EEE4121F-A
Mobile and Wireless Networks

Radio Spectrum

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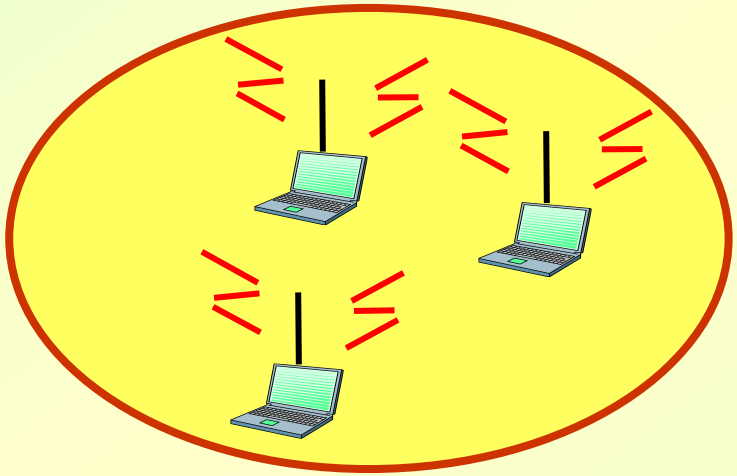
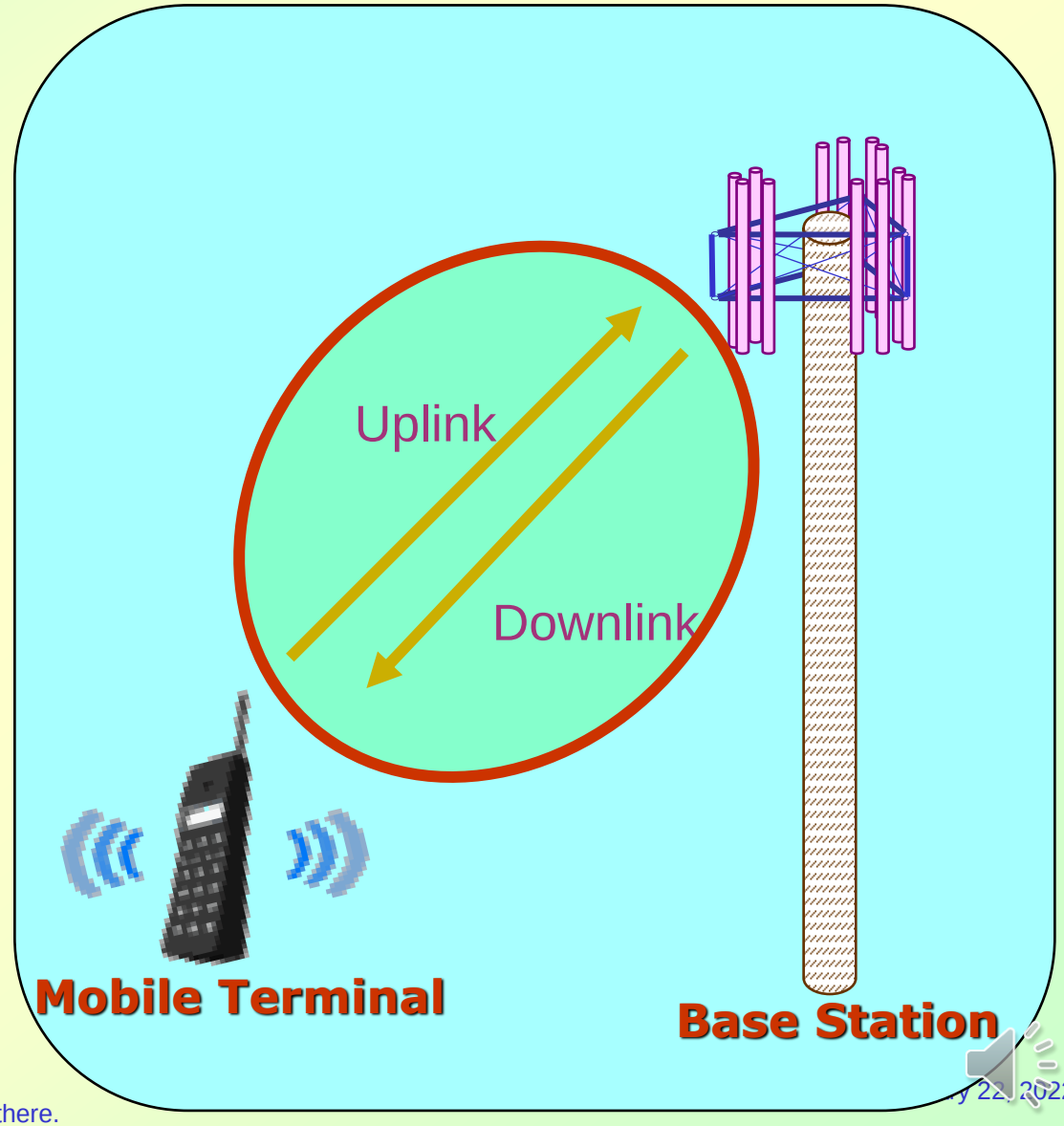
Frequency Spectrum Allocation

Radio frequency is one of the major resources in wireless communication

4 Major Resources

(1) Frequency
(2) Power
(3) Time
(4) Space





Radio Spectrum

- The radio spectrum is the part of the electromagnetic spectrum with frequencies from 3 Hz to 3,000 GHz (3 THz)
- Electromagnetic waves in this frequency range, called radio waves, are widely used in modern technology, particularly in telecommunication
- To prevent interference between different users, the generation and transmission of radio waves is strictly regulated by national laws, coordinated by an international body, the International Telecommunication Union (ITU).

Table of ITU Radio Bands

http://en.wikipedia.org/wiki/Radio_spectrum

Band name	Abbr	ITU band	Frequency and wavelength in air	Example uses
sub-hertz	subHz	0	< 3 Hz > 100,000 km	Natural and man-made electromagnetic waves (millihertz, microhertz, nanohertz) from earth, ionosphere, sun, planets, etc.[citation needed]
Extremely low frequency	ELF	1	3–30 Hz 100,000 km – 10,000 km	Communication with submarines
Super low frequency	SLF	2	30–300 Hz 10,000 km – 1000 km	Communication with submarines, Main power (50/60Hz)
Ultra low frequency	ULF	3	300–3000 Hz 1000 km – 100 km	Communication within mines
Very low frequency	VLF	4	3–30 kHz 100 km – 10 km	Submarine communication, avalanche beacons, wireless heart rate monitors, geophysics
Low frequency	LF	5	30–300 kHz 10 km – 1 km	Navigation, time signals, AM longwave broadcasting, RFID, amateur radio
Medium frequency	MF	6	300–3000 kHz 1 km – 100 m	AM (medium-wave) broadcasts, amateur radio
High frequency	HF	7	3–30 MHz 100 m – 10 m	Shortwave broadcasts, citizens' band radio, amateur radio and over-the-horizon aviation communications, RFID, Over-the-horizon radar, Automatic link establishment (ALE) / Near Vertical Incidence Skywave (NVIS) radio communications, Marine and mobile radio telephony
Very high frequency	VHF	8	30–300 MHz 10 m – 1 m	FM, television broadcasts and line-of-sight ground-to-aircraft and aircraft-to-aircraft communications. Land Mobile and Maritime Mobile communications, amateur radio, weather radio
Ultra high frequency	UHF	9	300–3000 MHz 1 m – 100 mm	Television broadcasts, microwave ovens, mobile phones, wireless LAN, Bluetooth, ZigBee, GPS and two-way radios such as Land Mobile, FRS and GMRS radios, amateur radio
Super high frequency	SHF	10	3–30 GHz 100 mm – 10 mm	Microwave devices, wireless LAN, most modern radars, communications satellites, amateur radio
Extremely high frequency	EHF	11	30–300 GHz 10 mm – 1 mm	Radio astronomy, high-frequency microwave radio relay, microwave remote sensing, amateur radio

Frequency Spectrum Allocation

- International Telecommunications Union (ITU)

  The International Telecommunications Union (ITU) is a specialized United Nations agency, headquartered in Geneva, Switzerland, that coordinates telecommunications matters among member countries. Use of the radio spectrum is largely coordinated through the Radiocommunications Sector (ITU-R), which develops technical coordination criteria and standards for such use, and through various periodic conferences attended by member nations of the ITU

- European Telecommunications Standards Institute (ETSI)

  The European Telecommunications Standards Institute (ETSI) is a non-profit organization whose mission is to determine and produce the telecommunications standards. It is an open forum that unites 490 members from 34 countries, representing administrations, network operators, manufacturers, service providers, and users

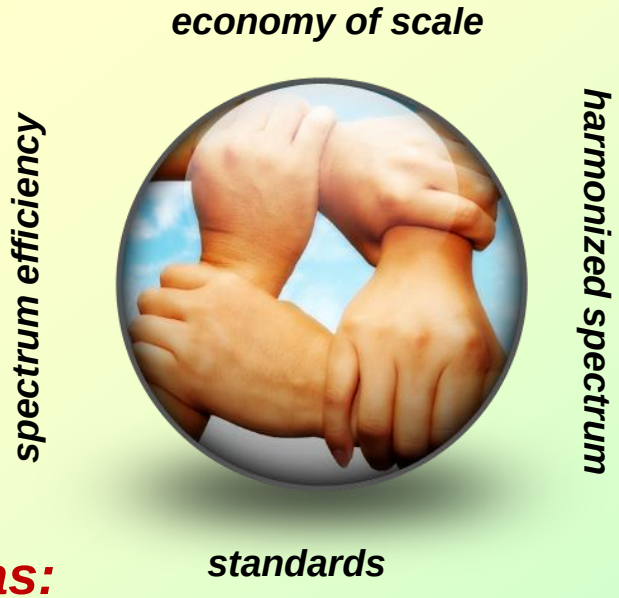
Frequency Spectrum Allocation

- In South Africa, the Independent Communications Authority of South Africa (ICASA) is the regulator for the communications, broadcasting and postal services sector.
- ICASA was established by an Act of statute the Independent Communications Authority of South Africa Act of 2000
- In USA, the Federal Communications Commission (FCC) is the regulator for communication services.
- The FCC is an independent agency of the United States government established by the Communications Act of 1934

Benefits of Harmonized Spectrum and Standards

Harmonized spectrum is key for development of public mobile broadband access as well as for industry to be able to successfully respond to national policy goals by providing standardized products

- *Economy of scale (based on a mass market)*
- *Easy cross-border coordination*
- *Cross-border operation (between countries)*
- *Global roaming capabilities*
- *Interoperability choice and convenience*
- *Efficient use of spectrum (also in border areas)*



Frequency Spectrum band may be classified as: (1) Unlicensed or (2) Licensed

Providing affordable services to all

Source: Ericsson 2011

(1) Unlicensed Frequency Spectrum

- There are unlicensed and licensed frequency spectrum
- Unlicensed frequency Spectrum requires no license: lower cost
- However, at the expense of not able to prevent other people to use the same spectrum causing interference and degrading the quality of service

(1) Unlicensed Frequency Spectrum

- The industrial, scientific and medical (ISM) are unlicensed radio bands
- They were originally reserved internationally for the use of RF electromagnetic fields for industrial, scientific and medical purposes other than communications.
- In general, communication devices using the ISM bands must tolerate any interference from ISM equipment

(1) Unlicensed Radio Spectrum (ISM bands)

ISM frequencies as per ITU table of allocation

The following bands are designated for industrial, scientific and medical (ISM) applications:

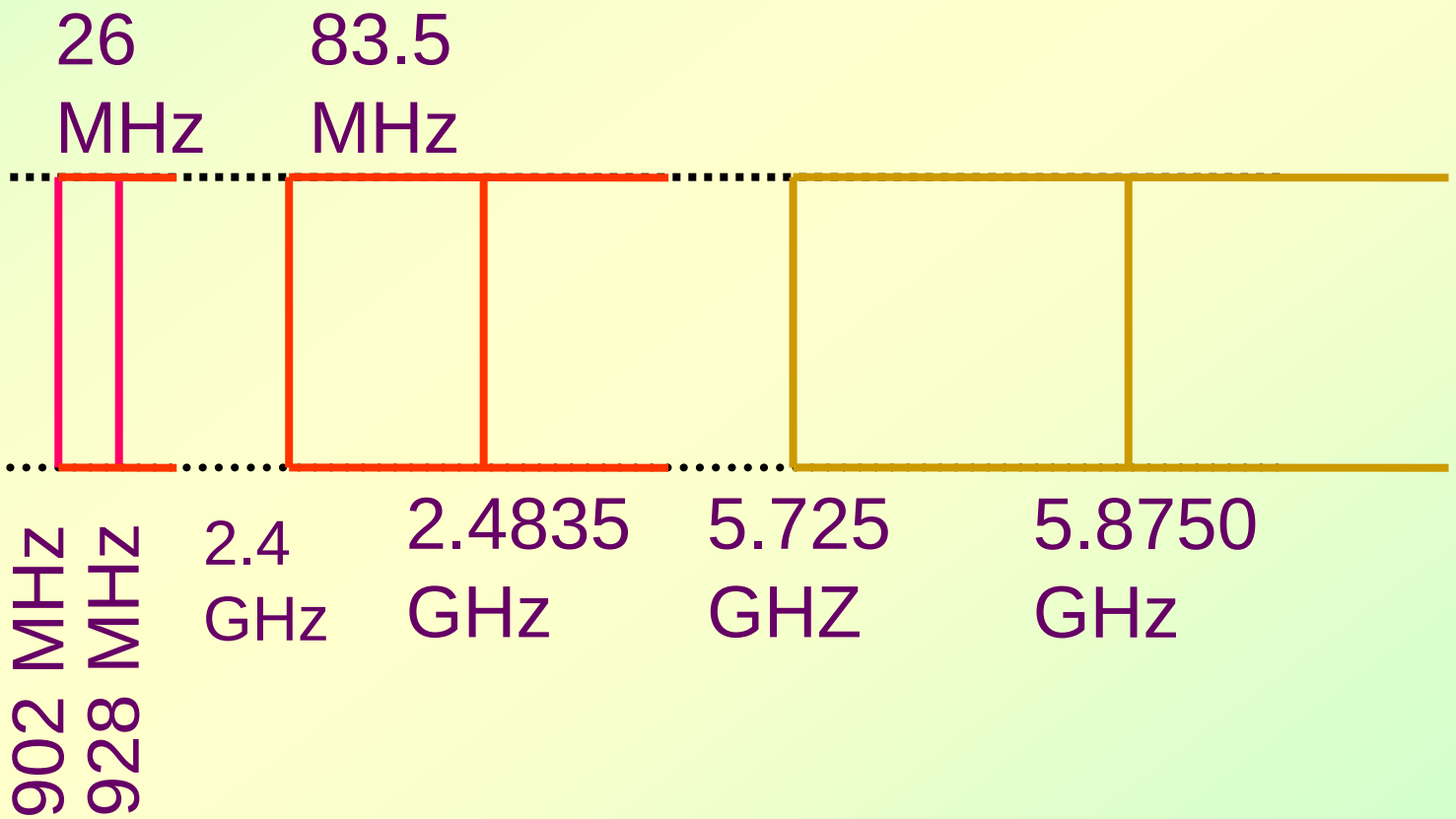
- 6 765-6 795 kHz (centre frequency 6 780 kHz),
- 433.05-434.79 MHz (centre frequency 433.92 MHz)
- 61-61.5 GHz (centre frequency 61.25 GHz),
- 122-123 GHz (centre frequency 122.5 GHz), and
- 244-246 GHz (centre frequency 245 GHz)

The following bands are also designated for (ISM) applications:

- 13 553-13 567 kHz (centre frequency 13 560 kHz),
- 26 957-27 283 kHz (centre frequency 27 120 kHz),
- 40.66-40.70 MHz (centre frequency 40.68 MHz),
- 902-928 MHz in Region 2 (centre frequency 915 MHz),
- 2 400-2 500 MHz (centre frequency 2 450 MHz),
- 5 725-5 875 MHz (centre frequency 5 800 MHz), and
- 24-24.25 GHz (centre frequency 24.125 GHz)

(1) Unlicensed Radio Spectrum (ISM bands)

- The 2.4 GHz is the only unlicensed band available worldwide (ISM band)



(2) Licensed Frequency Spectrum

- Use of spectrum by license holder in a geographic region is protected by the law in that nation
- In order to provide service to customers, operator must acquire the spectra at all cost
- Expensive licensing fee but better QoS because of exclusive right to use the spectrum

Spectrum Allocation Strategies

Spectrum can be allocated in the following two ways:

(1) Fixed spectrum allocation

(2) Dynamic spectrum allocation

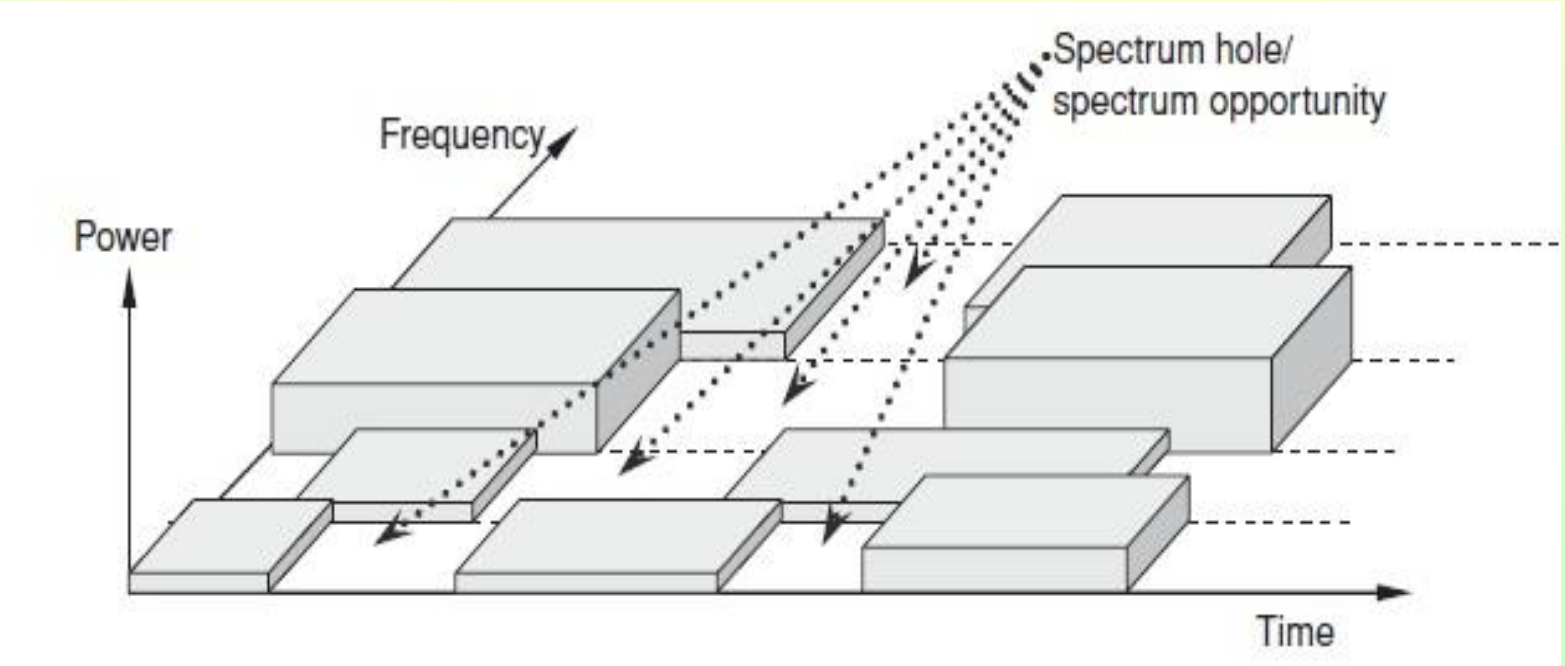
(1) Fixed Spectrum Allocation (licensed spectrum)

A fixed six-tuple definition of the right to access the spectrum is given as:

License **:⇔{**frequency, space, transmit power, licensee, type of use, duration of license**}**

Limitations of Fixed Spectrum Allocation

- Underutilization of the frequency spectrum as shown in the study by FCC.
- The command-and-control nature of the conventional spectrum allocation scheme which results in holes in the spectrum.



Limitations of Fixed Spectrum Allocation

- Fixed type of spectrum usage for specific services
- License granted for a large region
- Spectrum is licensed in large chunks.
- Prohibited spectrum access by unlicensed users (Secondary access)

(2) Dynamic Spectrum Allocation

Dynamic spectrum allocation can be classified in the following three ways:

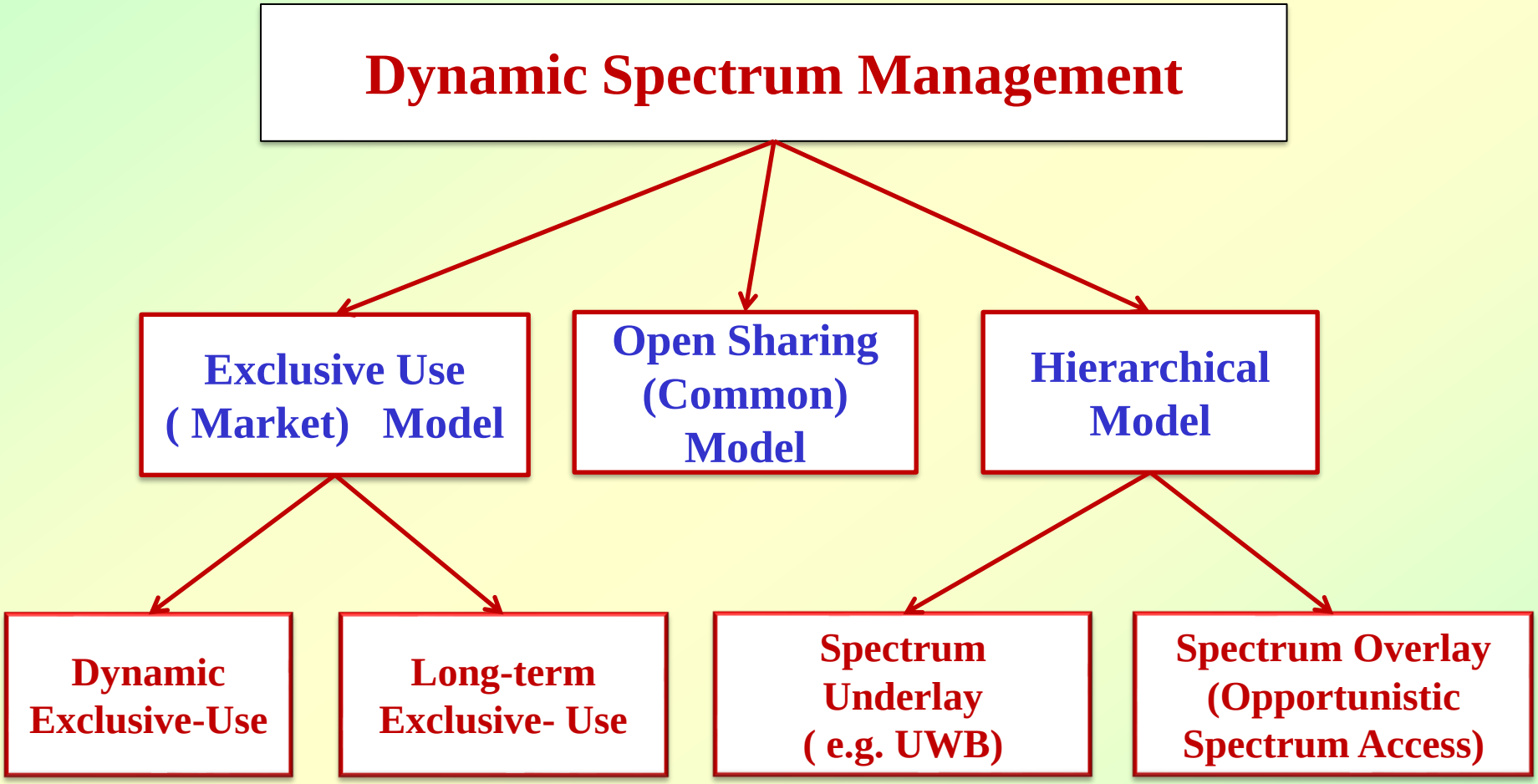
(a) Open sharing (Commons-use): Spectrum is open for access to all users i.e. no license required. E.g. the ISM band

(b) Hierarchical model (Shared-use): licensed users (primary) are allocated a frequency band which can be accessed by secondary (unlicensed) users. It is realized using:

- Spectrum underlay: transmits in the presence of primary users with a carefully regulated transmission power.
- Spectrum overlay: opportunistically exploits holes in the spectrum.

(c) Exclusive- use: A licensed user can grant access to its frequency band to an unlicensed user for a certain period of time.

Classification of Dynamic Spectrum Management Models



(A) Exclusive Use Model

The exclusive use model still retains the current spectrum fixed allocation, but with little flexibility given to the license holder for spectrum utilization; the two basic model here are: **Dynamic Exclusive-Use and Long-term Exclusive-Use.**

(b) Open Sharing Model

This model allows for the free access of a given spectrum by various devices based on some common rules (e.g. power of transmission).

Hence it is free to various networks once these common rules are observed.

Examples of the open shared or commons spectrum are the Institutional, Scientific and medical (ISM) 2.4GHz spectrum and the Unlicensed National Information Infrastructure (UNII) 5GHz spectrum.

(c) Hierarchical Model

This model allows unlicensed users to freely access the spectrum of the licensed users, but without causing harmful interference to the licensed users. Hierarchical model can be grouped into two:

(i) Spectrum underlay

The Primary user (PU) and the secondary user (SU) use the same spectrum at the same time and at the same place.

The SU transmits at low power such that the inference of the SU is less than the inference threshold for the PU.

(ii) Spectrum overlay

This is the most exciting and challenging approach. It allows SU to access white spaces in PU's spectrum and vacate within a time bound on the return of PU to such white spaces.

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“Ability may get you to the top, but it takes character to keep you there.”
- John Wooden

“Intelligence plus character - that is the goal of true education.”
-Dr. Martin Luther King, Jr

"The measure of a man's character is what he would do if he knew he never would be found out."
-Thomas Babington Macaulay

Ability may get you to the top, but it takes character to keep you there.