Modeling Cognitive Radio Equipments for Opportunistic Spectrum Access

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Presentation outline

- Cognitive radio equipment
- Management architecture: HDCRAM
- HDCRAM metamodel
- Cognitive radio tooling
- Example of an Opportunistic Spectrum Access scenario
- Conclusion

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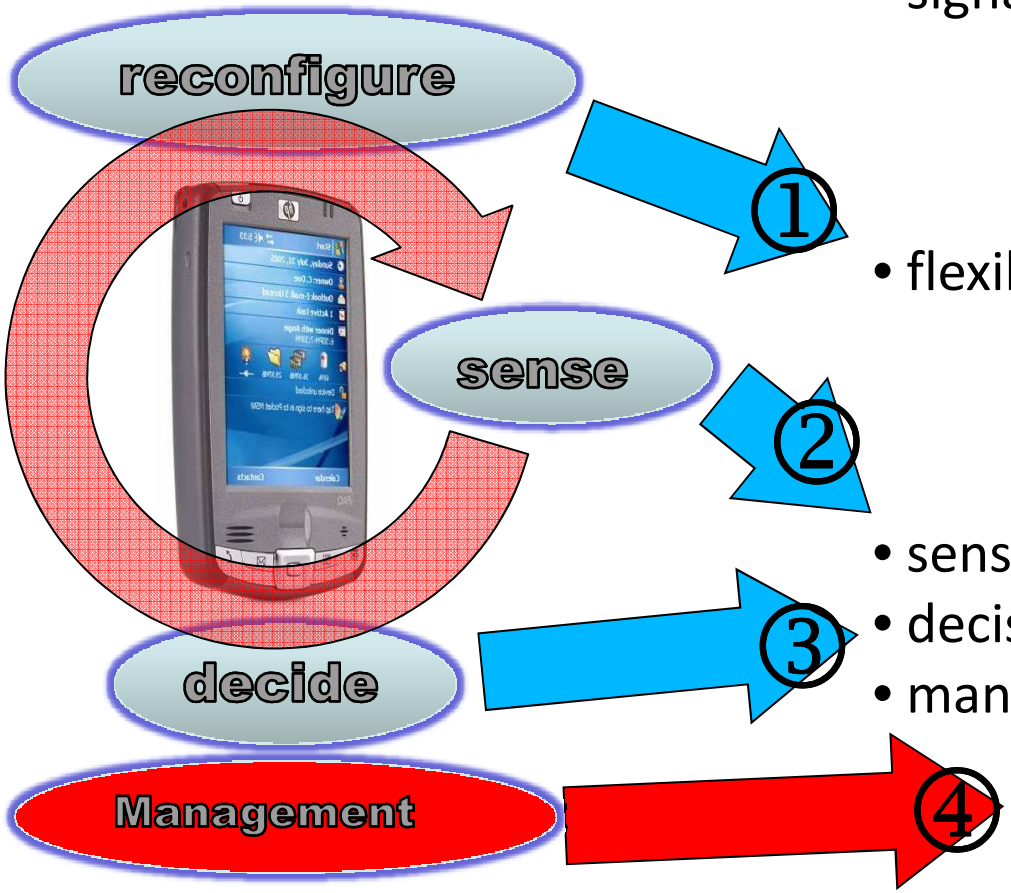
Cognitive radio equipment

- **Simplified cognitive cycle**



A cognitive radio (CR) equipment is made of

- signal processing
  - radio for PHY layer
  - also any other layer processing
- flexible platform and processing
  - multi-processing
  - heterogeneous (DSP, FPGA…)
  - adaptive signal processing
- sensing signal processing
- decision making processing
- management architecture (HDCRAM)
  - reconfiguration management
  - cognitive management

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④ Cognitive management

- **In order to integrate «sense/decide/configure» into a common equipment: HDCRAM**
  - ***H****ierarchical and* ***D****istributed* ***C****ognitive* ***R****adio* ***A****rchitecture* ***M****anagement*
- **HDCRAM = rules to follow inside a CR equipment in order to implement CR cycle**
- **HDCRAM Metamodel**

[1] Loïg GODARD, Christophe MOY, Jacques PALICOT, "An Executable Meta-Model of a Hierarchical and Distributed Architecture Management for the Design of Cognitive Radio Equipments", Annals of Telecommunications, Special issue on Cognitive Radio, vol. 64, pp.463-482, number 7-8, Aug. 2009

- **High level design tool for CR equipments**

[2] Christophe MOY, "High-Level Design Approach for the Specification of Cognitive Radio Equipments Management APIs", Journal of Network and System Management - Special Issue on Management Functionalities for Cognitive Wireless Networks and Systems, vol. 18, number 1, pp. 64-96, Mar. 2010

HDCRAM vs SCA

- **SCA and HDCRAM are two frameworks**
  - that are meta-modeled
- **SCA is related to Reconfiguration Management sub-part of HDCRAM**
  - HDCRAM goes further in order to support run-time reconfiguration or a radio
    - more flexible than SCA ≡ flexibility at configuration but not at run-time (which is required for CR)
    - lower-level, closer to electronics (no abstraction)
  - HDCRAM also integrates sensing and decision making ➔ management architecture for cognitive radio

HDCRAM vs SCA tools

- **SCA tools**
  - modeling environment (Spectra CX of Prismtech)
  - ORB generation (Spectra ORB)
- **HDCRAM tooling**
  - modeling environment: CoRaDE
  - management architecture code generation

➔ one possibility of code generation (could be): SCA 2.2.2 or 4.0 compliant code generation

➔ or others (we have our own which targets execution time efficiency)

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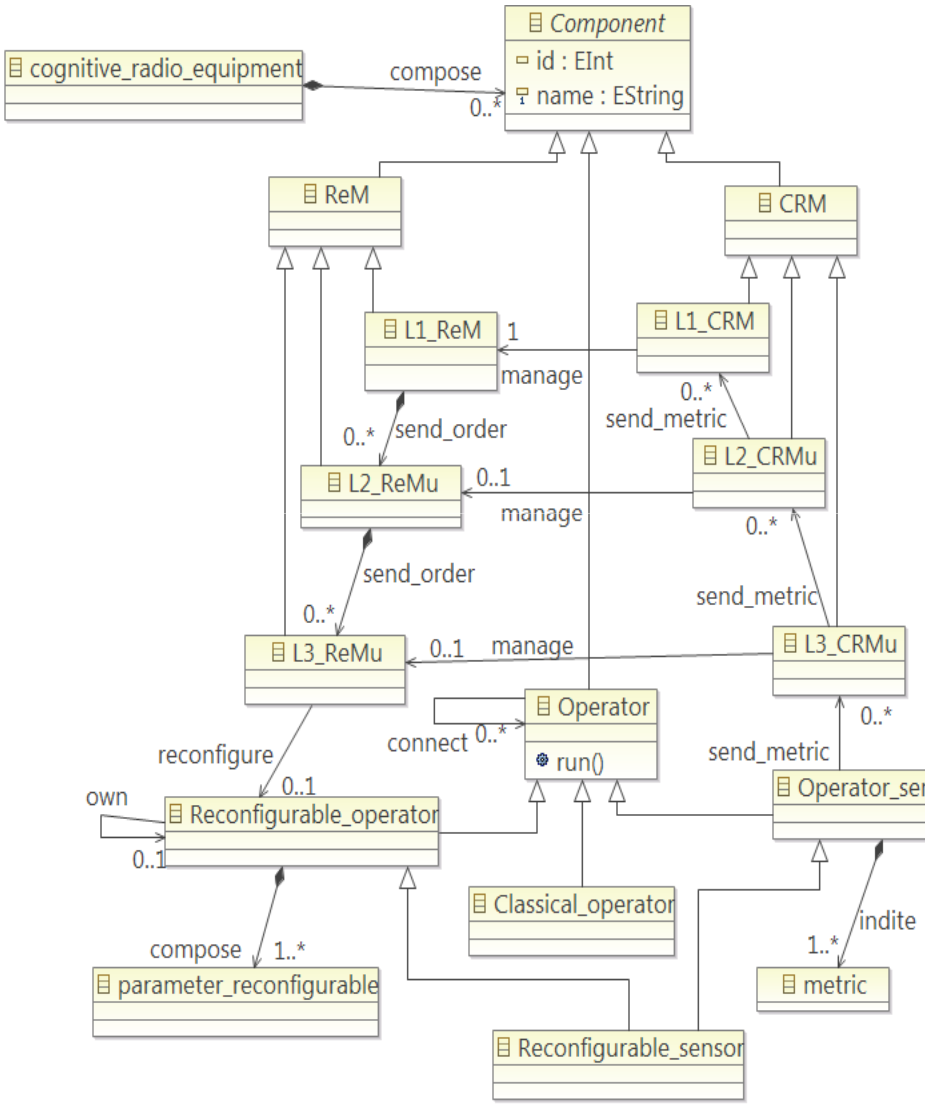
HDCRAM metamodel



MOF can be viewed as a standard to write metamodels.

MOF metamodels are usually modeled as UML class diagrams.

A supporting standard of MOF is XMI .

One purpose of XML Metadata Interchange (XMI) is to enable easy interchange of metadata between UML-based modeling tools and MOF-based metadata repositories in distributed heterogeneous environments.

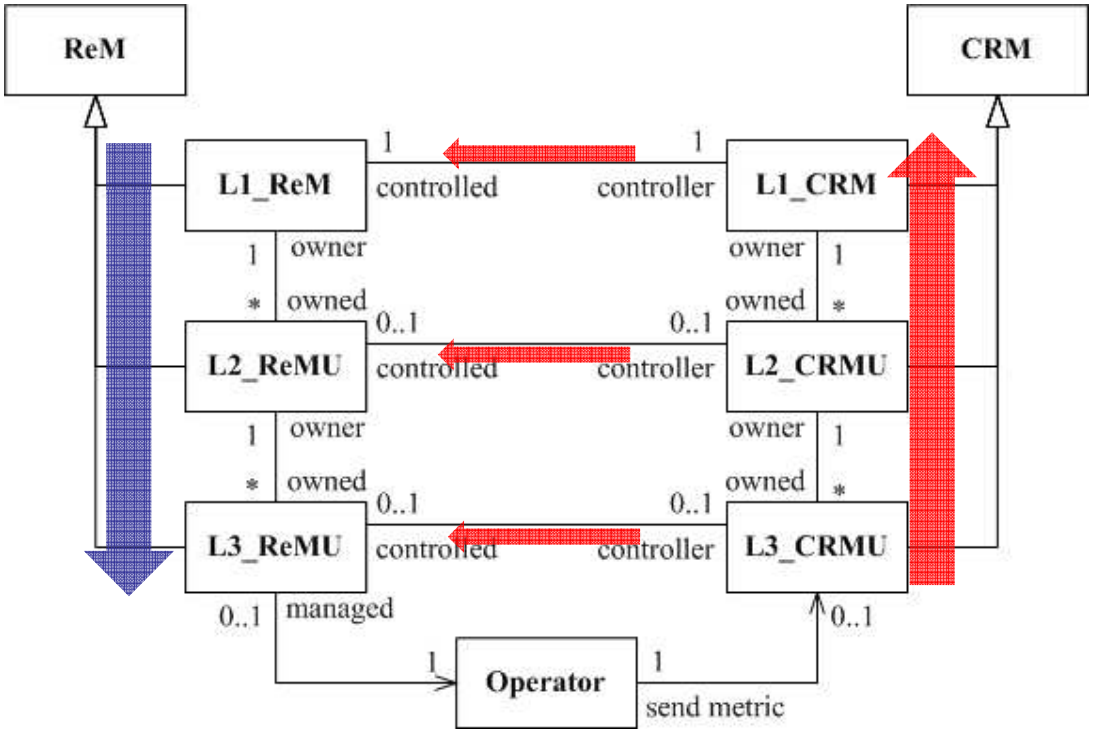
XMI is also commonly used as the medium by which models are passed from modeling tools to software generation tools as part of model-driven engineering.

HDCRAM metamodel (simplified)

- **HDCRAM metamodel**
  - factorized view
  - formalization of the rules

cognitive flow

reconfiguration flow



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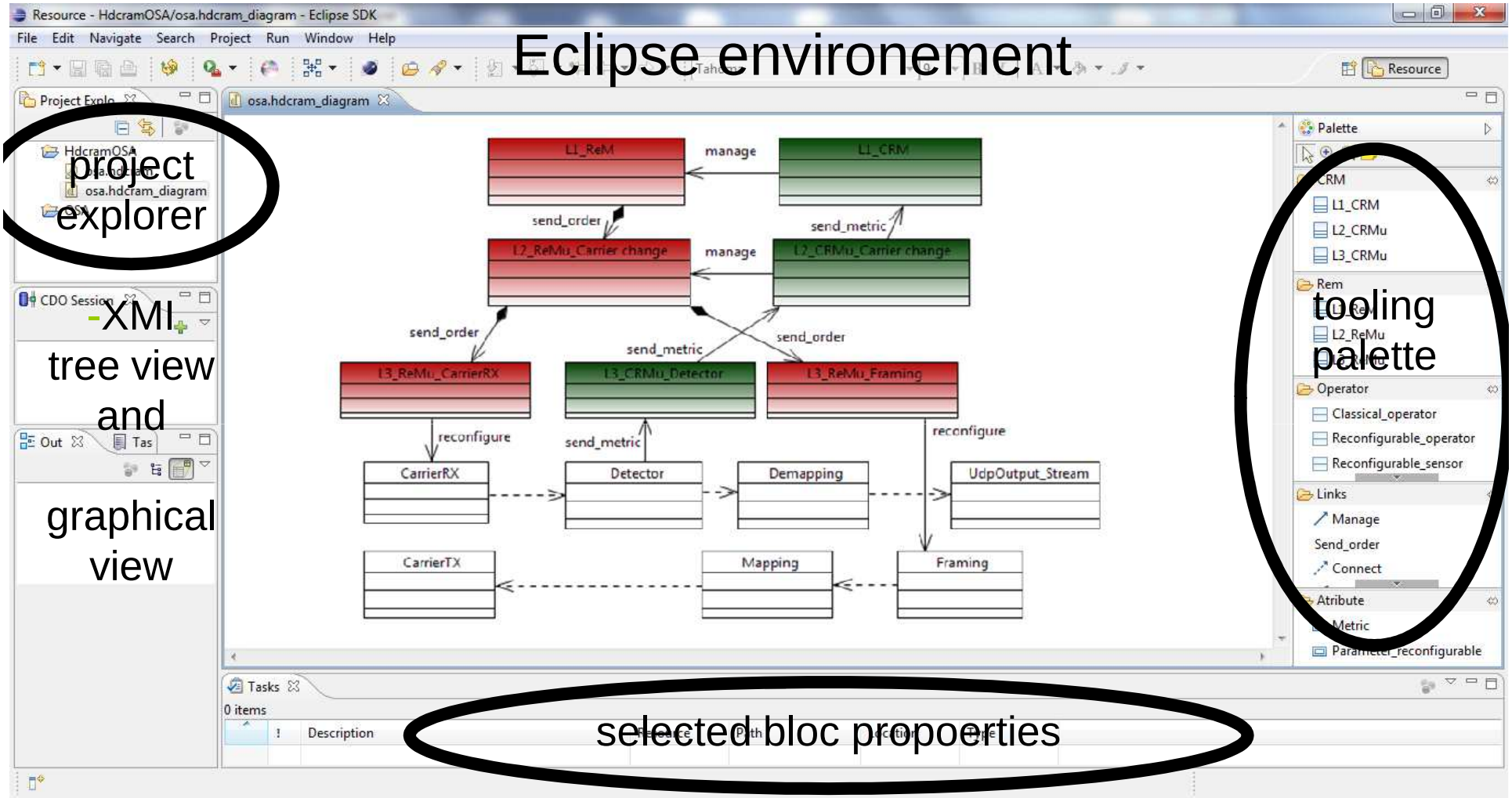
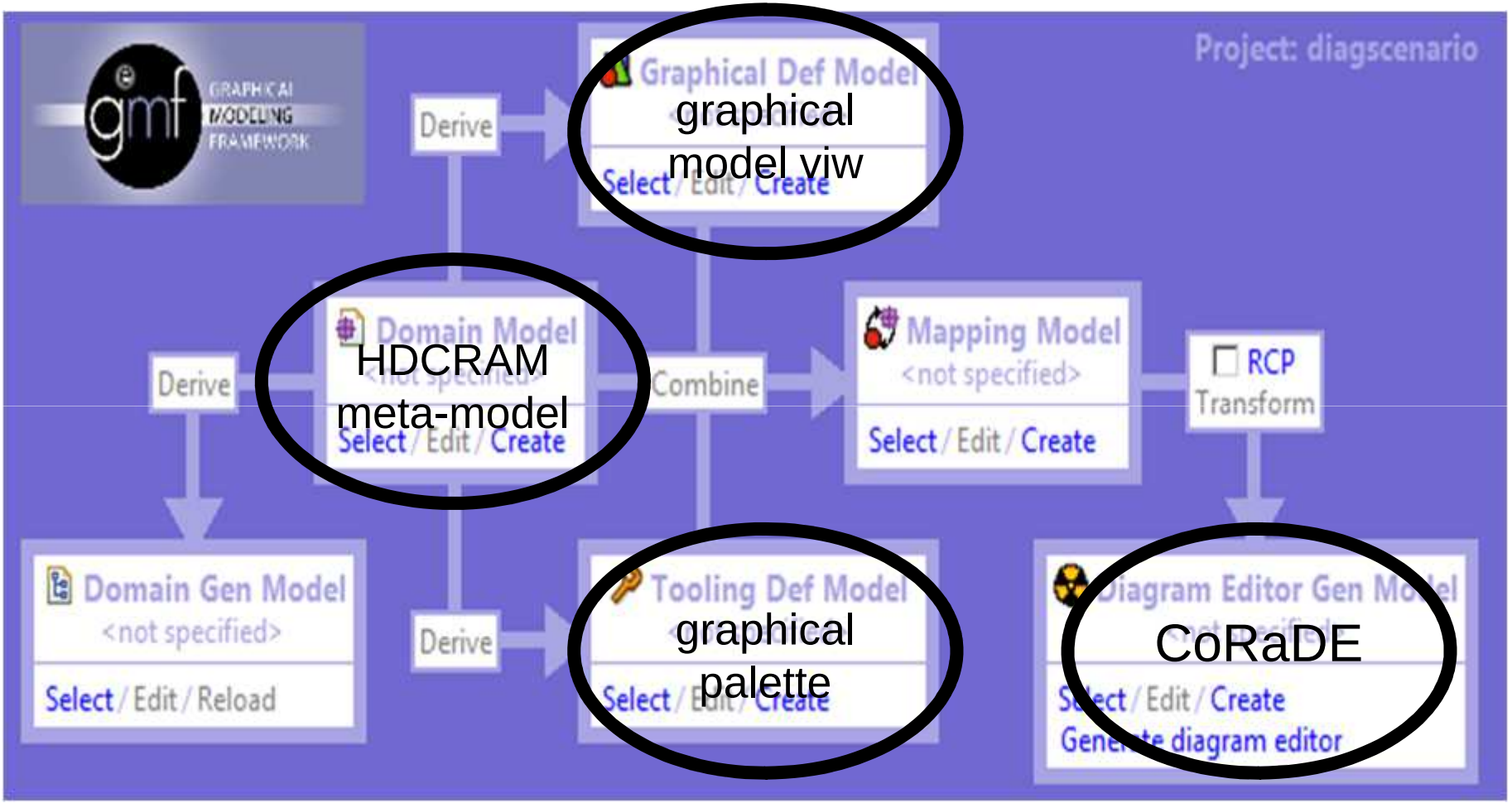
CoRaDE
(Cognitive Radio Design Environment)



Oussama Lazrak, Pierre Leray, Christophe Moy, "HDCRAM Proof-of-Concept for Opportunistic Spectrum Access", DSD Euromicro Conference, Cesme, Turquey, 5-8 September 2012

CoRaDE tool development process



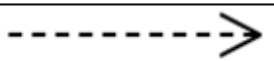
CoRaDE semantic

Domain Model Definition is a conceptual model for describing the diagram generated by the editor

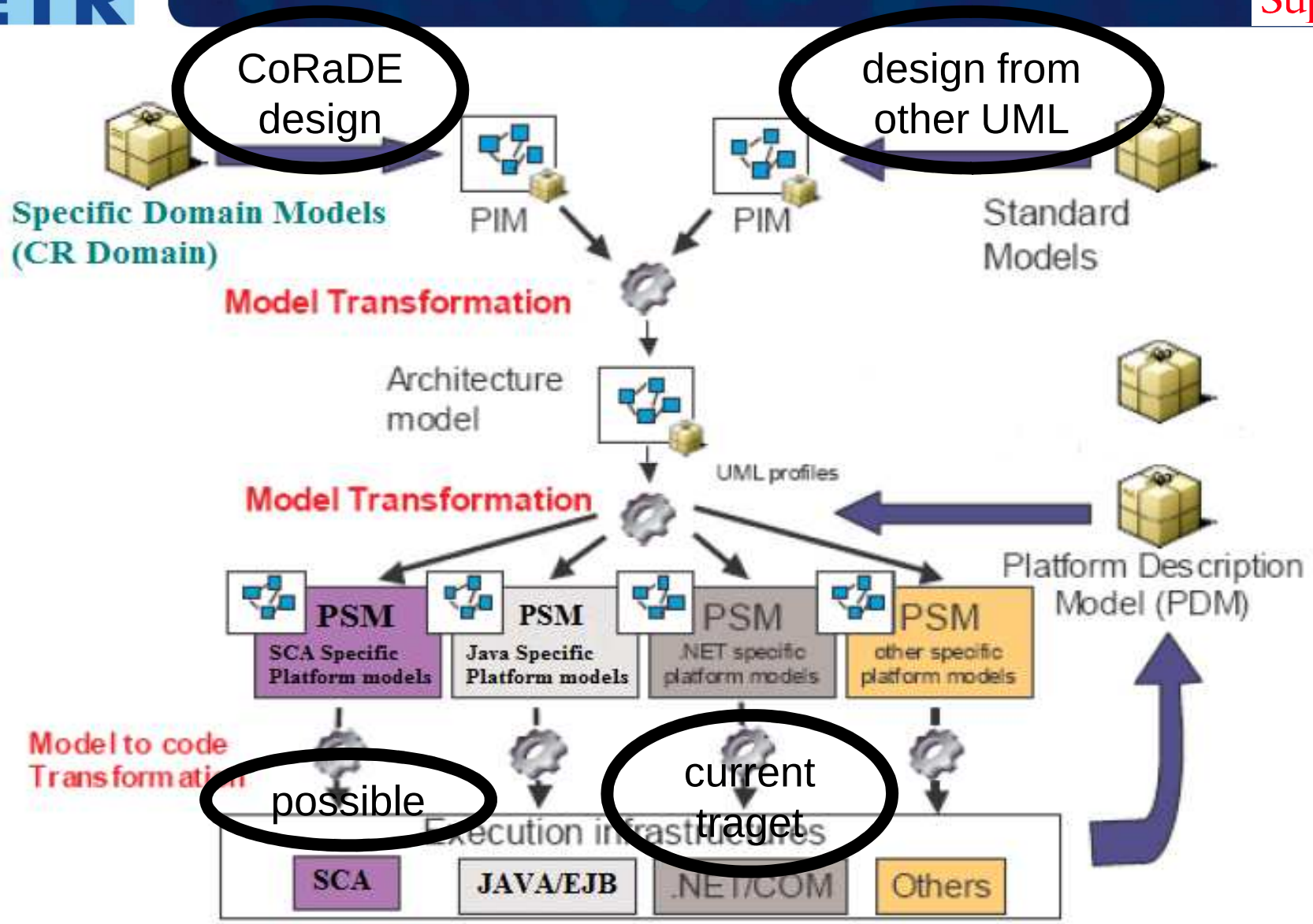
Graphical Definition determines the semantics of the generated diagrams. For our editor, we chose to reuse UML notations described by MOF for the presentation of node and path.

Tooling Definition allows customizing the editor by adding options in the bar menu for models validation.

Mapping Definition consists in combining the three previous models into one.

Node/Path	Notation	TYPE
Operator	ClassName	Class
ReM	ClassName	Class
CRM	ClassName	Class
manage		Association
connect		Dependency
send_metric		Association
reconfigure		Association
send order		Composition
implement		Generalization

CR development cycle



Code generation

- **Current work at tooling level**
  - code generation for a platform made of GPP (baseband processing) and USRP
  - evaluation: comparison with already manually generated code for OSA scenario
- **Future work at tooling level**
  - heterogeneous platform made of GPP and FPGA
  - evaluation: comparison with current manually generated code for OSA scenario

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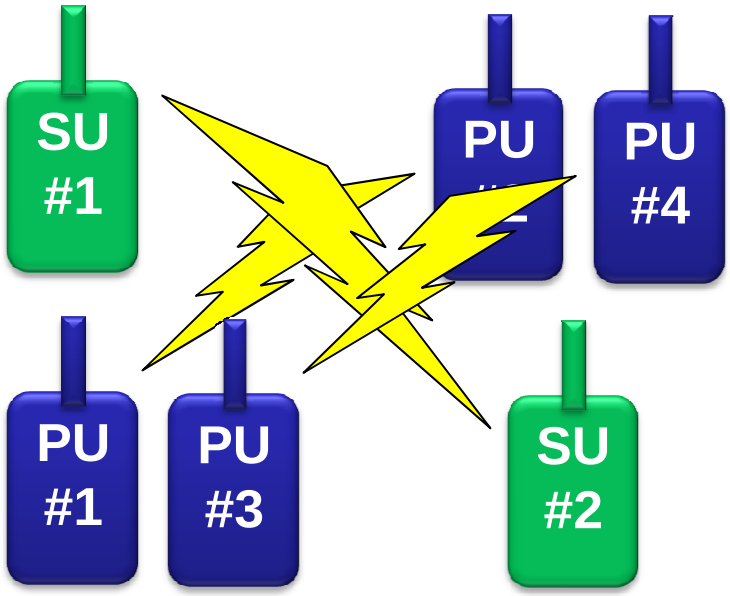
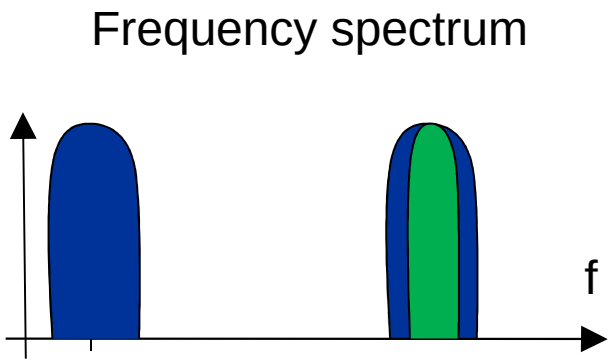
Opportunistic Spectrum Access - OSA

- In a radio network of primary users (PU)
- Secundary users (SU) are allowed to use free frequencies
- At the condition that it leaves the occupied frequency as soon as a PU wants to use it





Secundary user requirement

- **Secundary users need to incorporate cognitive radio (CR) features in the equipments**
  - sensors
  - reconfigurable radio capabilities

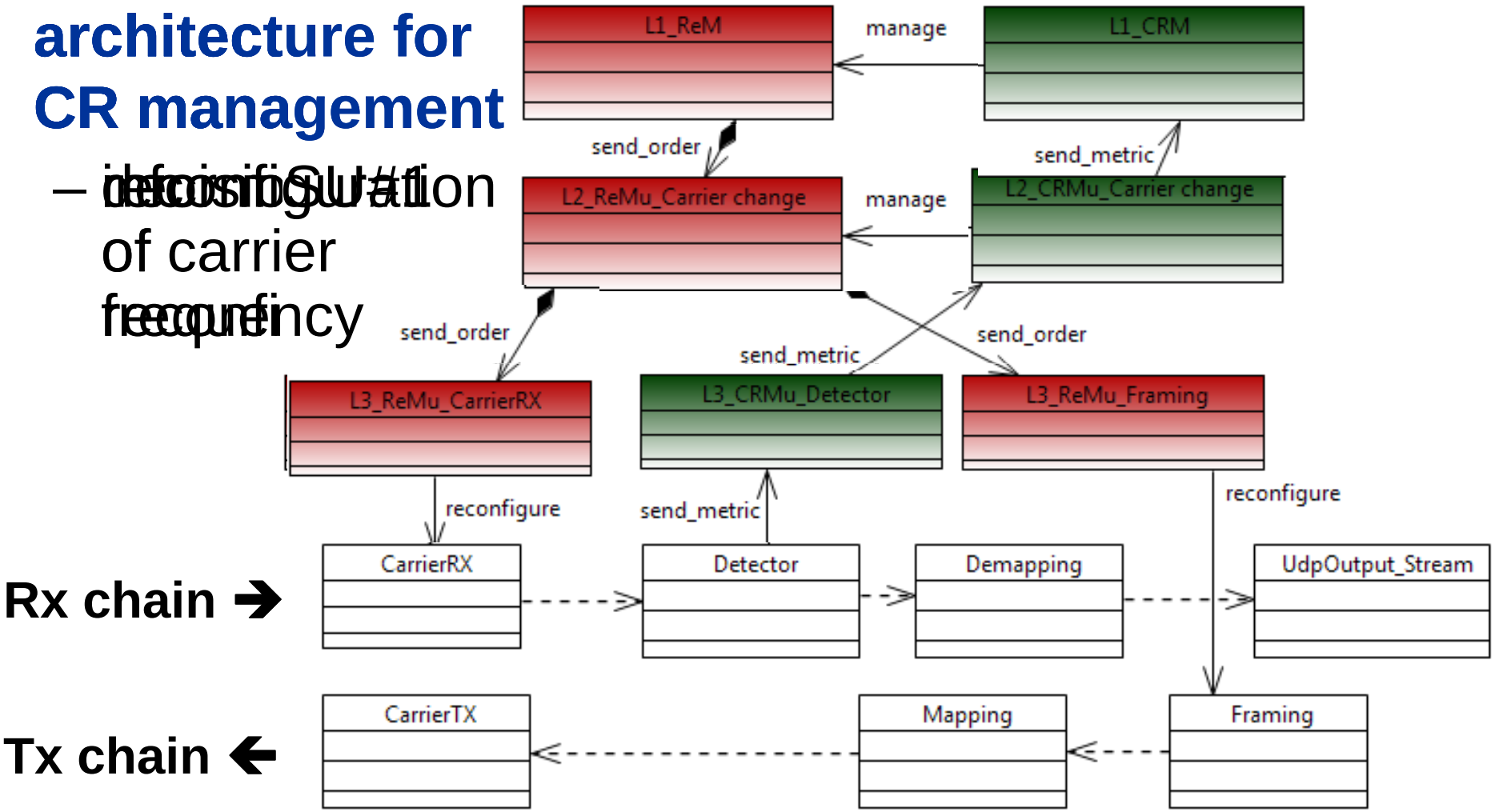
➔ **in addition to usual radio processing**

- **Sensor**
  - detection of primary user at the same frequency
- **Reconfigurable operators**
  - carrier frequency

➔ **need specific CR management: HDCRAM**

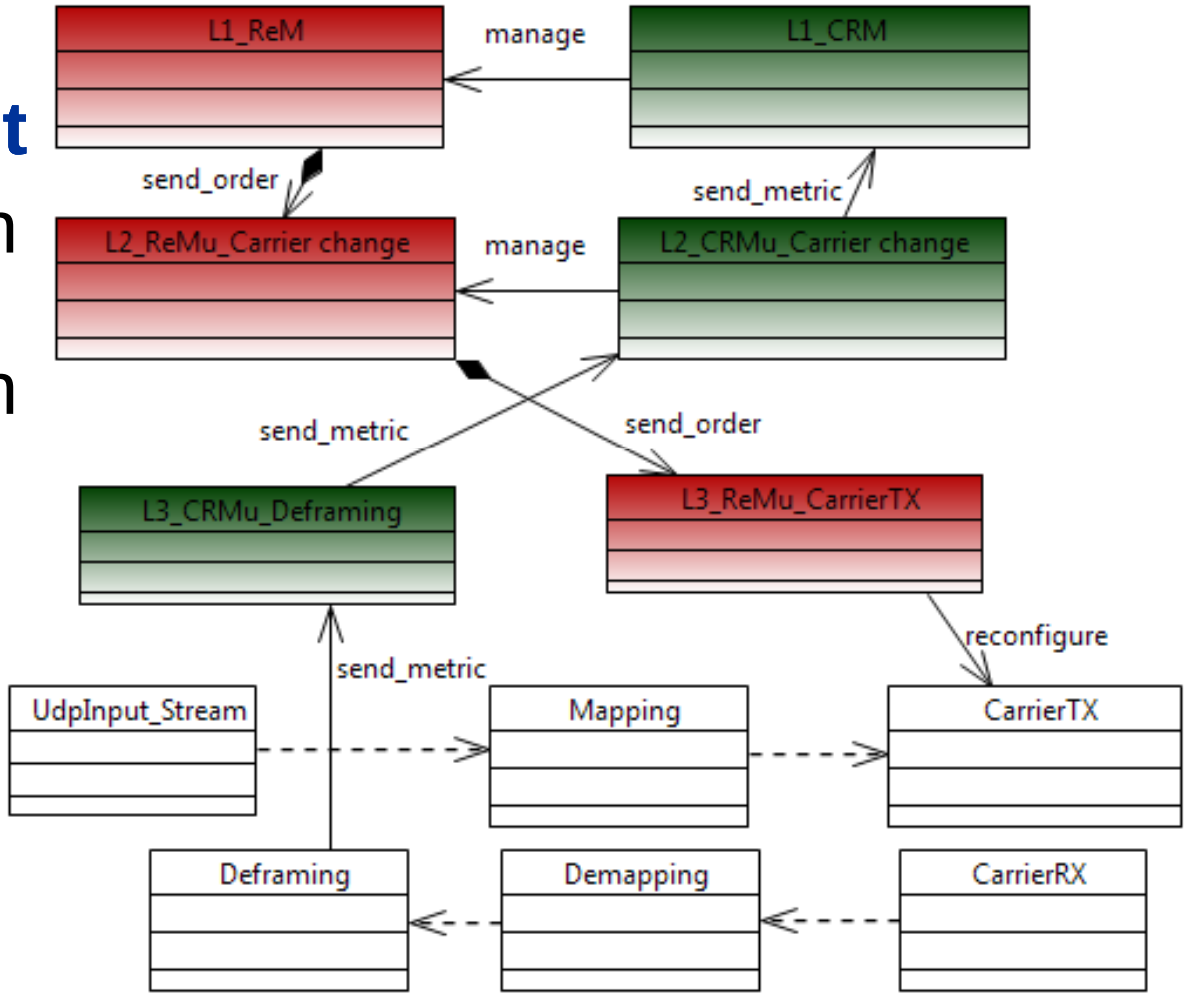
HDCRAM deployment in SU#1 CR equipment

- HDCRAM Radio processing for SU#1 architecture for CR management
  - Reconfiguration of carrier frequency



HDCRAM deployment in SU#2 CR equipment

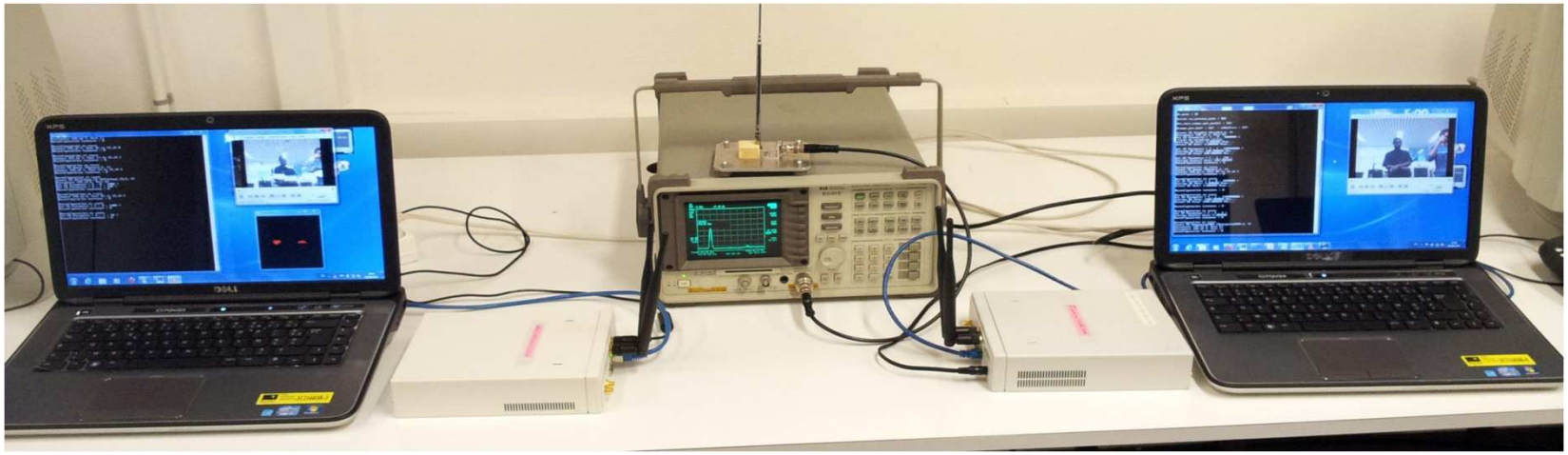
- HDCRAM Radio processing for SU#2 architecture for CR management
  - decision of carrier reconfiguration



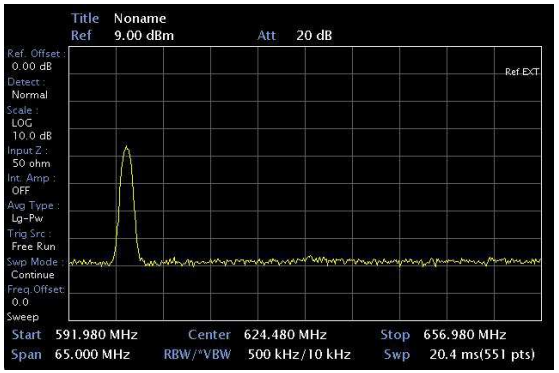
Tx chain ←

Rx chain →

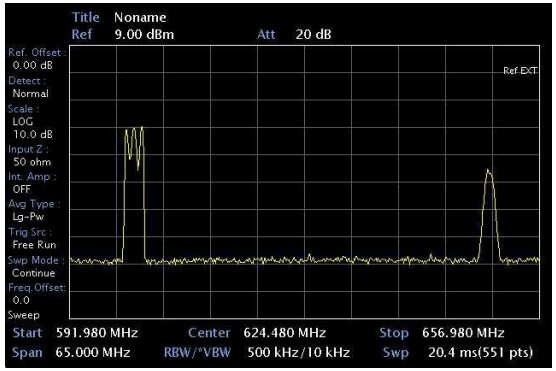
Experiments description



Demonstrator: from left to right – 1) SU#1 is composed of a laptop executing a video service transmitted (simple BPSK modulation scheme) through a USRP (white box) at a RF frequency F1 of 600 MHz (respectively F2 of 650 MHz) – 2) RF signal generator is transmitting at a frequency different form 600 MHz – 3) a spectrum analyzer is used to observe in real-time what is the frequency used by SUs – 4) SU#2 is also composed of a laptop and a USRP platform converting radio signal at 600 MHz (respectively 650 MHz) to baseband so that laptop executes a video player to display the video stream transmitted through a SU channel



Spectrum analyzer snapshot with SUs communicating at 650 MHz, while PU is at 600 MHz



Conclusion

- **We have been working on HDCRAM for 5 to 10 years now**
- **For our own purposes and benefit**
- **Now time to share with others: need of tooling**
  - CoRaDE design environment for cognitive radio to deploy HDCRAM
- **Help for combining/exchanging designs between users for multiple CR scenari**
- **Still on work…**

Thanks

- **If you want to read more**
  - SCEE web site:
    http://www.rennes.supelec.fr/ren/rd/scee/
  - SCEE vision on Cognitive Radio:
    http://www.rennes.supelec.fr/ren/perso/cmoy/SCEE-CR/
  - last papers on that topic:
    Lazrak O, Leray P, Moy C
    "HDCRAM Proof-of-Concept for Opportunistic Spectrum Access"
    DSD Conference, Cesme, Turquey, 5-8 September 2012