Taxonomy of Cognitive Radio Applications

Dr. Artūras Medeišis, Vilnius Gediminas Technical University
Dr. Oliver Holland, King’s College London (presenter)
Dr. Luca De Nardis, Sapienza University of Rome
Presentation overview

- Problem formulation
- Definitions of CR use cases and applications
- Building inventory of use cases: from early Mitola to modern ETSI, etc.
- The proposal for unified taxonomy
- Technological capability identification and rendezvous
- Conclusions
Problem formulation

- A lot of diverging definitions of CR
- A lot of very different CR use cases and applications hypothesised
- Pulled between two poles: technological framework and application/business framework
- The need to provide a unified taxonomy mapping/marrying the two
Definitions

- We refer to “Use case” as originally the business type of CR deployment scenario.
- We refer to “Application” as originally the technological kind of CR deployment or architecture, e.g. as radiocommunications service (mobile, fixed, etc) or similar.
- However we later see that the differences often become blurred, hence for simplicity we may assume the Use Cases $\equiv$ Applications.
Inventory of CR use cases

- Mitola (2000):
  - spectrum pooling – concept still surviving as DSA
  - network management protocols - surviving
  - services delivery - surviving
  - stability of type-certified downloads – extinct

- Mitola (2010, in Wyglinski, et al.), new additions such as:
  - Value proposition
  - Multimedia
  - Spectrum Auctions
  - Sentient Spaces
Inventory of CR use cases (2)

- **ITU WP5A:**
  - CR-assisted re-configuration for Multi-RAT access
    - Elsewhere referred to as “heterogeneous CR”
  - Use of CR for more efficient network management
    - Cf. Mitola’s “network management protocols”
  - CR as enabler of cooperative spectrum access
    - Cf. Mitola’s “spectrum pooling”, DSA
DSA - “institution on its own”

- Clearly the evolution of original Mitola’s spectrum pooling concept
- Given that opportunistic spectrum access offers (intuitively) most promising value proposition, has developed into large field (cf. DySPAN SC)
- Own taxonomy proposals, e.g. Zhao, 2007:

![Diagram of DSA concepts]

- Dynamic Spectrum Access
  - Dynamic Exclusive Use Model
  - Open Sharing Model (Spectrum Commons Model)
  - Hierarchical Access Model
- Spectrum Property Rights
- Dynamic Spectrum Allocation
- Spectrum Underlay (Ultra Wide Band)
- Spectrum Overlay (Opportunistic Spectrum Access)
ETSI TC RRS view

- **SDR Reference Architecture for Mobile Device:**
  - Terminal-Centric Configuration in a Heterogeneous Radio Context
  - Network driven Terminal Configuration in a Heterogeneous Radio Context
  - Addition of new features, such as support for novel radio systems, to Mobile Devices
  - Provision of a new cognitive feature (e.g. cross-technology spectrum measurement)

- **Reconfigurable Radio Systems operating in IMT bands and GSM bands:**
  - Spectrum refarming
  - Upgrading a pre-existing RAT and deploy of a new RAT to a pre-existing network
  - Addition of multiple standards modes
  - Radio Resource optimization
  - Cognition enabler

- **Operation in White Space Frequency bands:**
  - Mid-/long range wireless access over white space frequency bands
  - Short range wireless access over white space frequency bands
  - Ad-hoc networking over white space frequency bands
  - TV White Space (TVWS) usage for Cellular Communication
What we make of the overview

- Plethora of use cases, but basically some recurring concepts seem to reappear again and again
- The different contexts tend to mask the main essential features
- In June 2011 we proposed using “utility” as differentiating factor, hence the “Application-driven” CR Taxonomy
- Now we would like to combine this with the “Technology-driven” approach, where CR technology (essentially – the degree of cognition) is the differentiating factor
Application-driven taxonomy

Cognitive Radio

- DSA
  - ITU3
  - M1
  - Real-time spectrum auctions (lease)
  - Opportunistic exploitation of spectrum holes
  - “Advanced” commons, “underlay”
  - Self-provided
  - Managed
  - Geolocation DB
  - CPC

- Wireless network management
  - ITU2
  - M2
  - Coverage expansion, ad hoc, mesh networking
  - RAN congestion mngmnt, capacity enhancement
  - Self-organisation (re-configurability/upgrades)
  - Energy saving, “Green” network
  - M5
  - M8

- User-aware wireless services
  - ITU2
  - M3
  - User as 8th OSI layer (QoS → QoI)
  - Location aware multimedia (social networking)
  - Sentient spaces (assisted living, robotics)
  - M6

- Heterogeneous networking
  - ITU1
  - M4
  - Terminal-centric multi-RAT access
  - Network-driven multi-RAT access
  - “On-the-fly” addition of new RATs, features
  - E1
  - E2
  - E3

- Geolocation DB
  - E10
  - E11
  - E13

- ETSI case X

- Mitola’s case X

- ITU X

- ETSI case X
Technology-driven taxonomy

Level I: Radio information detection

Level II: Radio parameter adaptation

Level III: Learning

Level IV: Re-orientation
Technology-driven taxonomy (2)
Practical value

- Morphological importance of clear analytical identification and allocation of any discussed CR applications, to avoid ambiguity and repetitions – “all speaking the same language”
- Practical technical importance through hierarchical “tagging”, i.e., precise unambiguous description of a particular use case and technological capability as a part of certain “CR genome” to assist the mutual recognition and rendezvous mechanisms
Example of CR “genome” building

- **Example of CR “genome” building**

- **DSA**
  - Real-time spectrum auctions (lease)
  - Opportunistic exploitation of spectrum holes
  - ‘Advanced’ commons, “underlay”

- **Wireless network management**
  - Coverage expansion, ad hoc, mesh networking
  - RAN congestion mgmnt, capacity enhancement
  - Self-organisation (re-configurability/upgrades)
  - Energy saving, “Green” network

- **User-aware wireless services**
  - User as 8th OSI layer (QoS → QoI)
  - Location aware multimedia (social networking)
  - Sentient spaces (assisted living, robotics)

- **Heterogeneous networking**
  - Terminal-centric multi-RAT access
  - Network-driven multi-RAT access
  - “On-the-fly” addition of new RATs, features

- **Geolocation DB**
  - Self-provided
  - Managed

- **CPC**

---

- E.g.: GDB-based TVWS system – class ABBA
- E.g.: Energy saving “Green” CRN – class BD

In that way “genetic code” unambiguously tells:
- hierarchical level
- specific branch
- ultimate type of application

---

- possibility of future extension (at each level) when/if necessary
E.g. CR rendezvous process Stage 1: service/application discovery

- Service/application information (including regulatory constraints) universally obtained by means of CPC, database lookup, beacons, Tx pre-ambles, etc.

Then newly activated CR device creates a list of available services and regulatory constraints in given band(s), then can choose which services to connect with or which resource to use (dependent on regulations).
E.g. CR rendezvous process
Stage 2: technological profile

- After initial contact, the network and new device could exchange details of technological capabilities, service rules, etc.
Conclusions, future work

- Possibility of universal, expandable, unambiguous codification of all CR applications
- Technical “tagging” of applications to ensure their recognition and differentiation in the operational field; complete rendezvous of devices
- We would welcome broader debate on establishing such a universal taxonomy, which would unite technological and use-case/business aspects
Acknowledgements

- This work was supported by:
  - COST Action IC0905 “TERRA”, [www.cost-terra.org](http://www.cost-terra.org)
  - ICT-ACROPOLIS Network of Excellence, FP7 Grant Number 257626, [www.ict-acropolis.eu](http://www.ict-acropolis.eu)
  - Research grant from Lithuanian Council of Science, n. COST-1/2012