# Economical and Technical Impacts on Spectrum Management: A nightmate or a dream?

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# The Technical Facts about today's Spectrum



- Spectrum is a natural resource as water, energy… and has to be shared as other natural resources
- Spectrum can be re-used almost indefinitively as we increase the number of Base Stations and so the infrastructure cost
- Service given by spectrum usage is dependent on infrastructure design (MS to BS distance) and highly variable propagation conditions
- Different part of spectrum have different characteristics in particular propagation….

**Actions are needed to optimise spectrum usage (between applications and technologies) with technical constraints.**



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# Present Spectrum Allocation (1)



- Spectrum is allocated in bands « owned » by users due to technical differences and for simplicity of equipment design
- Every Network is run independently with basically NO sharing
- It is presently more economic to ask more spectrum rather than to increase the density of a network
- But in fact very few bands are really used at a given time and at a given place

**SPECTRUM is at the same time scarce and free for many users : we have to better PAY AND USE.**

**SPECTRUM is at the same time fully occupied (like broadcast services in UHF bands) and little used: we have to better SHARE - sharing means acceptable « Interference »**



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# Present Spectrum Allocation (2)



- Demand for spectrum will accelerate due to growing success of the different public radio systems like satellites, WANs, MANs, LANs and PANs,
- Nothing will be able to stop the move towards high bit rates everywhere and at any time,
- At the same time, other users of the spectrum (military, broadcast, scientific..) also increase their uses.



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# Present Spectrum Allocation (3)



- It seems that present radio resource management has reached its limits:

  - The allocation by frequency bands leads globally to an inefficient system where the usable spectrum is paradoxally at the same time fully occupied, in high demand and badly used,

  - The allocation of servives becomes obsolete since different technologies offer the same services and a technology can accommodate many services,

  - Allocation by country if no longer valid; technically and economically radio systems are developed to be used worldwide and so the corresponding frequencies.



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# Present Spectrum Allocation (4)



- Liberalisation and globalisation have fully invaded the various domains of frequency usages bringing their benefits in terms of dynamic competition, lower prices and better services.

- But, this makes more difficult the harmonisation and coordination of multiple users.

- Optimum spectrum usage should take into account the following fundamental principles:
  - **Market Driven Allocation and Assignment**
  - **Competitive service provision**
  - **Regulatory Flexibility and Technological Neutrality**
  - **International co-ordination.**



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# Technical Characteristics of Frequencies



- At transmission, the radio parameters of interest are
  - Frequency Band and BW
  - Transmitter location
  - Coding/modulation schemes
  - Power
  - Antenna diversity and gain
  - Spurious Emissions profile
- What is really matters is the signal at the reception and it is affected by
  - Frequency shift due to Doppler Effect
  - Time, frequency, space dispersion due to multipaths
  - Loss due to distance, masks…
  - Protection Ratio required against noise and interference

**In a Real Transmission Situations,**

- **Frequency strength fades rapidly away and this is different at different bands**
- **Signal dynamic ranges to more than 150 dB (a weak signal can bring an annoying interference and strong signal can introduce spurious emissions over a large bandwidth)**
- **A frequency can be reused indefinitely at distances and usage depends on the antenna location and height that are quite constrained.**



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# Various Sharing Methods



>Various Present Sharing Methods

- Time Sharing
- Frequency Sharing
- Geographical Sharing
- Code or power Sharing

>They are aimed to be Interference limited sharing

- Based on worse traffic conditions with QoS targets (lost traffic, delay, error rate and speech quality,…)
- Direct or indirect revenues must cover the infrastructure costs



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# Some Early Sharing Schemes



- PAMR : Many small traffics are trunked
- DECT : enables to share dynamically the same spectrum for very high efficiency. But, limited success to domestic and intra-company networks.
- Some users to share the same band :Example is military and GSM or WiFi in France – this is accepted when the usages are geographically separated.
- Ad-Hoc Systems: Such as Bluetooth, WiFi and WiMax,
- Ultra WideBand (UWB) :By spreading over a large band, the noise introduced in all bands is acceptable, because the spectrum is occupied and badly used. UWB is a false solution to real sharing problem.



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# Future Evolution in Spectrum Management



What does the future bring?

Spectrum is a precious commodity
and SHARING with acceptable interference is the future



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# Required Sharing Schemes and Priorities (1)



- General Sharing conditions should be GENERAL and not done on a case by case basis
- The key strategy for sharing of natural resources
  - **Provide infrastructure to satisfy in normal situation all demands**
  - **In case of exceptional (temporary) situations, set the priorities**

This implies:

- To satisfy all demands: Group the maximum of radio access systems in the largest available bandwidth:

**A step to introduce flexible/Unified Access to different networks, using Software Defined Radio (SDR) capacity (SDR is defined as the result of an evolutionary process from hardware-based equipment to fully software based equipment)**



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# Required Sharing Schemes and Priorities (2)



- Exceptional situations due to accidents, network failures, social events, etc. then demand/traffic can not be satisfied in those situations and we

  - Lower the quality : such as waiting time, delays, error rate, etc.

  - Set the priorities : Difficult issue since it is application dependent, simple rules can help such as privileges for some cases, higher cost categories and control mechanisms.



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# SPORT VIEWS Project: SDR and Cognitive Radio: Spectrum Management Implications (1)



| | Definition | General characteristics |
|---|---|---|
| **Software Defined Radio** | **Radio system**<br><br>In SDR based radio systems, functionality on physical transmission level is to a large extent implemented in software. | Creates the possibility for the radio system to **generate a wide variety of possible waveforms and associated settings**.<br>Many type of modulation can be accomplished over a broad range of frequencies, thereby an SDR is capable of servicing more than one class of service |
| **Cognitive Radio** | **Radio system**<br>Radio that is capable of cognitive behaviour (autonomously finds its way in the radio spectrum). More advanced approach where intelligent transmitters can measure their radio environment and adapt dynamically to a rapidly changing situation to maintain the best possible service. | Radio that is **aware of its environment** (vacant frequencies, user preferences, prevailing spectrum rules, and operator tariffs), and employs this acquired information in a reasoning process, that leads it to **decide on its transmission behaviour** |



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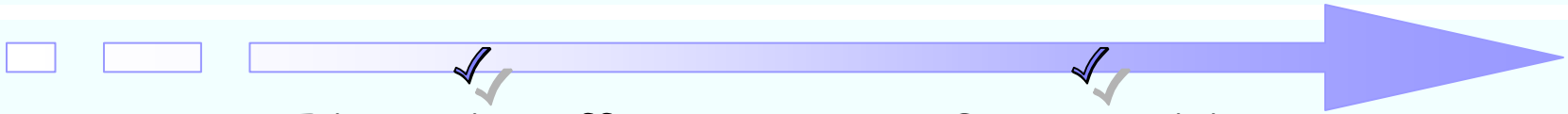
# SPORT VIEWS Project: SDR and Cognitive Radio: Spectrum Management Implications (2)

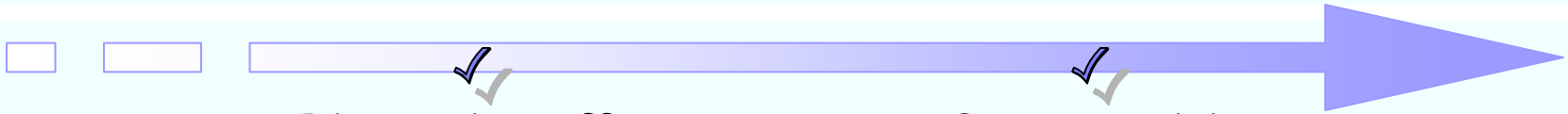




| | Disruptive effects | Opportunities |
|---|---|---|
| **Software Defined Radio** | | |
| Technology | Risk of **intentional or unintentional software modifications** and use of frequencies, output power, or modulation types that are not approved.<br><br>**Interference prevention** requirements<br><br>**Certification of SDR based systems and applications** | **Dynamic spectrum allocation systems**<br><br>**Adaptability to spectral environment** (channels, modulations schemes, access methods).<br>Minimization of power usage<br><br>**Adaptability to new standards** (implementation through software updates). Re-configurability of base stations and mobile terminals.<br><br>**Economies of scale** (fewer chip designs)<br><br>Might help **solving interoperability difficulties and legacy issues** |

# SPORT VIEWS Project: SDR and Cognitive Radio: Spectrum Management Implications (3)





| | Disruptive effects | Opportunities |
|---|---|---|
| **Cognitive Radio** | | |
| Technology | **Wideband sensing, opportunity detection and interference prevention** (primary user's signal detection technologies)<br><br>Necessity to **prioritize waveforms** (e.g. putting first short range systems operating in unlicensed spectrum)<br><br>Same **software (modifications) and hardware (certification) challenges** as SDR | **Dynamic spectrum allocation systems**<br><br>Allow multiple, independent communications devices to coexist within **shared spectrum**<br><br>**Multi-Mode terminals** (overcome incompatibilities among communication services)<br><br>Enable **secondary markets and spectrum leasing** |



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# Spectrum Pricing (Economical Approach)



- Money is the base of our economic system and can be extended to regulated spectrum allocation:
  - Spectrum users come from domains with very different constraints and motivations: military, broadcast, telecom,..
  - Spectrum Pricing should be proportional to the business for which spectrum is to be used (opposition to high prices to get a license)
  - Safe harbour for public interest applications (military and scientific applications) - different pricing or even no pricing should apply!!
  - AFTER ALL, paying is not enough: spectrum must be used for the benefit of all -any spectrum users should pay for its spectrum rights an use them (PAY&USE principle)
  - Spectrum markets (auctions and secondary trading) should be limited and used with caution.
  - Spectrum should never become a free source of income nor a Stock Exchange value good, but fees should be aimed at incentives or means for better radio resource management through refarming funds at national and international levels, incentives for better efficiency and incentive for radio interference-pollution.



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# Conclusions (1)



- Today's Radio Resource Management is facing a dramatic need for evolution with no clear way ahead.
- The challenge is important since many interesting developments and services that can affect everybody's life can exist only if a better spectrum sharing is organised.
- Spectrum Sharing is still a feudal system of the middle age, i.e. each network has full right on its territory.
- This cake slicing approach must rapidly evolve to a flexible, evolutive co-ordination between users



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# Conclusions (2)



- New sharing schemes are necessary and it should take place in time, in bandwidth, in power, in geographical locations etc, at the same time, and **ALL TOGETHER**
  - SDR/Cognitive Radio have a high potential for dynamic spectrum management
  - SDR products and techhnology are a reality today
  - **Cognitive Radios** have the ability to implement protocols and policies beyond traditional communications
- Need to set up new rules and new international working groups to establish the rules

**SUPER DYNAMIC SPECTRUM MANAGEMENT BASED ON GENERALISED SPECTRUM PRICING IS THE FUTURE**



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