End-to-end Cognitive Radio Testbed (EECRT)

current state and proposal for continuation
TEKES TRIAL program

Department of Communications and Networking
School of Electrical Engineering
Aalto University
EECRT testbed

- Implementation of a cognitive radio testbed for a large network
- The testbed is intended for investigating
  - Radio usage business models
    - Investigating spectrum management techno-economic models
  - End-to-end network throughput optimization
    - Radio interface selection algorithms with the focus on end-to-end performance
  - Dynamic Spectrum & Bandwidth Management (DSM) and Cognitive Radio Resource Management (CRRM) algorithms
    - Transmission of real data on physical layer is controlled by RRM algorithms
Testbed Architecture

Cellular Operator 1 (existing infrastructure)

Cellular Operator 2 (existing infrastructure)

Comnet WLAN network (existing infrastructure)

White Space Operator (part of testbed)

Black Space Operator (part of testbed)

Each Cloud is an independent economic actor

User Equipment (part of testbed)
**Testbed Components**

- **White space base station**
  - potentially multiple RATs

- **Black space base station**
  - potentially multiple RATs

- **Dynamic Spectrum Manager**
  - spectrum policy, regulations, brokerage

- **Self-organization & RRM server**
  - per operator multicell CR functionalities

- **User plane server**
  - application layer server
  - flow-level performance collection

- **CR UE**
  - dongle connection to (multiple) cellular operators
  - WLAN connection to comnet
  - white & black space CR (potentially multiple RATs)

- **Legacy Radio UE, state-of-art connectivity**
  - dongle connection to (multiple) cellular operators
  - WLAN connection to comnet
Concurrent Modeling of Business and Technical Architectures

- Result from agent based modeling: How the spectrum leasing time duration impacts income of different market participants.

Themes for the second phase of the project

• Value system modeling
  – Data analysis of spatial demand and its implications for CR value
  – Coasean approach to spectrum markets (transaction benefit and cost analysis)
  – Continuation: market differences from a regulatory perspective
  – Continuation: value system evolution towards CR

• Techno-economic modeling
  – Investment analysis of CR benefits for Finnish mobile operators
  – Possibly coupled with game theory
Intelligent selection of Radio Access

- Collects the data
- Processes the data

Connection Information DB

Measures the connection

Cellular Operator 1 (existing infrastructure)

Cellular Operator 2 (existing infrastructure)

Comnet WLAN network (existing infrastructure)

User plane server
Intelligent selection of Radio Access

• Demo of intelligent access selection for 3G network
  – Laptop with several mobile phones connected
  – Mobile phones
    • Provide internet access
  – Our application
    • Collects network/location information from the phones
    • Query an external database for selecting best network
    • Selects the connection over multiple phones

• Research questions
  – Machine learning algorithms for analyzing the collected data
  – Selection algorithms performance measurement and testing
  – Integration of the path selection with other technologies
“Living lab” software radio network

• The testbed is intended for investigating DSM and RRM in a realistic radio network environment

• The network is made of reconfigurable software radios
  – The platform allows to transmit a “real” data over radio interface
  – Each TxRx is configurable by RRM manager
    • LTE TDD type radio interface with addressable resource blocks
  – We have 18 radios
    • Radio can transmit “real data” and uses (max) 10 MHz
    • RF carrier can be tuned in interval: 0.4 - 4.4 GHz
  – Multiple RRM managers can cooperate
    • RRM can communicate with network manager
    • RRM can be controlled remotely
Interference management research

• We have designed a flexible platform that allows to test the interference control algorithms in the real environment
  – We could measure the interference conditions in the receivers
  – The transmitters and receivers could communicate among themselves
• We could use polarization for improving the coexistence of multiple transmitters
• We can test SON algorithms and estimate their performance in the network
Research questions

• How to control interference in heterogeneous network?
  – We can configure the transmitters to follow different RRM strategies and measure the performance of the network

• How to control interference inside one network with different level of communication between local entities?

• How to control interference in neighboring networks?
  – For example co-primary network.
  – D2D network.

• How much interference is observed in an indoor network?
  – We can measure the actual interference conditions
How to distribute the interference control among different control levels?

DSM – dynamic spectrum management among different network controls
JRRM – joint radio resource management inside one network
RRM – local radio resource management