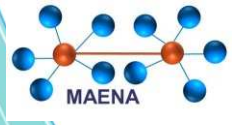
COGNITIVE RADIO :
THOUGHTS AND PROJECTS

COgnitive **RA**dio for dynamic **S**pectrum **Ma**nagement



Multi b**A**nd **E**fficient **N**etworks for **A**d hoc communications

Thierry Defaix

DGA / DT / Mi / SPC

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DGA

OUTLINE

- Introduction
- CORASMA
  - Context / Aims
  - Results & Conclusions
- MEANA
  - Objectives
- Conclusion

Introduction

- Optimizing Spectrum Management
- Why?
  - Spectrum scarcity.
  - The military spectrum has been reduced
  - Static frequency management and planning tools are no more adapted
- Hopes
  - Evolving and emerging radio communications technologies: - SDR & CR:
    - sharing possibilities
    - more flexible use of spectrum
- Military specificities
  - No infrastructure – Ad hoc networks
  - Mobility
  - Unknown, miscellaneous and unpredictable environment
  - EW threats

CORASMA 2010-2013

« COgnitive RAdio for dynamic Spectrum MAnagement »

- European Defence Agency
- AD HOC B – 7 countries & 14 industrial/academic partners

Partner	Country
THALES Belgium	Belgium
SUPELEC*	France
THALES Communications &Security S.A. - France – Coordinator	France
Fraunhofer FKIE*	Germany
THALES Defence & Security Systems	Germany
Karlsruhe Institute of Technology*	Germany
CNIT – University of Florence*	Italy
Selex Sistemi Integrati S.p.A.	Italy
Selex Communications	Italy
THALES Italia	Italy
ALMAMATER (University of Bologna)*	Italy
ASSECO POLAND SA*	Poland
Military University of Technology	Poland
RADMOR*	Poland
Tekever Communications Systems	Portugal
Saab AB	Sweden

CORASMA - Project

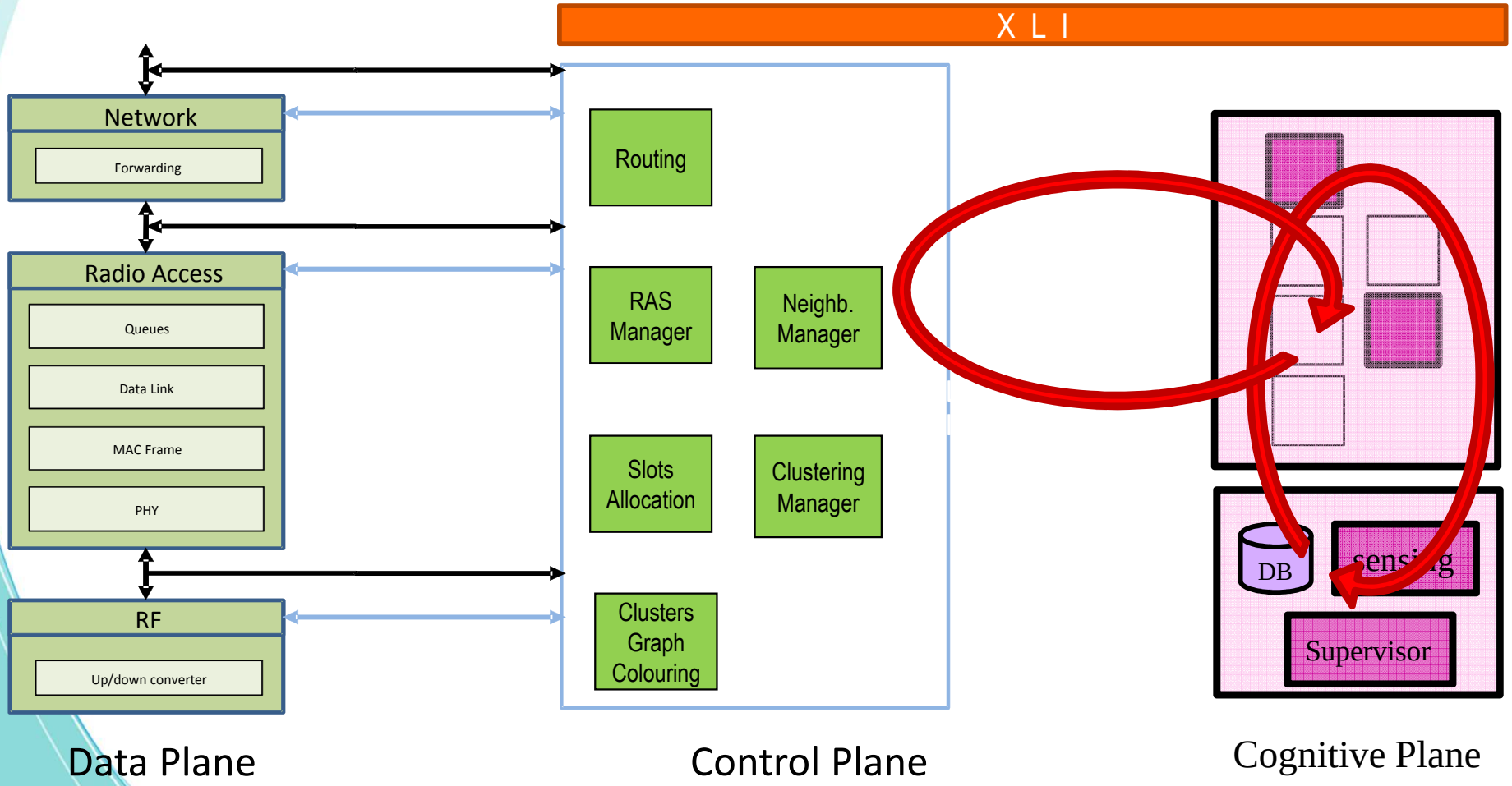
- Cognitive Radio concept is expected to bring two main capabilities
  - Dynamic spectrum allocation, allowing more flexible operations
  - Adaptive link management, improving spectral resource usage

- Project main objectives
  - Study the application of the Cognitive Radio concept to military radio communication systems
  - Develop a simulator to compare cognitive solutions

How to assess performance?

- Objective #1: Performance should be assessed from an operational perspective
  - Simulator: All layers implementation + adapted metrics (technical + operational) + operational scenarios
- Objective #2: Simulations should be as accurate as possible
  - To really capture interference effects (frequency reuse, jammers, …)
  - To assess real implementation of CR solutions in waveforms (signaling, robustness, …)
  - Simulator: High-Fidelity simulation at PHY (with I/Q), MAC, NET, Apps + digital terrain w/ propagation model
- Objective #3: enable each partner to implement its own cognitive solution smoothly and to be able to make fair comparison with other solutions of other partners
  - Flexibility, modularity
  - Simulator: Cognitive Plane architecture, common metrics and displays

Data plane, control plane & cognitive plane



CORASMA Evaluation – 2014-2015

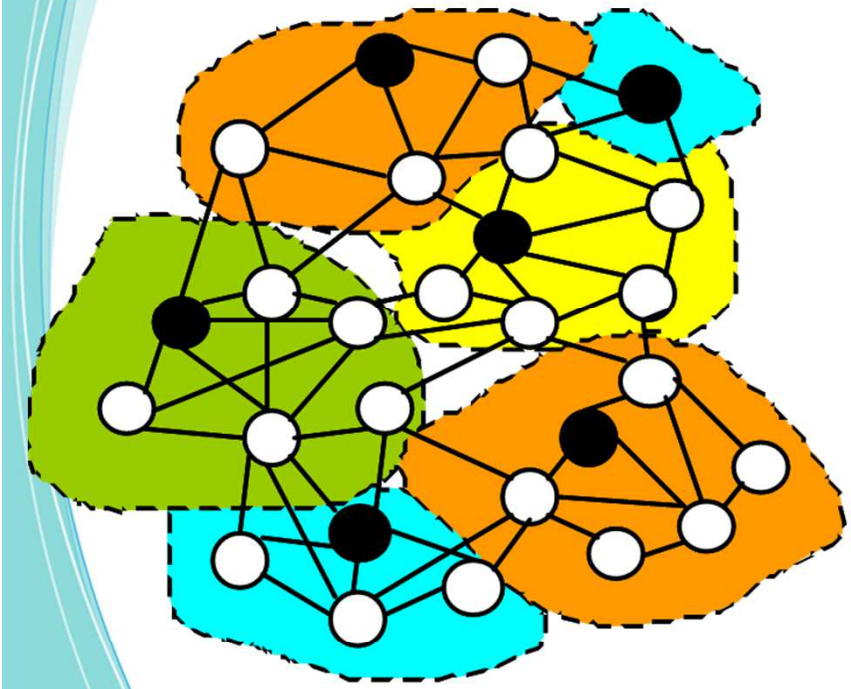
- 6 different « cognitive » solutions

	Slot allocation	Cluster Graph coloring	RAS manager	Routing	Clustering	Retransmission Manager	Header Compression	Other
MUT		X			X			
Saab		X					X	
Selex		X						
TBE	X	X						
TCS		X						
TES								FH sequence selection

- Cognitive engine:
  - Game theory (distributed (FRA), centralized (ITA))
  - Genetic algorithms (BEL)
  - Heuristics (POL, SWE, GER)

CORASMA Evaluation – French solution

PhD Student Luca Rose



Cluster frequency « coloring »

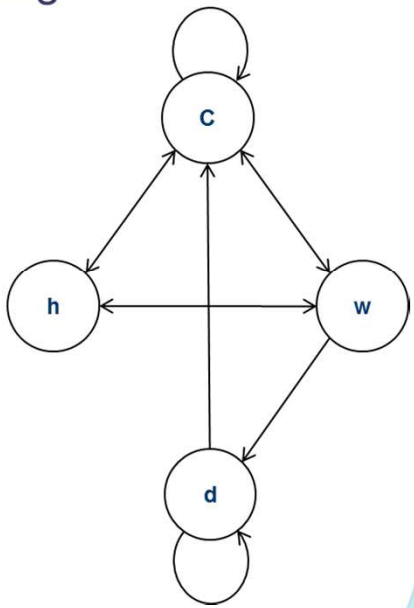
Moods
c: content
d: discontent
w: watchful
h: hopeful

- Content
  . Experiments new actions with probability ε
- Discontent
  . Experiments new actions

- C -> H: no experiment, utility increases
  . H -> C: if utility increases or equal
  . H -> W: if utility decreases
- C -> W: no experiment, utility decreases
  . W -> H: if utility increases
  . W -> C: if utility equal
  . W -> D: if utility decreases

Trial and Error Learning

(H. P. Young, 2009)



$$u_k(\mathbf{p}) := \frac{1}{1+|L_k|\beta}\left(1-\frac{p_k}{p_{MAX}}+\beta\sum_{\ell\in L_k}1_{[\Gamma_\ell(\mathbf{p})>\Gamma_k]}\right)$$

Power minimization

SINR constraints

"Self-Organization in Decentralized Networks: A Trial and Error Learning Approach"
Luca Rose, Samir M. Perlaza, Christophe J. Le Martret, Mérouane Debbah
IEEE Transactions on Wireless Communications – Vol 13, No 1, January 2014

CORASMA Evaluation – Lessons learnt

- Project as a whole
  - A lot of work for very ambitious aims
  - Almost all the objectives were achieved because of the involvement of all the partners
  - ITA > FRA / SWE
- What are the benefits of CR?
  - First results are interesting and promising (Lack of time to run enough simulations, to tune all the algorithms parameters,…)
  - Feeling that it is a right direction to enhance and ease the communication resource management
- The full stack HiFi simulator concept has been successfully implemented
  - Defining realistic scenarios is difficult and requires a lot of work
  - HiFi simulator/simulations are very complex and require many various skills
  - There is a need to develop specific tools to automatically post-process the network simulation results / metrics

MAENA 2017-2020

« Multi bAnd Efficient Networks for Ad hoc communications »

- **EDA – AD HOC B – 8 countries & 18 partners**
- **Wishes:**
  - **Capitalize on CORASMA simulator and lessons learnt**
  - **Multi-bands: V, U and V+U**
    - to elaborate global solutions for tactical wireless networks considering both the VHF and UHF bands within the Dynamic Spectrum Management (DSM) paradigm
    - enhance the performance (resilience, reliability, delay, …) of the communication system services due to better usage of the available spectrum
  - **Simulator:**
    - Usable to simulate mobile ad hoc networks with either VHF or UHF
    - Capable of handling networks with dozens of nodes
    - Modeling in details propagation effects and interference
    - Offering graphical tools for and easy configuration and results analysis
    - Having a modular and extensible architecture

MAENA – DSM
Dynamic Spectrum Management

- **Towards Dynamic Spectrum Management**
  - **Today, the spectrum is managed by deconflicted fixed assignments, mainly through manual procedures.**
- **NATO Group "Cognitive Radio in NATO II" -** IST104/RTG-050
  - https://www.sto.nato.int **– ref** STO-TR-IST-104
- **The vision is that this should evolve towards a more dynamic and automated management of the spectrum at 2 levels:**
  - **1/ At a system level where procedures should be developed to enable two way exchanges between the central control management entity and the radios on the operation theatre.**
  - **2/ At the network level where dedicated procedures should allow local adaptations of the communication network to optimize its configuration under system level decision constraints.**

CONCLUSIONS

- Cognitive radio : a promising concept
- Defining rules to introduce CR system within the frequency bands
  - Regulation
  - Loyalty
  - Policies format
  - …
- Interest for the national tactical radios: mid/long-term

QUESTIONS ?