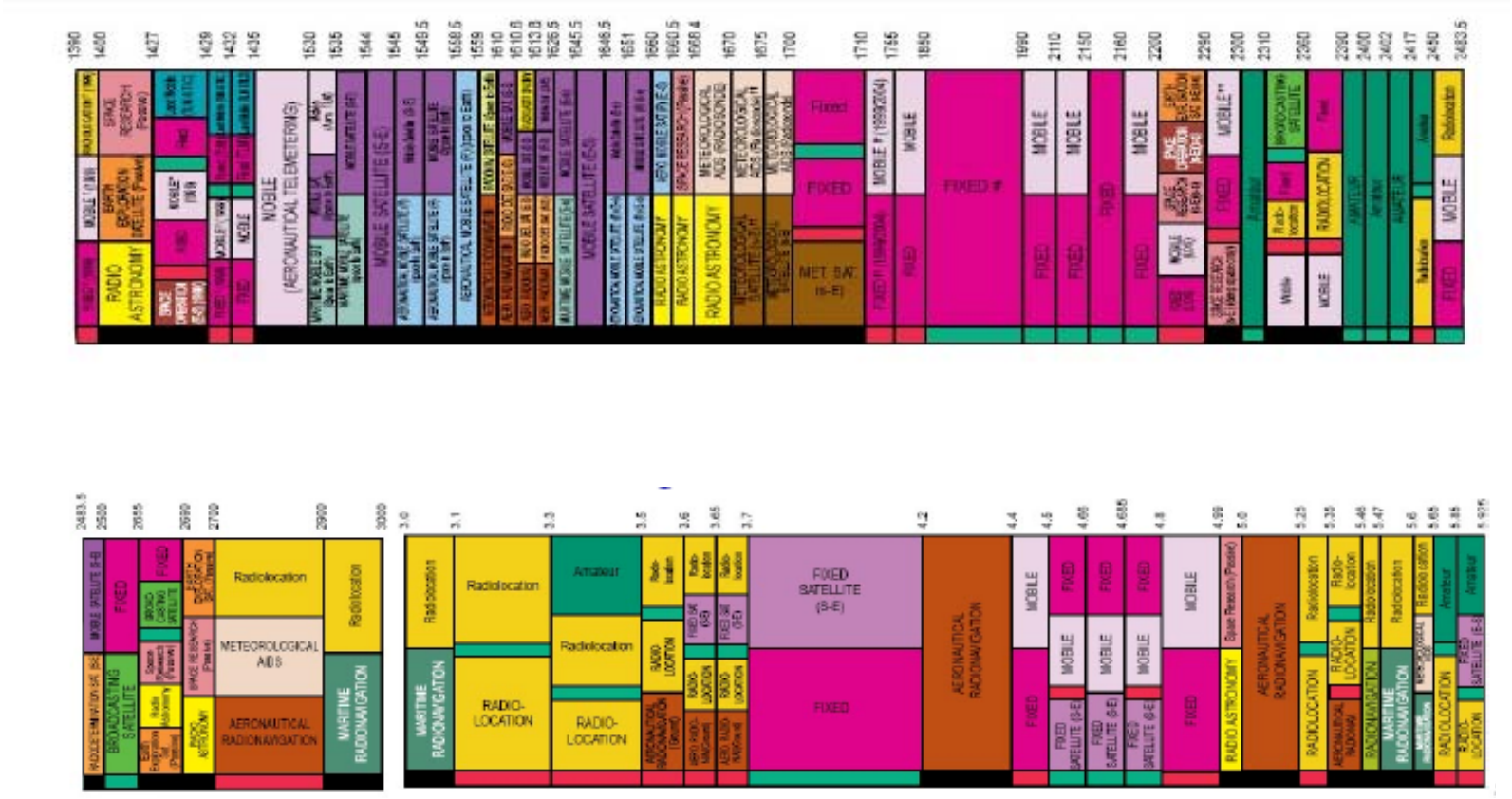
Cognitive radio Research Challenges

Aawatif M. Hayar

Mobile Communications Department, Eurecom Institute, Sophia Antipolis, France

E-mail; aawatif.menouni@eurecom.fr

Spectrum occupation from 1.39 to 5.923 GHz



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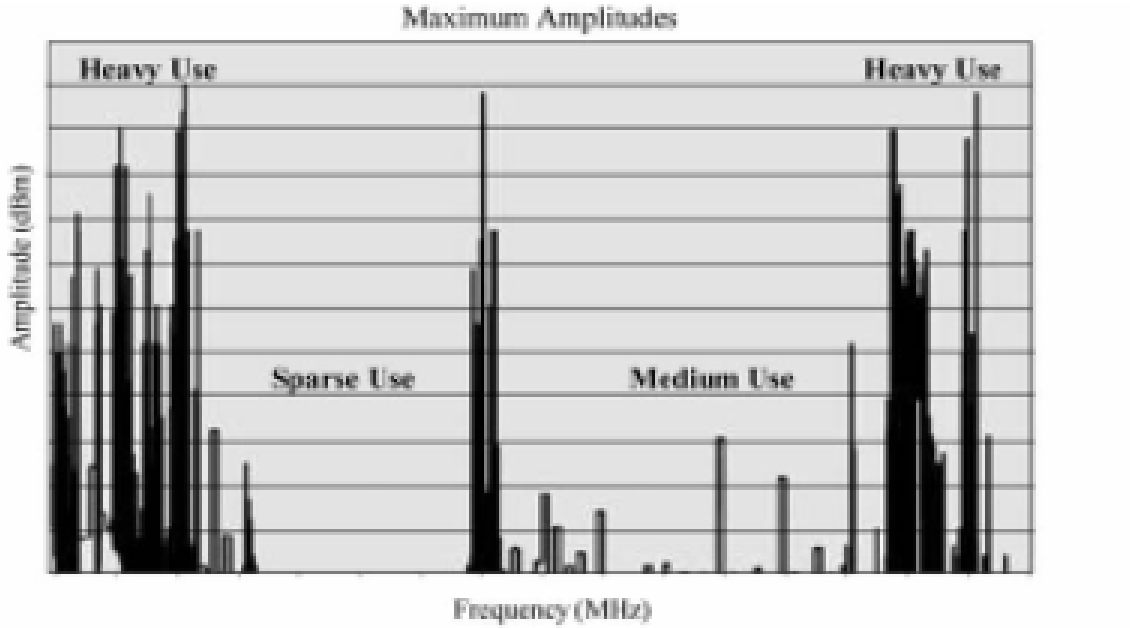
Spectrum utilization

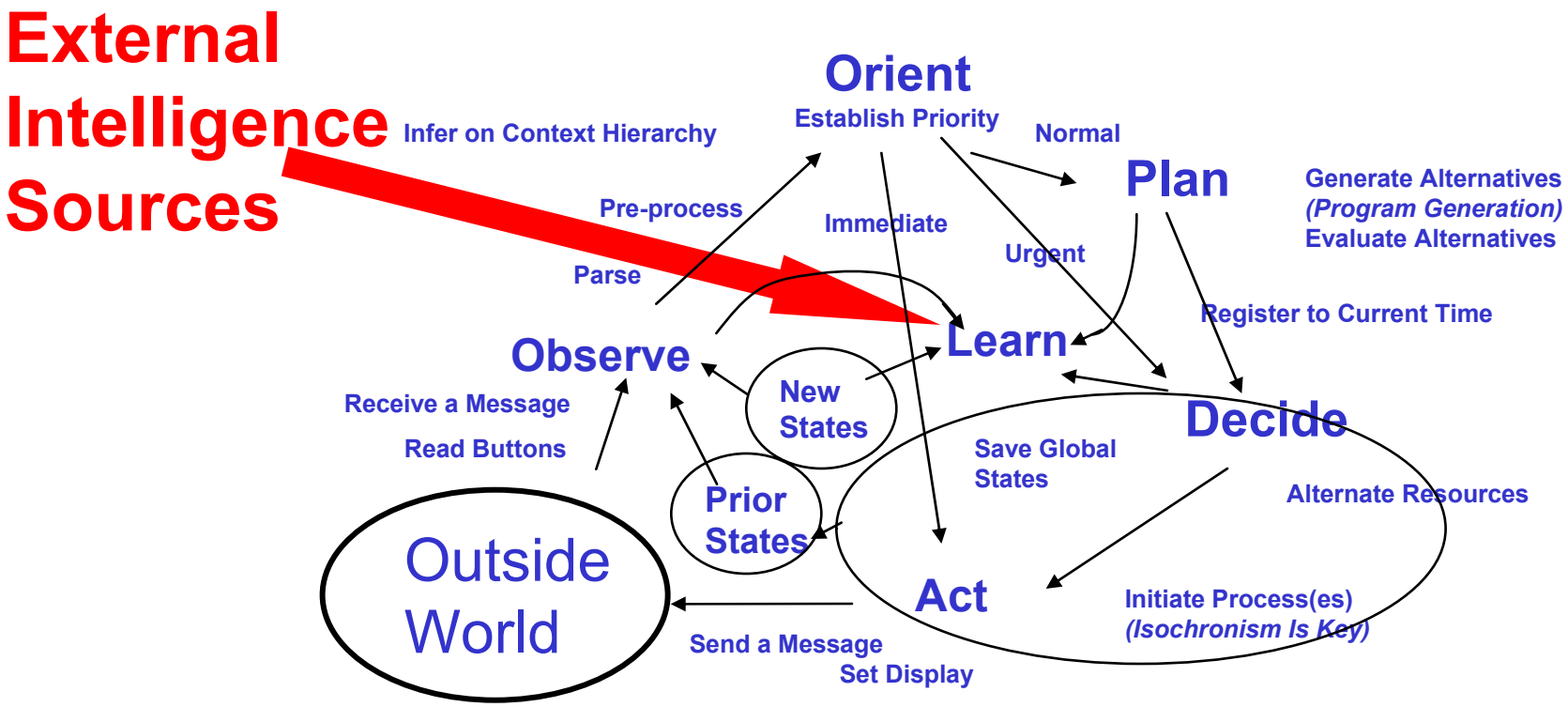
- In some locations and/or at some times of the day, 70 percent of the allocated spectrum may be sitting idle.
- The FCC has recently recommended that significantly greater spectral efficiency could be realized by deploying wireless devices that can coexist with the licensed users.



Cognitive radio: Definitions

- A new class of radios was defined by the term cognitive radio
- Several definitions (and variations) of Cognitive Radio exist:
  - Mitola- ”Cognitive radio signifies a radio that employs model based reasoning to achieve a specified level of competence in radio related domains”.
  - FCC - ”A cognitive radio (CR) is a radio that can change its transmitter parameters based on interaction with the environment in which it operates”.
- Such devices must be able to:
  - sense the spectral environment over a wide bandwidth,
  - detect the presence/absence of legacy users (primary users),
  - adapt the parameters of their communication scheme to their environment
  - communication does not interfere with primary users
- Spectrum Etiquette

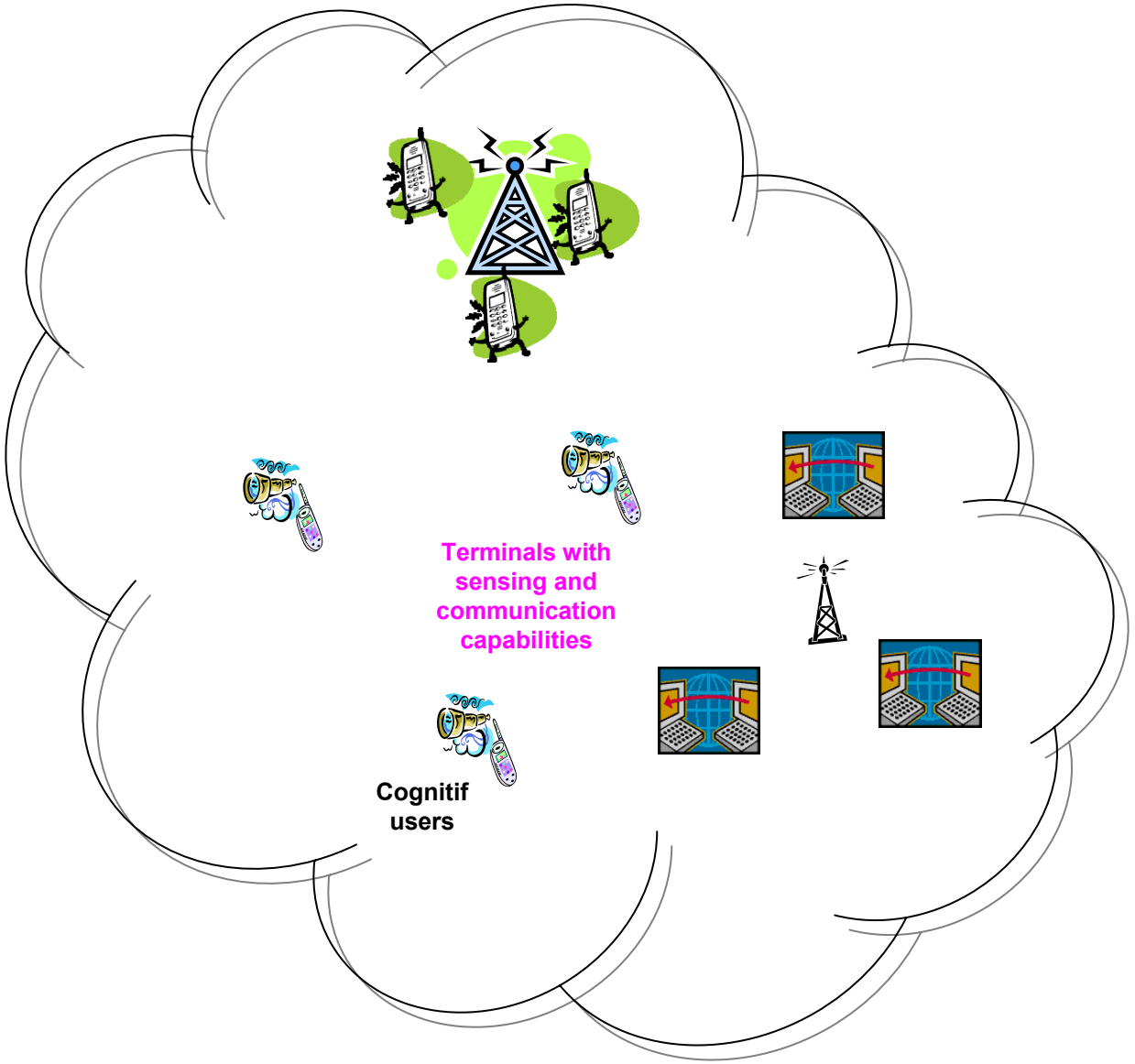
How Does a Cognitive Radio Get So Smart?



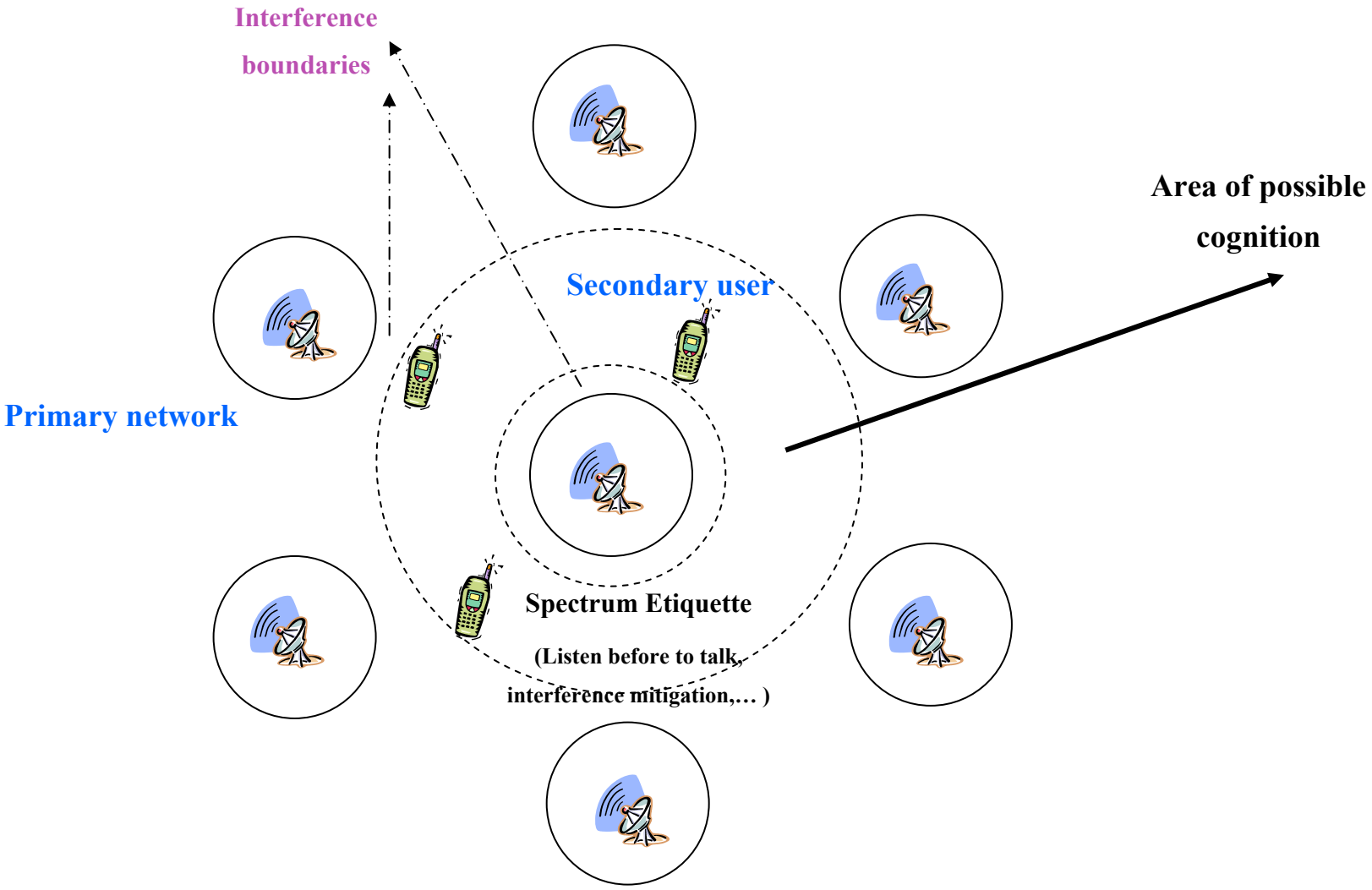
The Cognition Cycle

** J. Mitola, "Cognitive Radio for Flexible Mobile Multimedia Communications", IEEE Mobile Multimedia Conference, 1999, pp3-10*

Cognitive radio context



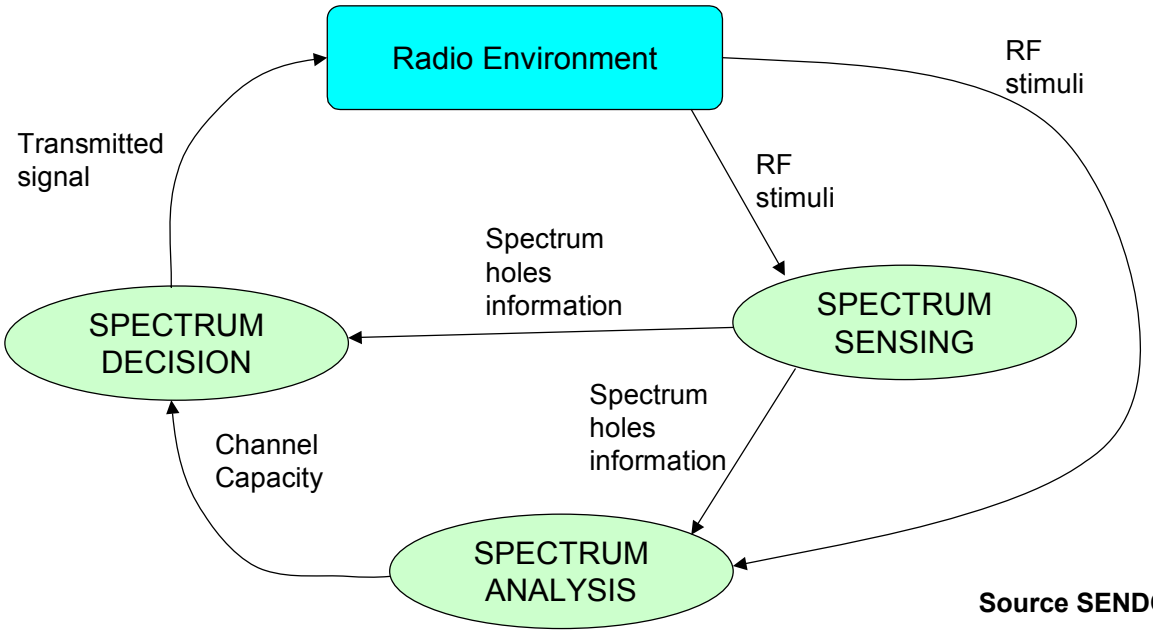
Area of possible cognitive radio operation



Cognitive radio challenges

- Efficient spectrum sensing techniques over wide bandwidth enabling opportunistic spectrum utilization decisions
- Interference management and control enabling multistandards co-existence
- Resource management, scheduling and power allocation algorithms
- Localization techniques
- Cognitive radio shared channel
- Model Based Reasoning for better match between user needs, local content and environmental context
- Distributed collaborative communication strategies
- Distributed protocols
- Cognitive and flexible radio architectures: Hardware/software design
- Regulation issues

Novel spectrum sensing techniques

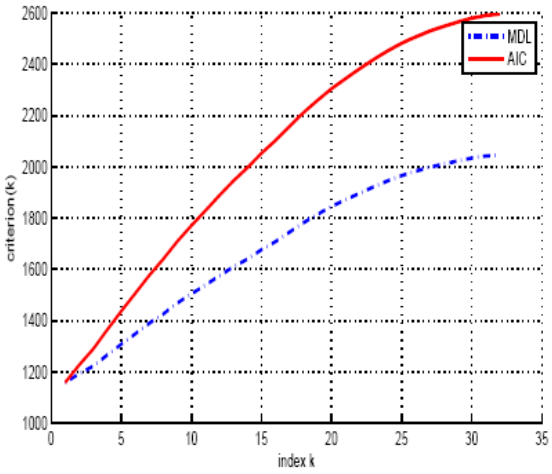


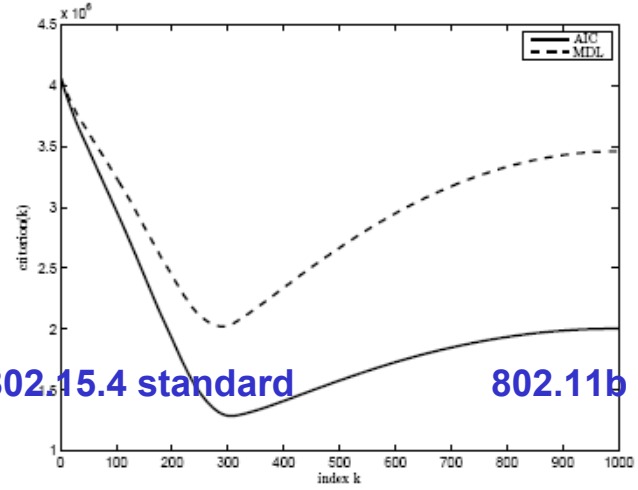
Source SENDORA Project

Novel Spectrum sensing techniques

- Classical sensing techniques with a priori knowledge
  - Cyclostationarity based
  - Matched filter based
  - Energy detection based
  - Sub space analysis based sensing
    - White hole: Noise is dominent, ‘large’ space dimension
    - Black hole: Signal is dominent, ‘reduced’ space dimension

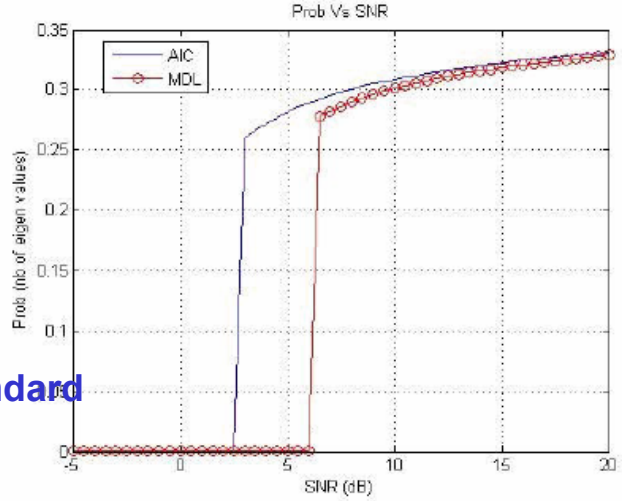
Sub Space Estimation Based Sensing





802.15.4 standard

802.11b standard

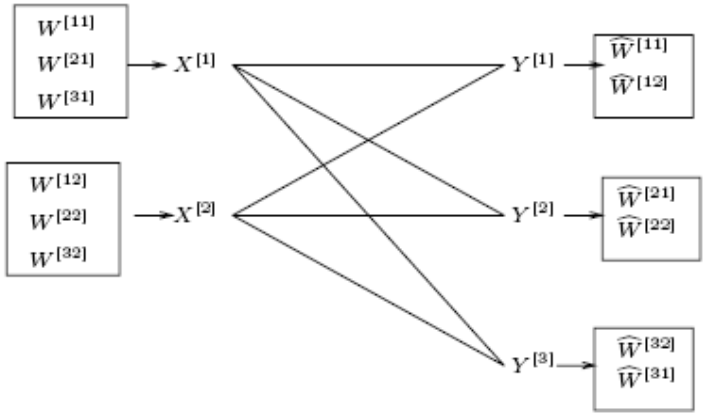


*Haddad, Majed;Menouni Hayar, Aawatif;Debbah, Merouane;Fetoui, Hedi "Cognitive radio sensing information theoretic criteria based", CrownCom 2007, 2nd International Conference on Cognitive Radio Oriented Wireless Networks and Communications, August 1-3, 2007, Orlando, USA

Interference Management, Example: X channel

Viveck R. Cadambe and Syed A. Jafar, have shown that the total number of degrees of freedom of the X channel with M transmitters and N receivers is

$$\frac{MN}{M+N-1}$$



They have also shown that this outerbound is achievable through **interference alignement** based on a simple TDMA strategy

* Viveck R. Cadambe, Syed A. Jafar, Degrees of Freedom for Wireless X Networks, preprint http://newport.eecs.uci.edu/~syed/newpage/resume.html#publicationslist ed. 22Nov07

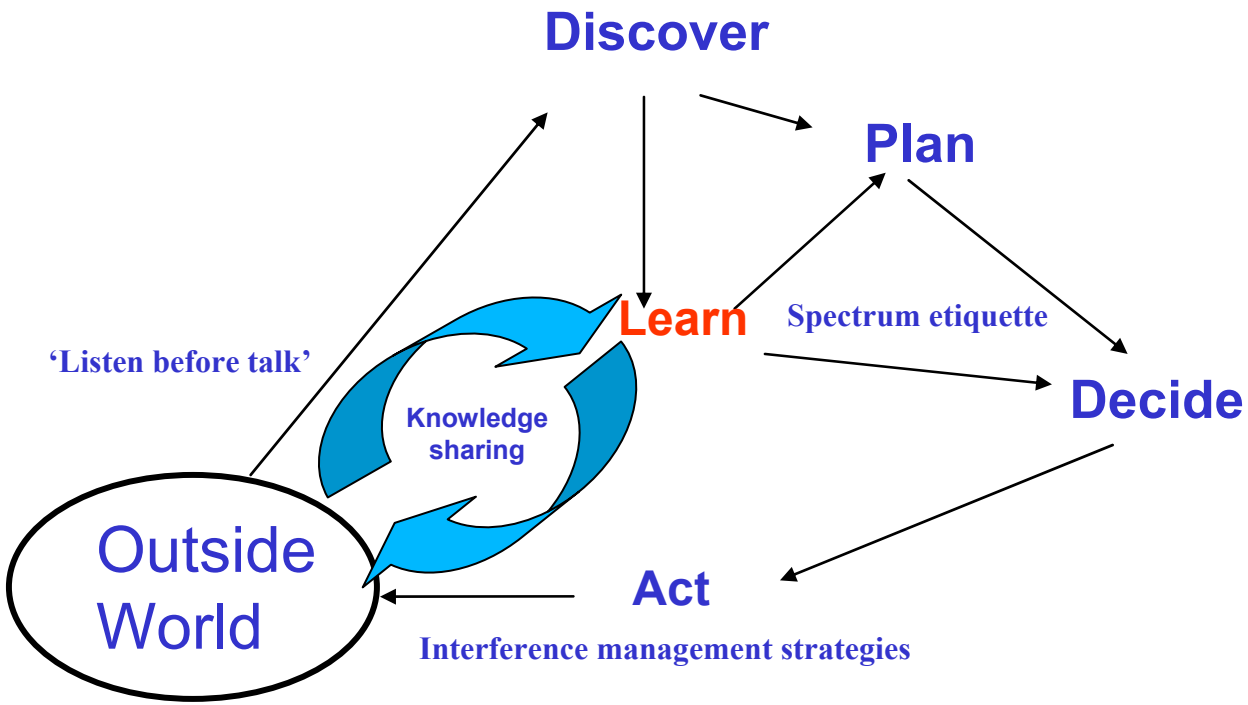
Cognitive radio has to guarantee "Sustainable" communication opportunities by **minimizing interference**!

Collaborative communications and relaying protocols

- **To collaborate or not to collaborate?**
  - **Novel collaborative transmission techniques have to be designed in accordance with the various interference constraints, in order to maximize or minimize various QoS metrics of interest (e.g. capacity, delay, etc…) in the presence of primary users.**
  - **Design of novel co-operative processing algorithms optimising (separately or jointly) the various processes involved, such as channel estimation, detection, synchronization, MIMO coding...**
- **Distributed protocols**

* Erik G. Larsson and Eduard A. Jorswieck,"The MISO Interference Channel: Competition versus Collaboration", Allerton 2007

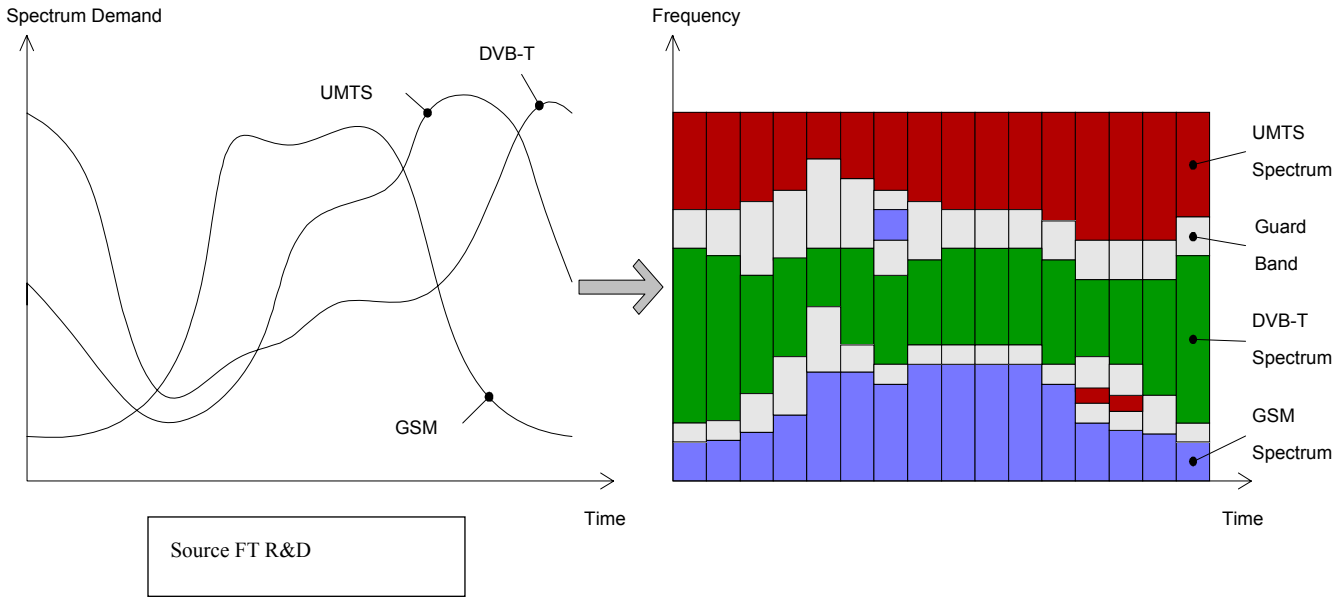
Information versus knowledge



The "modified" Cognition Cycle

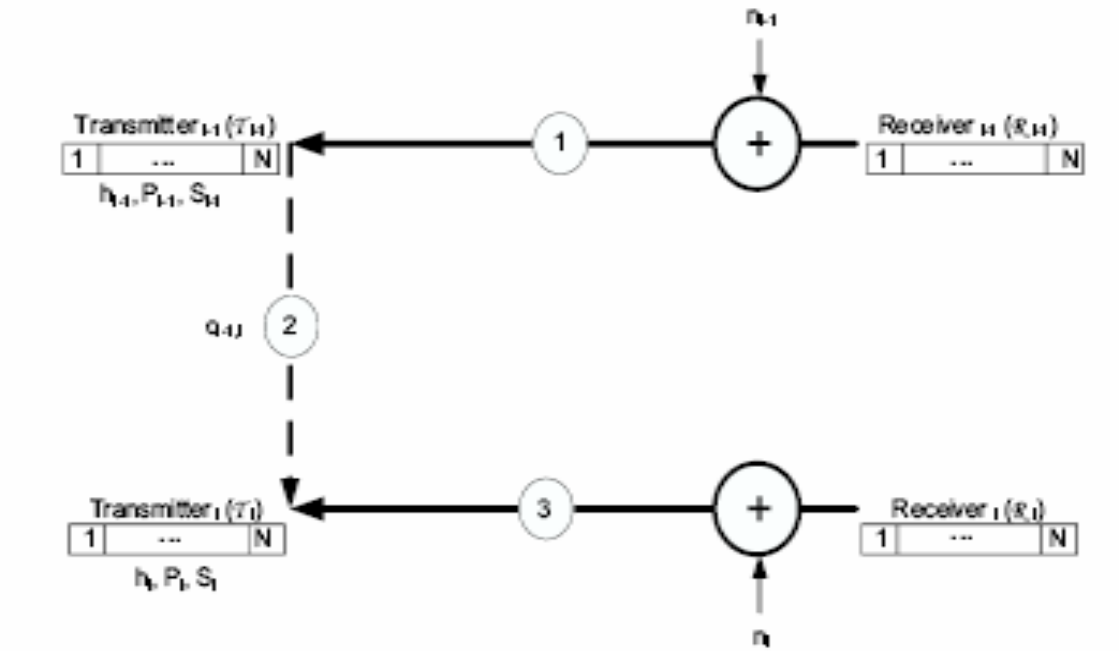
- Knowledge grow when it is shared

Cognitive radio scenarios: Spectrum Sharing opportunities

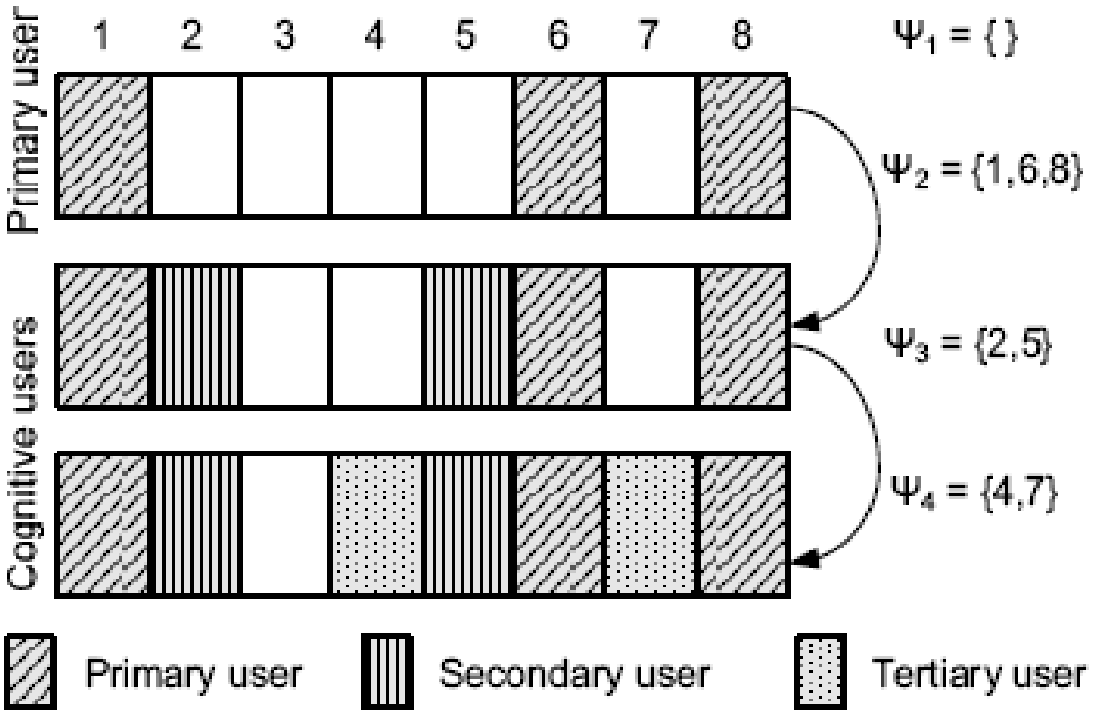


Source FT R&D

Resource allocation strategies: Example (1)



Resource allocation strategies: Example (2)



Resource allocation strategies: Example (3)

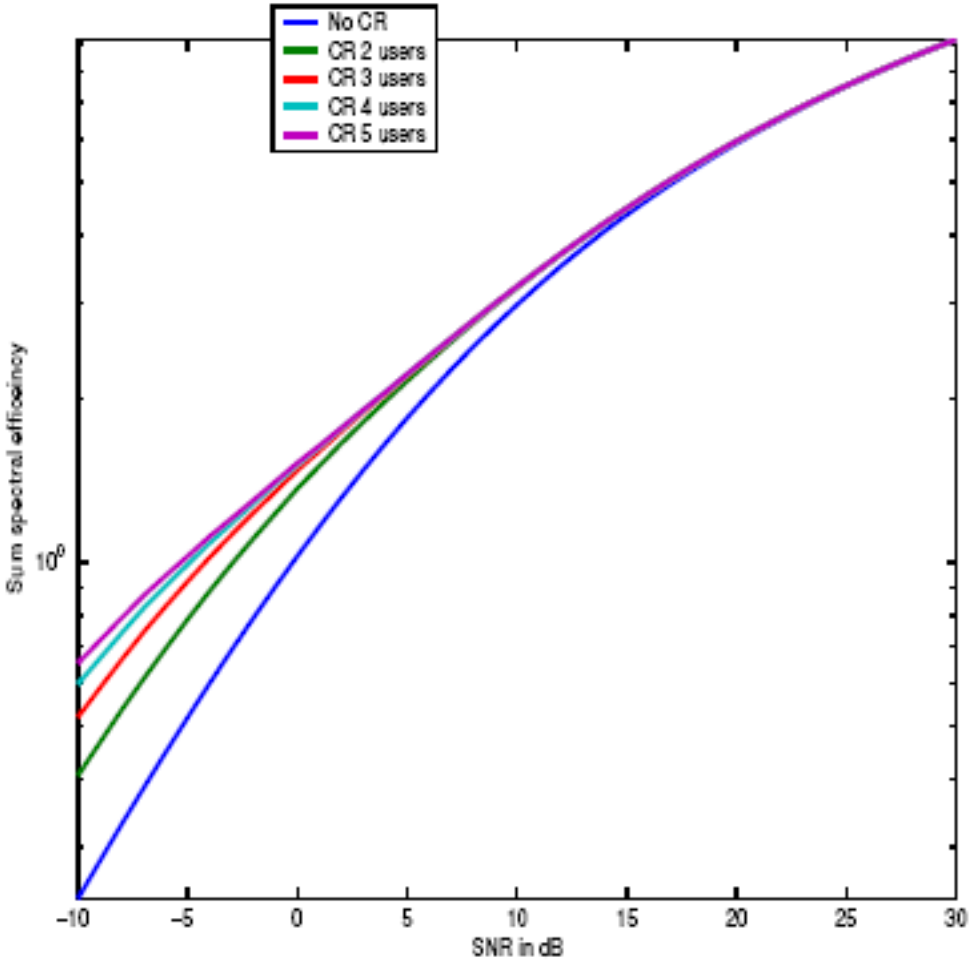


Fig. 3. Sum spectral efficiencies of the system with 5 users for $N = 512$ sub-bands.

Model based reasoning

Cognitive radio is:

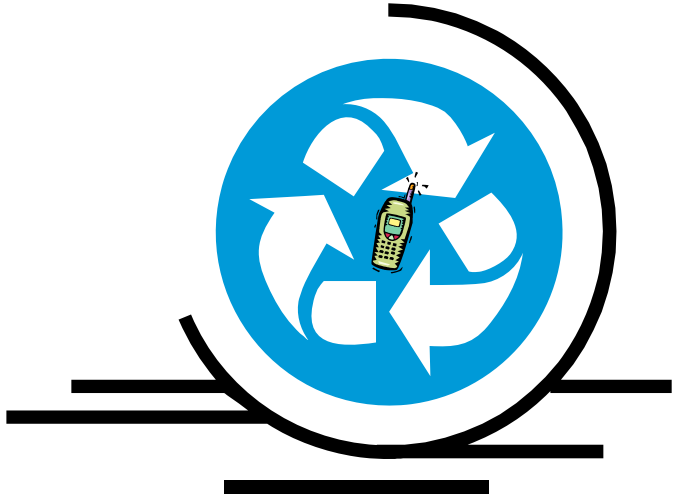
- **aware of its environment,**
- **capable of redefining its operating parameters in order to adapt to its context and optimize its performance without causing harmful degradation**

Flexible architectures to support cognitive radio concept

- **Multiple air interfaces**
  - GSM, WCDMA, DVB, WLAN, LTE, …
- **TX almost straightforward**
- **RX can be done in many ways**
  - Intra and inter-interfaces local/global optimization
  - Data types (complex, fixed point, vectors, …)
  - Similarities between processing
  - Data flows repartition
  - Tradeoffs monolithic integration / flexibility

Conclusion

We have to built a cognitive radio able to guarantee opportunistic "Sustainable" communication by deploying fancy strategies based on minimizing interference generation!



* Menouni Hayar, Aawatif;Knopp, Raymond;Pacalet, Renaud,"**Cognitive radio research and implementation challenges"** Asilomar 2007, Conference on Signals, Systems, and Computers, November 4 - 7, 2007, Asilomar, USA