Spectrum Management and Cognitive Radio

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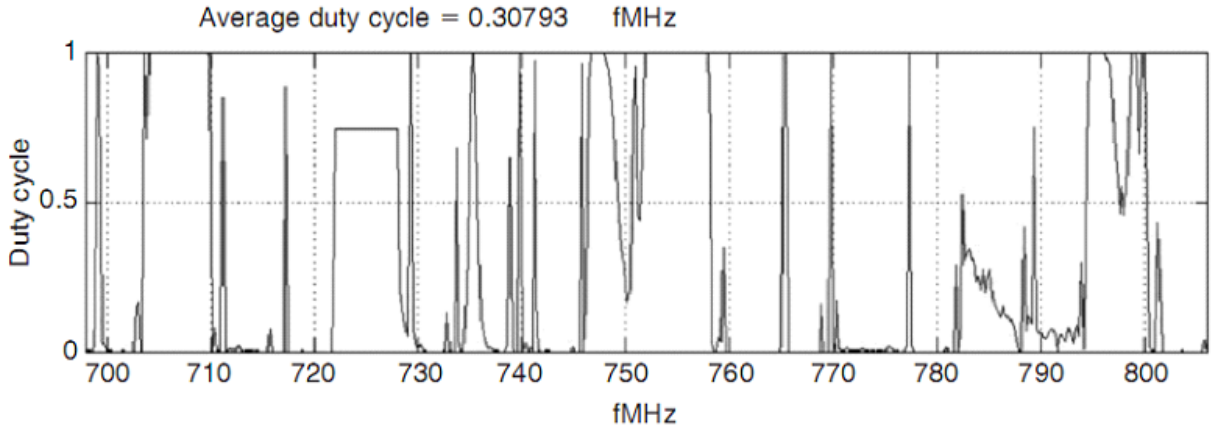
The spectrum scarcity problem

- **The dramatic increase in demand for spectrum is straining the effectiveness of the "Command & Control" spectrum assignment policy**
  - Significant spectrum bands remain unused



- **Goal: improve the spectrum usage enabling opportunistic access to the licensed bands without interfering with the primary users**

Radio gets smart: Cognitive Radio

- **CR: *Communication systems aware of their environment and internal state and able to decide about their operating behaviour based on that information and predefined objectives***
  - Context awareness, knowledge, learning capability, reconfigurability
  - Exploitation of ***spectrum holes*** and ***white spaces***

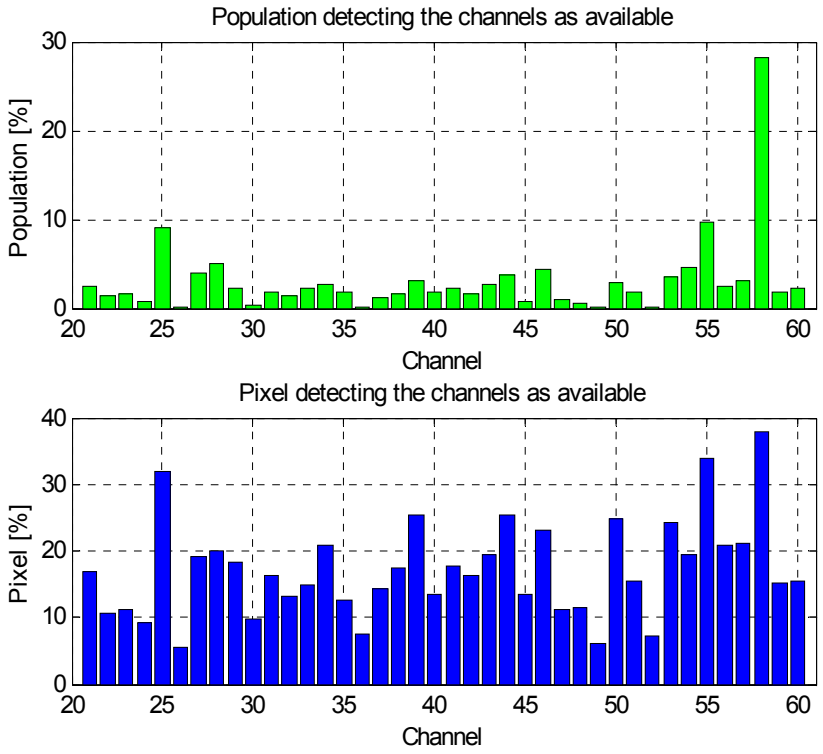
- **Many technical, managerial, and financial benefits:**
  - Suitability, Reliability, and Availability for the user
  - Network stability and performance
  - Market-based spectrum management approach
  - New service providers
  - Military and public safety networks

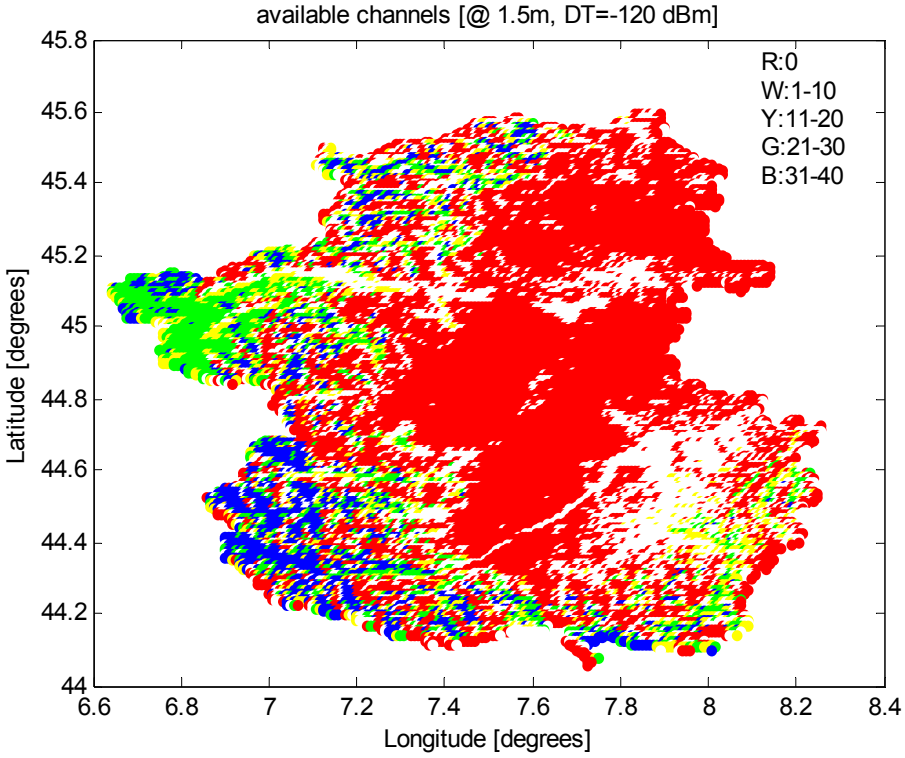
Cognitive Radio functionalities

- **Spectrum Sensing: detect bands that are vacant or accessible on a non-interfering basis**
  - Non-cooperative vs cooperative detection
  - Geo-location + sensing
- **Spectrum Mobility: change operating frequency if the channel is required by a PU or harmful interference is being generated**
- **Spectrum Management: identify the best available channel to meet the requirements, and provide fair spectrum assignment policies among CRs**
  - Analysis
  - Decision
  - Sharing

Amount of white space

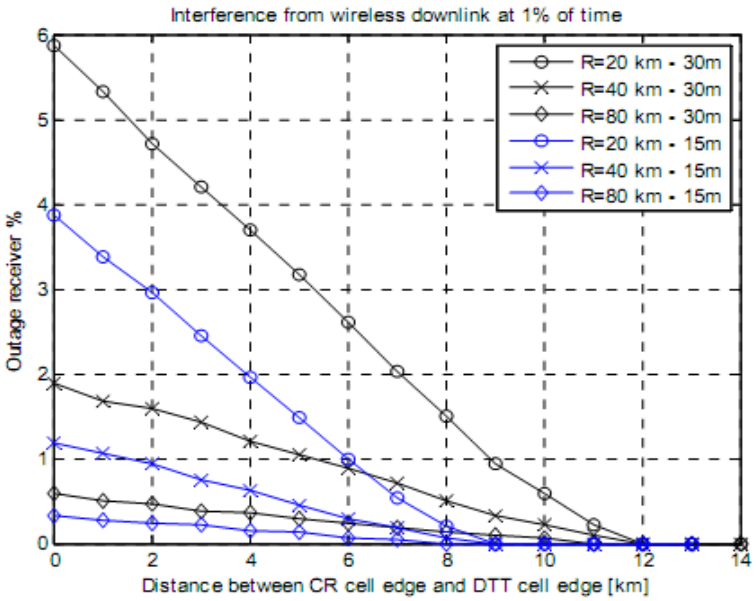
➢ **SE43:** define the requirements for the operation of CR systems in the white spaces of the UHF band 470-790 MHz to ensure the protection of primary services/systems and **investigate the consequential amount of spectrum potentially available as "white space"**





Cognitive Co-existence

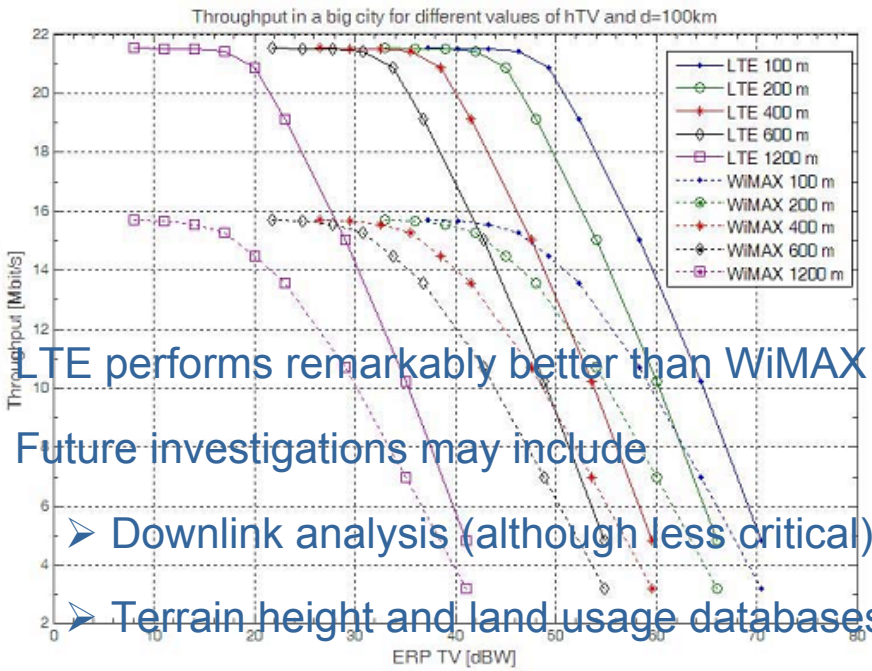
- **Analysis of Cognitive Co-existence in the UHF band after the Analog Switch-Off**
  - Propagation model: ITU P.1546 and Okumura-Hata
  - Scope: compute the percentage of outage DTT receivers and the guard distance between the interfering networks to guarantee specified coverage levels

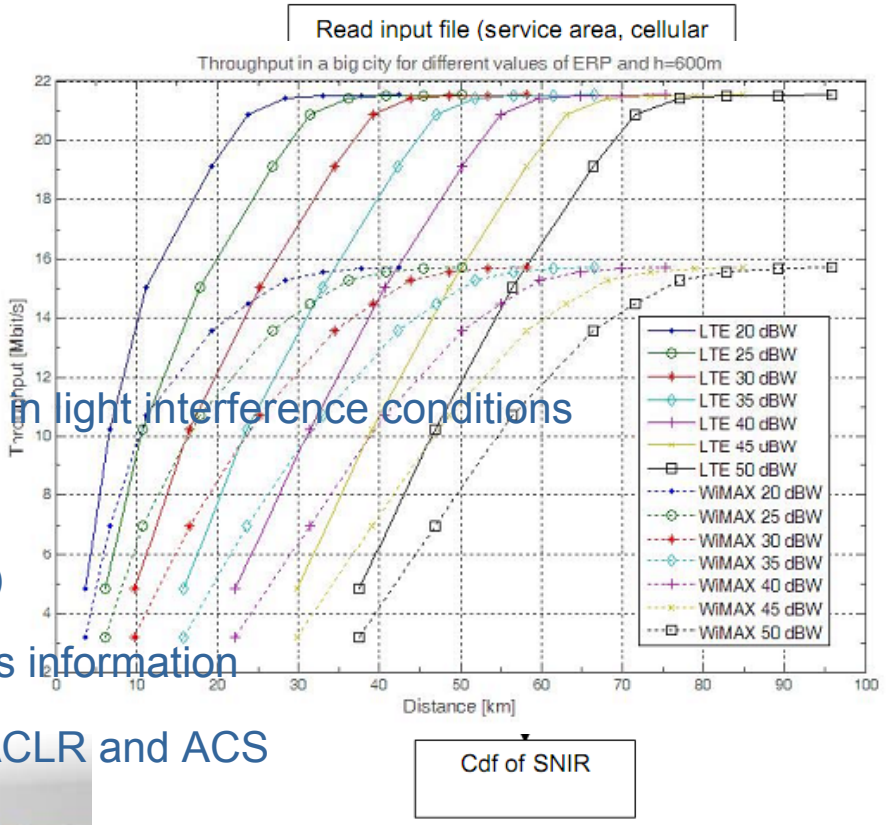


- Interference dominated by CR DL over CR UL
- DTT radius / CR radius ≈ 50
- …Cognitive Base Station?

Co-existence of WiMAX-LTE with DTT

- **WRC-07 allocated on a co-primary basis the UHF band 790-862 MHz to mobile services in Europe as from 2015, and allowed some EU countries to use it before 2015, subject to technical coordination with other countries**





- LTE performs remarkably better than WiMAX in light interference conditions
- Future investigations may include
  - Downlink analysis (although less critical)
  - Terrain height and land usage databases information
  - Adjacent channel interference through ACLR and ACS

Management approaches

- Many approaches to control the configuration of a CR network:
  - *Rule-based Reasoning*
  - *Game Theory*
  - *Neural Networks*
  - *Genetic Algorithms*
  - ***Swarm Intelligence***

Bio-inspired algorithms

- Any optimization problem can be described as a triple (S, Ω, f)
- In Combinatorial Optimization (CO) algorithms are classified as *complete* or *approximate*

- Swarm Intelligence techniques for finding approximate solutions
  - ***Ant Colony Optimization***: inspired by the foraging behaviour of ant colonies
  - ***Particle Swarm Optimization***: inspired by the social behaviours observed in animals

$$\mathbf{v}_i \leftarrow \mathbf{v}_i + \boldsymbol{\varphi}_1 \otimes (\mathbf{p}_i - \mathbf{x}_i) + \boldsymbol{\varphi}_2 \otimes (\mathbf{p}_g - \mathbf{x}_i),$$
$$\mathbf{x}_i \leftarrow \mathbf{x}_i + \mathbf{v}_i,$$

- Key issue: translate the control of spatial distance into a “distance” meaningful in a CRN
- PSO for multi-objective optimization
- PSO for dynamic optimization

Conclusions

- **CRs promise to solve the artificial spectrum scarcity problem, but present unique challenges**
- **There is not a general approach in designing a CR network**
- **Is it a feasible solution?**
  - ***Interference issues between DTT networks and mobile/cognitive networks***
  - ***Amount of spectrum available as white space***
  - ***PSO algorithms to control the configuration of a CR network***

THANK YOU!