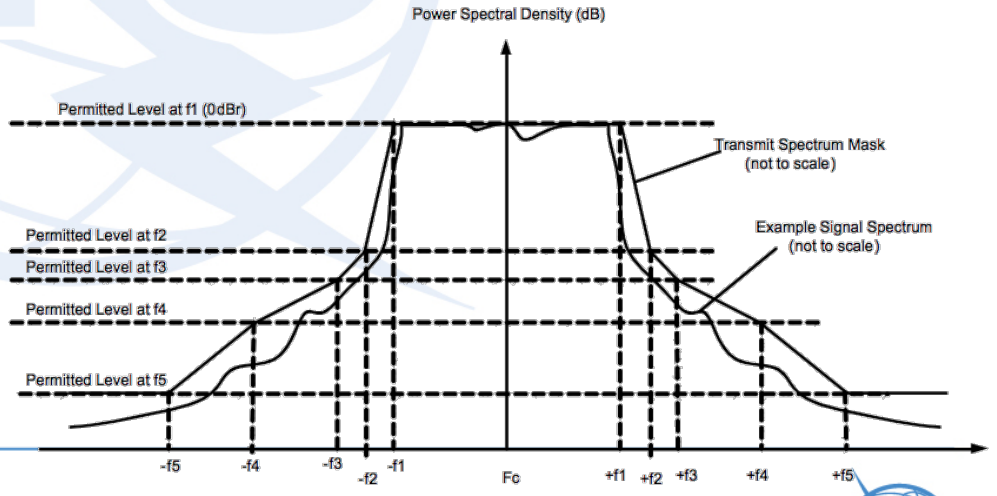
- The data rate could reach to **301.5 Mbps** for a **20 MHz** channel using the **64 QAM** with least coding
- Bigger channels may be created by aggregation of adjacent or dual-band multiple channels

Guard Band Requirement of Band Plan

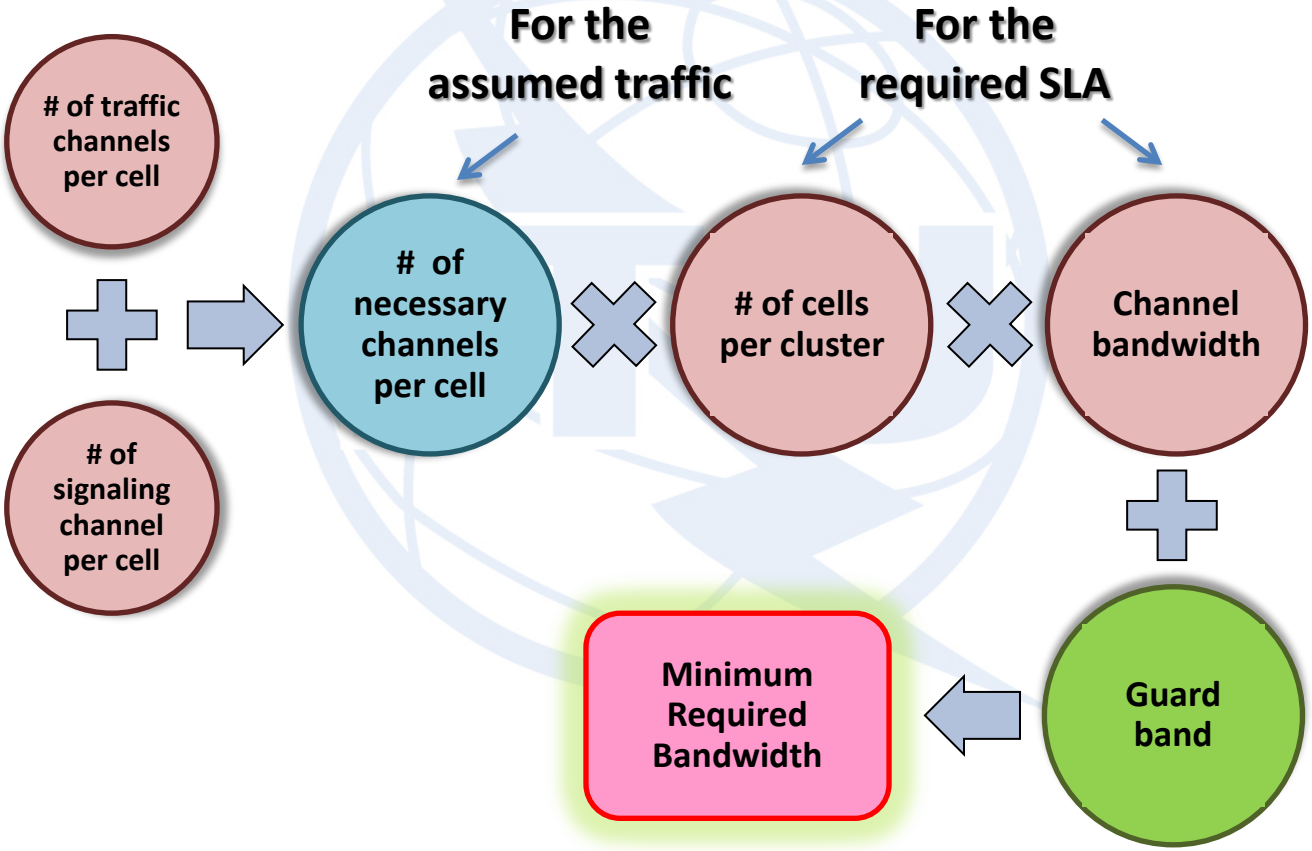
- **FDD duplexing scheme:**
  - No guard-band for regulator to segment spectrum for smaller blocks, but our experience shows that operators may face adjacent band interference if same tower used or towers become near to each other
- **TDD duplexing scheme:**
  - Without synchronization: A single TDD channel of 5 MHz size would assure non-interference operation. Sharp RRU filters would help for reduction of guardband size;
  - With uplink and downlink transmission synchronization: No guardband required, but the capacity may be reduced;

Emission Conditions of Frequency Band Plan

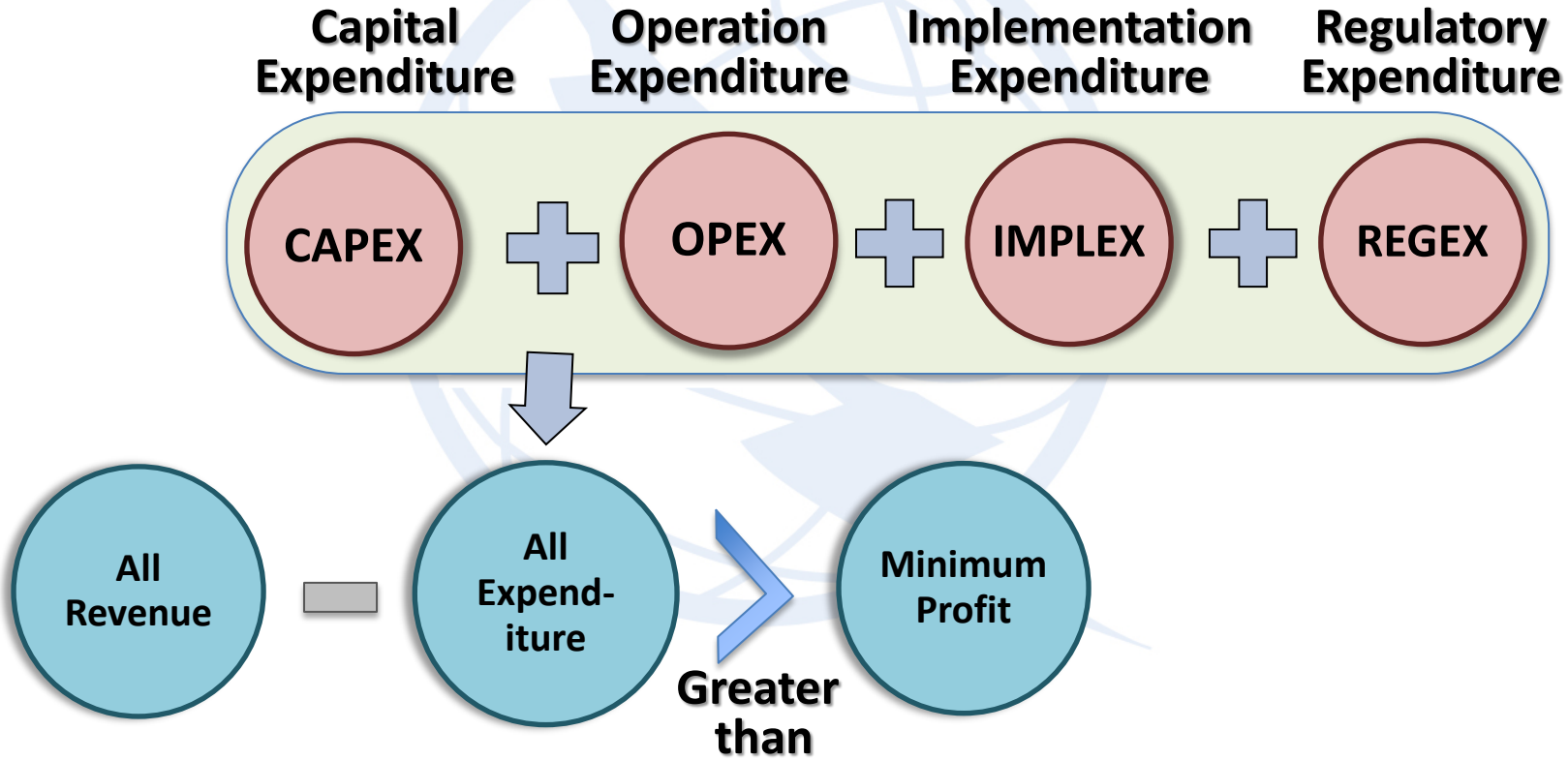
- Regulator may set, as license condition or separately:
  - Transmitter **radiation spectral mask** for in-band and out-off-band emission maximum levels to protect services in adjacent frequency bands
  - **Radiated power level** to restrict coverage area to licensed service-zones
  - Receiver **selectivity** and **sensitivity** to control network KPI



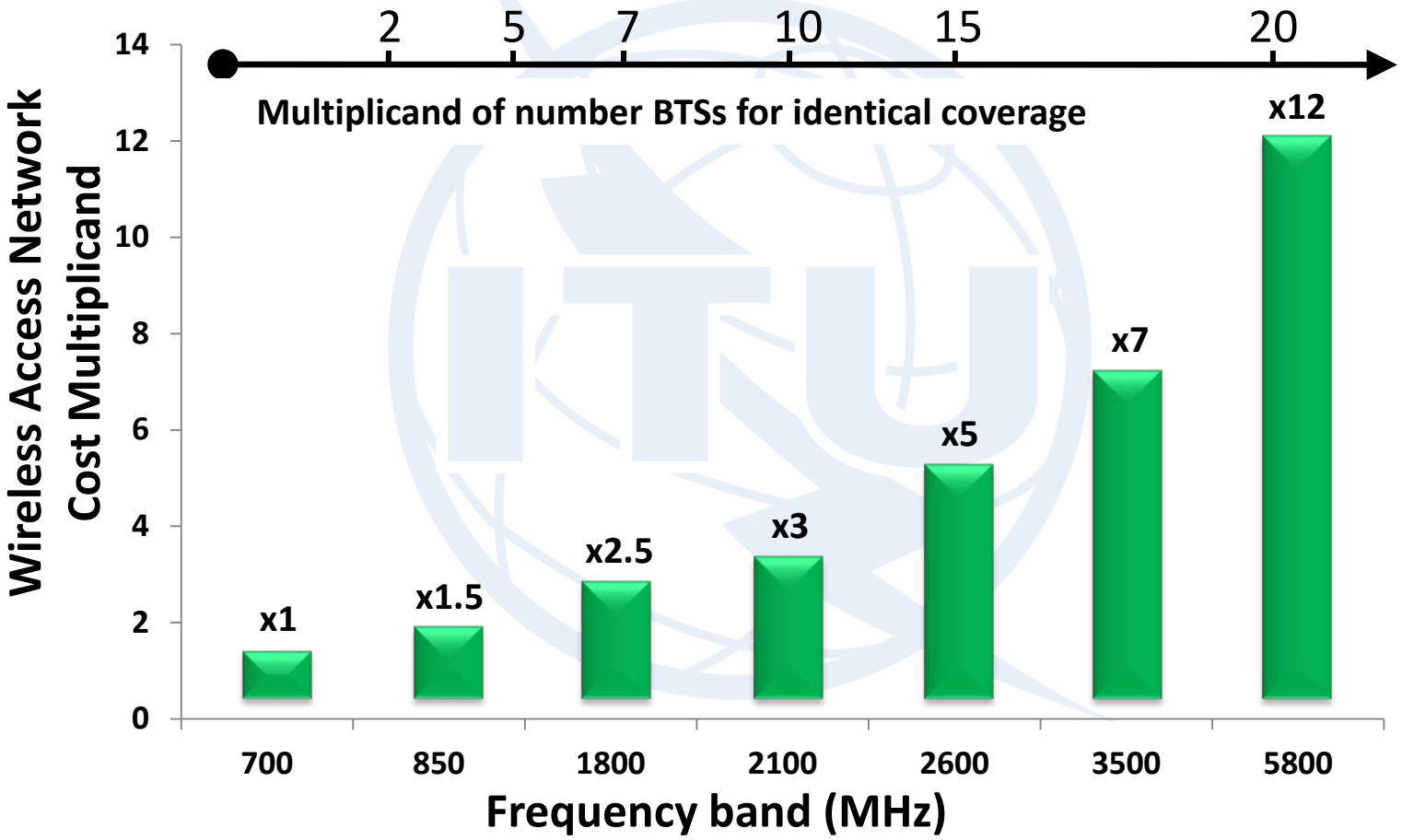
Minimum Amount of Spectrum from Technical Point of View



Minimum Amount of Spectrum from Economic Point of View

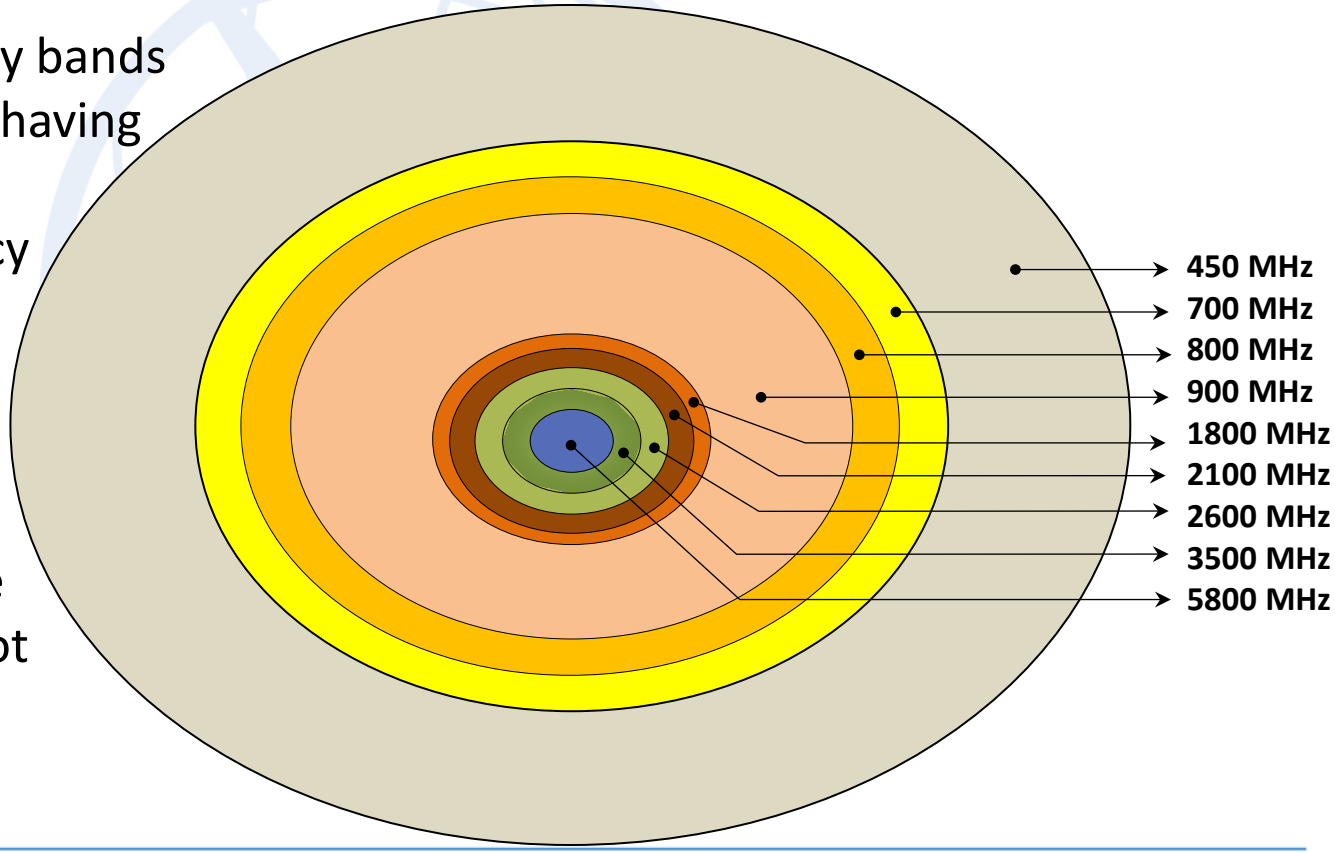


Frequency Band and CAPEX Dependence

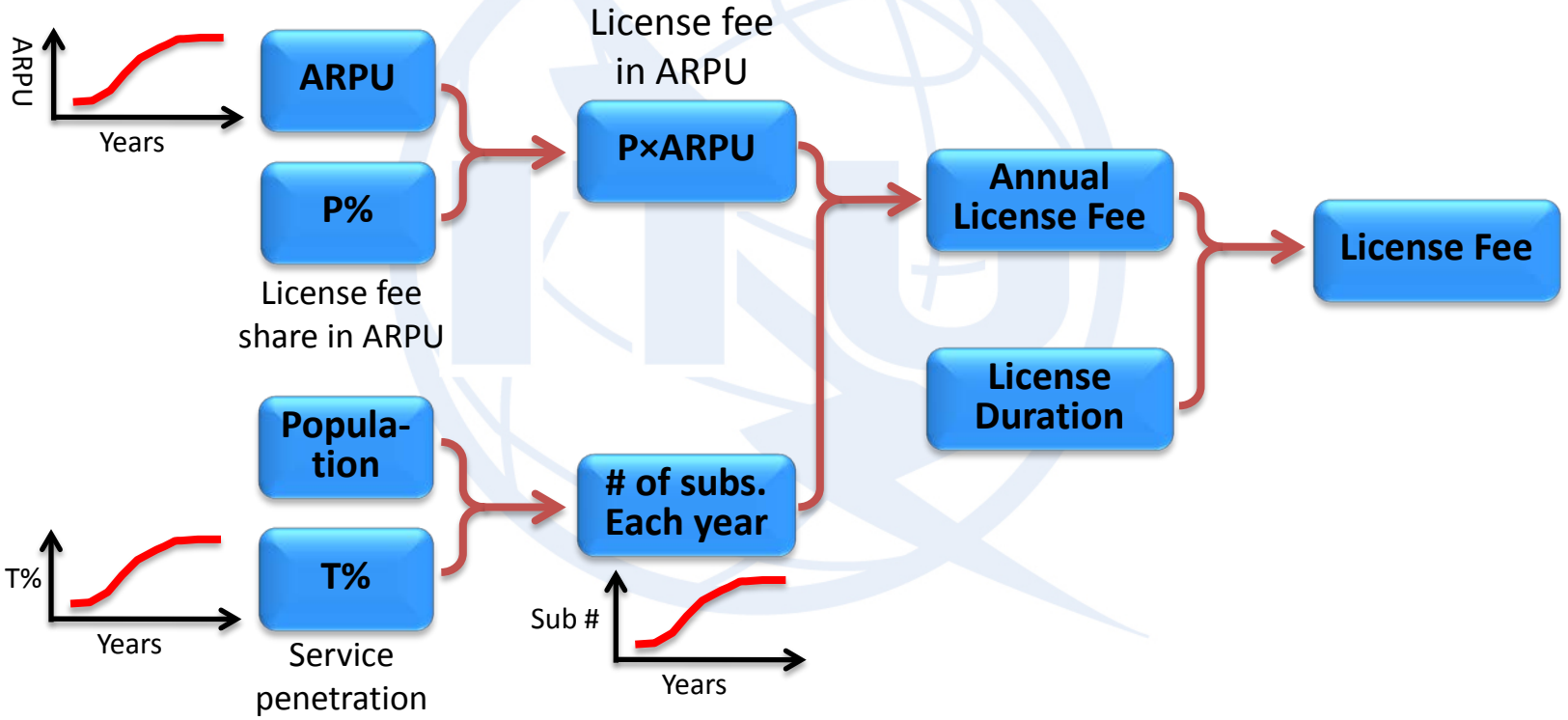


Comparing Relative Coverage Ares in Various Frequency Bands

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

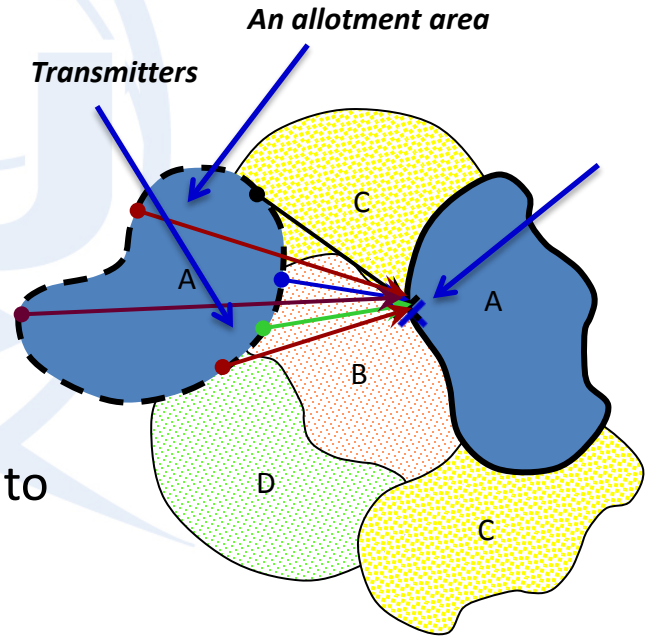


Bottom-Up Approach for Calculation of License Fee



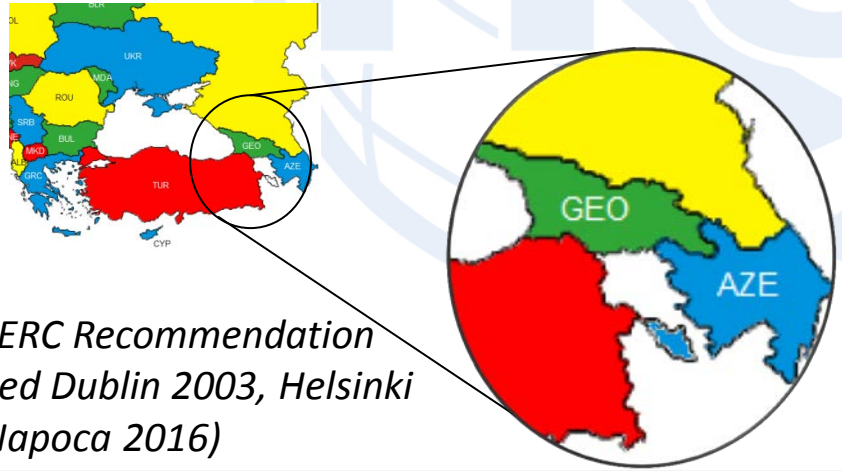
Geographical Planning of Spectrum
(Allotment Plan)

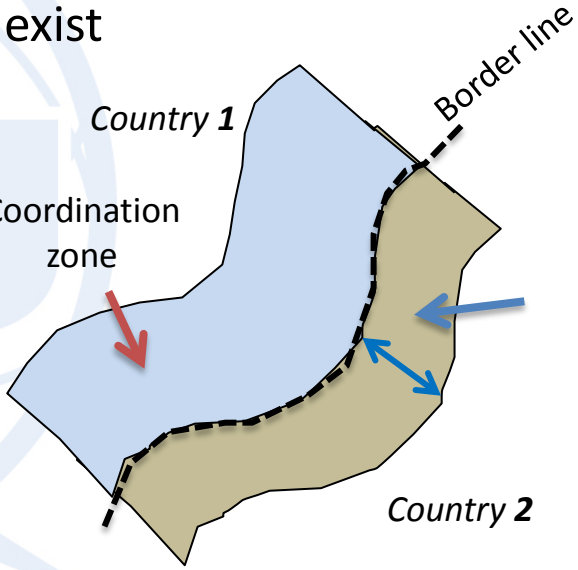
- Assigning of specific frequency blocks to given areas, without producing co-channel and adjacent channel interference to RX inside the other areas
- A reference propagation model, protection ratio, technical specification, minimum desired signal level (or BER) and emission masks are necessary for electromagnetic interference study
- In the study of a receiving point at the border of an allotment area, the aggregate interference level has to be calculated and has to be compared with threshold values
- Development of a technical tool is necessary to conduct above study



Exclusivity of Plan in Neighborhood to other Countries

- 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





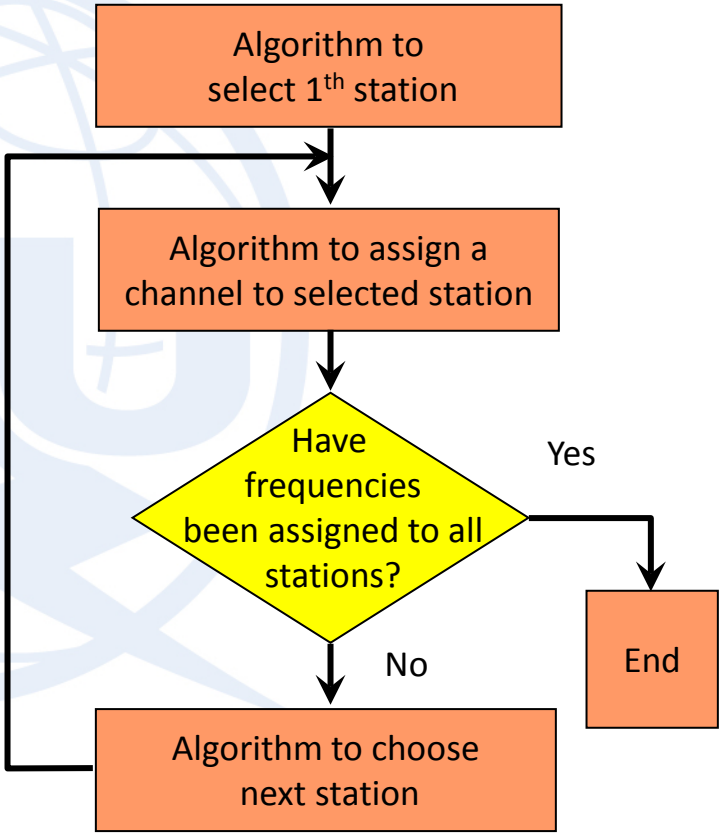
Reference: ERC Recommendation 01-01 (revised Dublin 2003, Helsinki 2007, Cluj-Napoca 2016)

Methods of Frequency Band Planning

- Linear frequency-site planning (based on uniform lattice)
  - Developed by Radio Broadcasting Institute in Hamburg
  - Used in St61, Ge63, RARC 1+ and Ge84
- Sequential frequency planning and assignment process
  - To fine a frequency for each station from list of stations
- Interference-free frequency assignment grids
  - Developed for land mobile service in Canada (Delfour & De Couvreur 1989)
- Cellular frequency-site planning
  - For cellular networks (channel repeat in $3.5R_0$ to $5.5R_0$)
  - Refer to Gamst, 1982 and Hale, 1981
- Flexible frequency-site planning
  - EMC procedure is in Vienna Agreement 2000, Ch.5
  - Use ITU-R SM.1599 for determination of the geographical and frequency distribution

Sequential Frequency Planning

- To find a frequency for each station in list
- Three algorithms shall be employed using combination of regulations and technical criteria



Re-farming of Spectrum

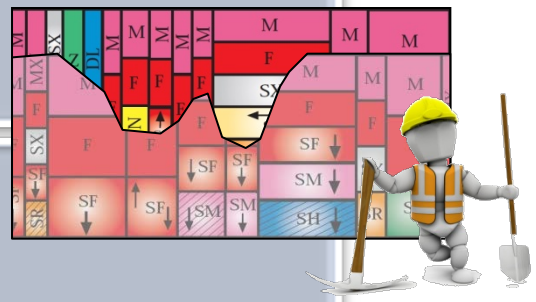
- The planned spectrum may have existing utilizations

Re-farming by Existing Users

- Operators upgrades technology of network
- Regulator may push operator according to a rollout plan
- Regulator may revise license conditions if reserved for such big changes, e.g. complementary technical conditions

Re-farming for New Users

- Existing utilization should be evacuated from planned frequency bands
- License conversion or stop of operation by license end re-farming by compensation, depending to the situation

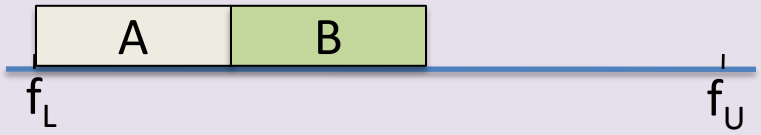


Practical Comments for Arranging of Frequency Blocks

- Contiguous allocation of spectrum for operators maximize spectral efficiency
- Future extension of allocated spectrum for operators to be considered
- Advance monitoring of concerned spectrum recommended

Examples (FDD)

Option 1:



- Future extension of A blocked
- Risk of adjacent band interference increased

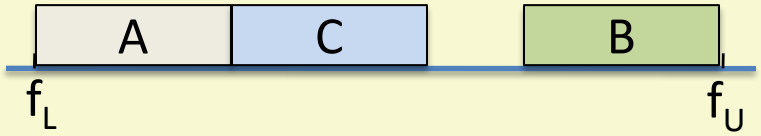
Option 2:

- Remaining spectrum segmented by two
- Risk of adjacent band interference increased

Option 3:

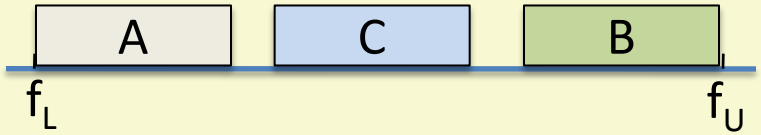
- No above difficulties

Option 1:



- Blocks extension of A, but no additional segmentation happens
- Risk of adjacent band interference increased

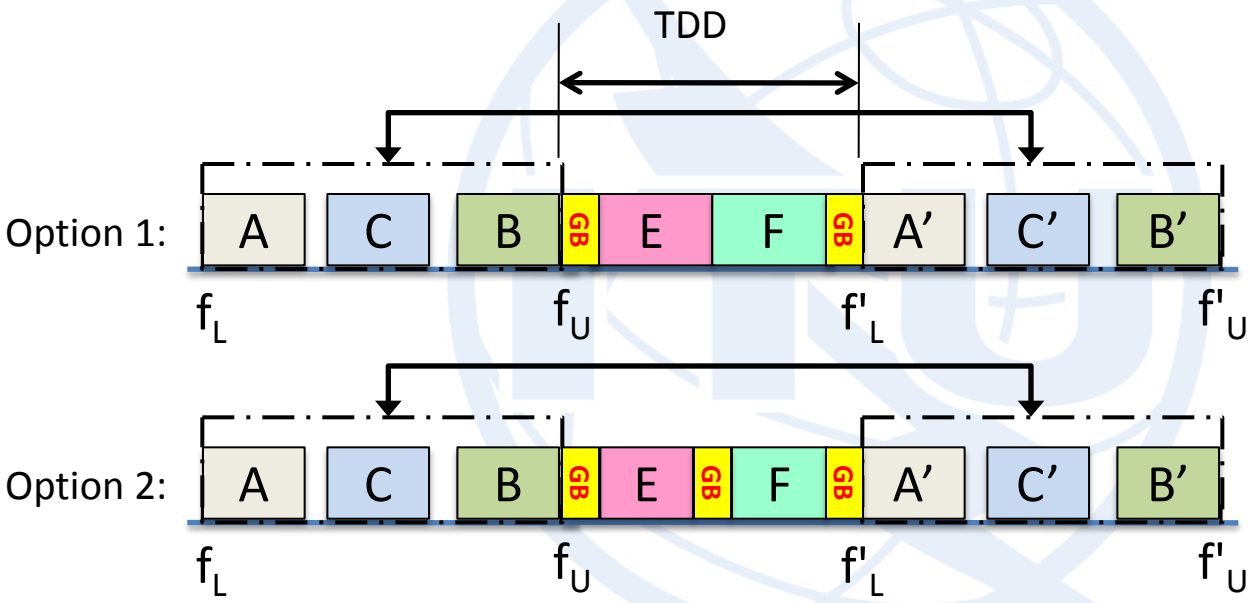
Option 2:



- Additional segmentation happened

✓ *C shall have big tuning range for removal of segmentation if new operator introduced*

Example (FDD + TDD)



- If there is synchronization requirement for **E** and **F**

- If there is no synchronization requirement for **E** and **F**

✓ *Regulator may allocate BG to the operators to use it once in areas became possible*

License Issuing Mechanism

- Auction
  - In an ***open*** auction participants may repeatedly bid and are aware of each other's previous bids.
  - In a ***closed*** auction buyers and/or sellers submit sealed bids
- Tender
- Allocation for a pre-determined price or a negotiated price

Primary Types of Auction

- **First-price sealed-bid auctions:** bidders place their bid in a sealed envelope and simultaneously hand them to the auctioneer. The envelopes are opened and the individual with the highest bid wins
- **Second-price sealed-bid auctions** (**Vickrey auctions**): same as above but second highest bid wins
- **Open Ascending-bid auctions** (**English auctions**): the price is steadily raised by auctioneer with bidders dropping out once the price becomes too high. This continues until there remains only one bidder who wins the auction at the current price
- **Open Descending-bid auctions** (**Dutch auctions**): the price starts at a level sufficiently high to deter all bidders and is progressively lowered until a bidder indicates that he is prepared to buy at the current price. He or she wins the auction and pays the price at which they bid
- **All pay auctions:** bidders place their bid in a sealed envelope and simultaneously hand them to the auctioneer. The envelopes are opened and the individual with the highest bid wins. All losing bidders are also required to make a payment to the auctioneer equal to their own bid
- **Homogenous item auctions:** such as spectrum auction (in which companies purchase licenses to use portions of the electromagnetic spectrum for communications)

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 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

Tender

- In this procedure, applicants and their bids are judged based on criteria set out beforehand, such as:
  - their financial resources,
  - their commitment to meet specified investment and build-out targets,
  - their ability to promote certain objectives such as:
    - rapid introduction of service,
    - wide geographic coverage,
    - reasonable prices,
    - quality and reliability

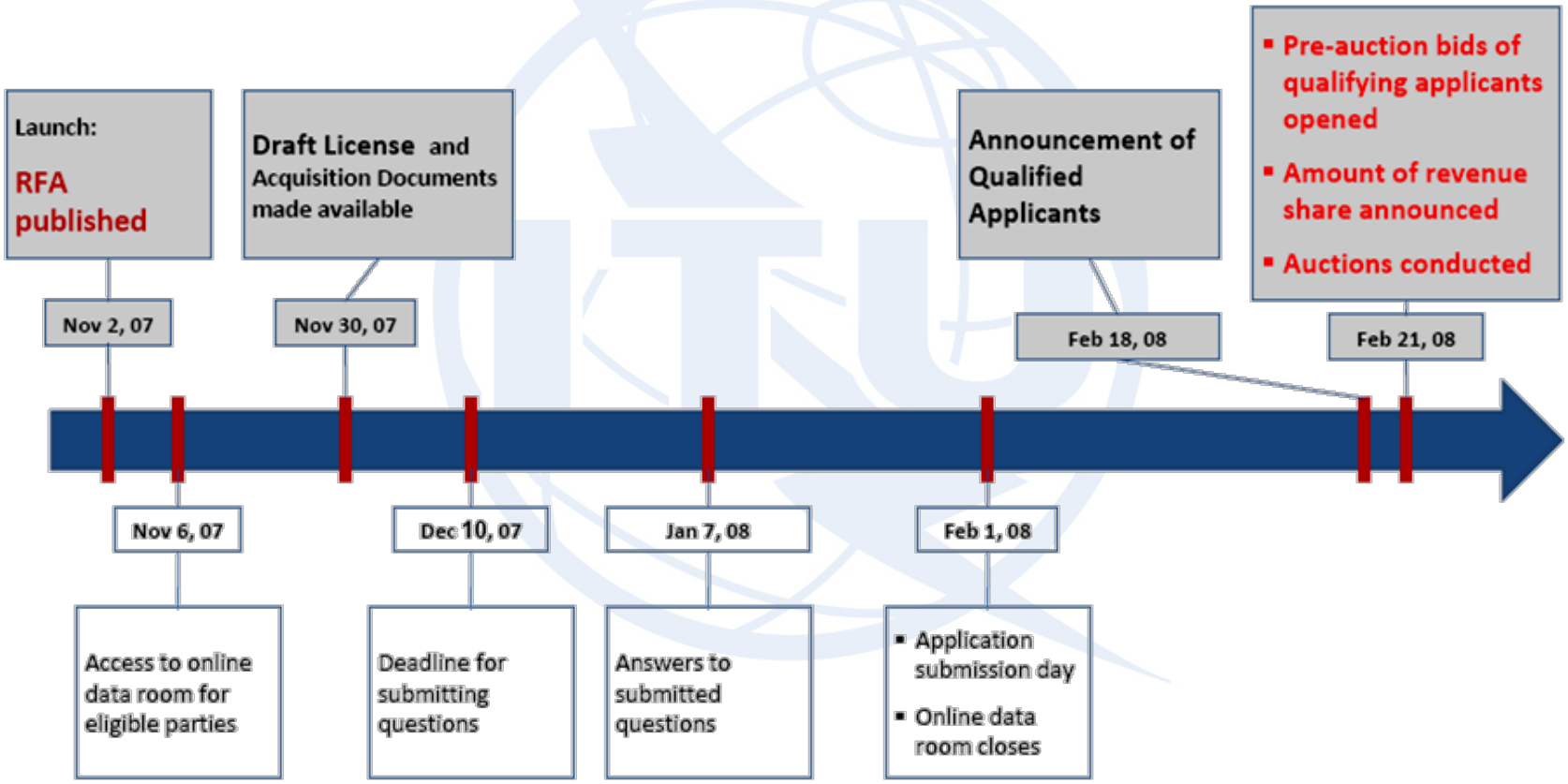
Tender
Advantage and Disadvantage

- **Advantage:**
  - The best service at the cheapest and fastest rate guaranteed
  - Speedy rollout and the extent of coverage
  - The regulator can examine the business plans of applicants
  - By awarding those who are most innovative, regulators can promote innovation
  - small license fees allow operators to provide better services that benefit the public
- **Disadvantage:**
  - Wasteful effects associated with a proposal-based process
  - Lack of transparency. The ability of the regulator to successfully identify the best proposals is limited

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



Thank You