SEnsor Network for Dynamic and cOgnitive Radio Access

Sendora

SEVENTH FRAMEWORK PROGRAMME

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THEME ICT-2007-1.1
The Network of the Future

Project 216076

SENDORA: Design of wireless sensor network aided cognitive radio systems

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THALES

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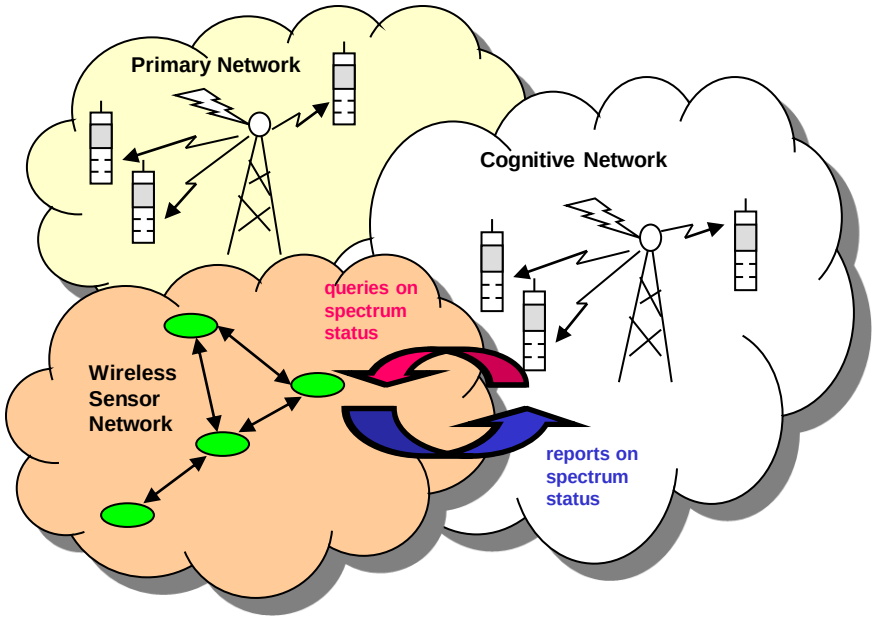
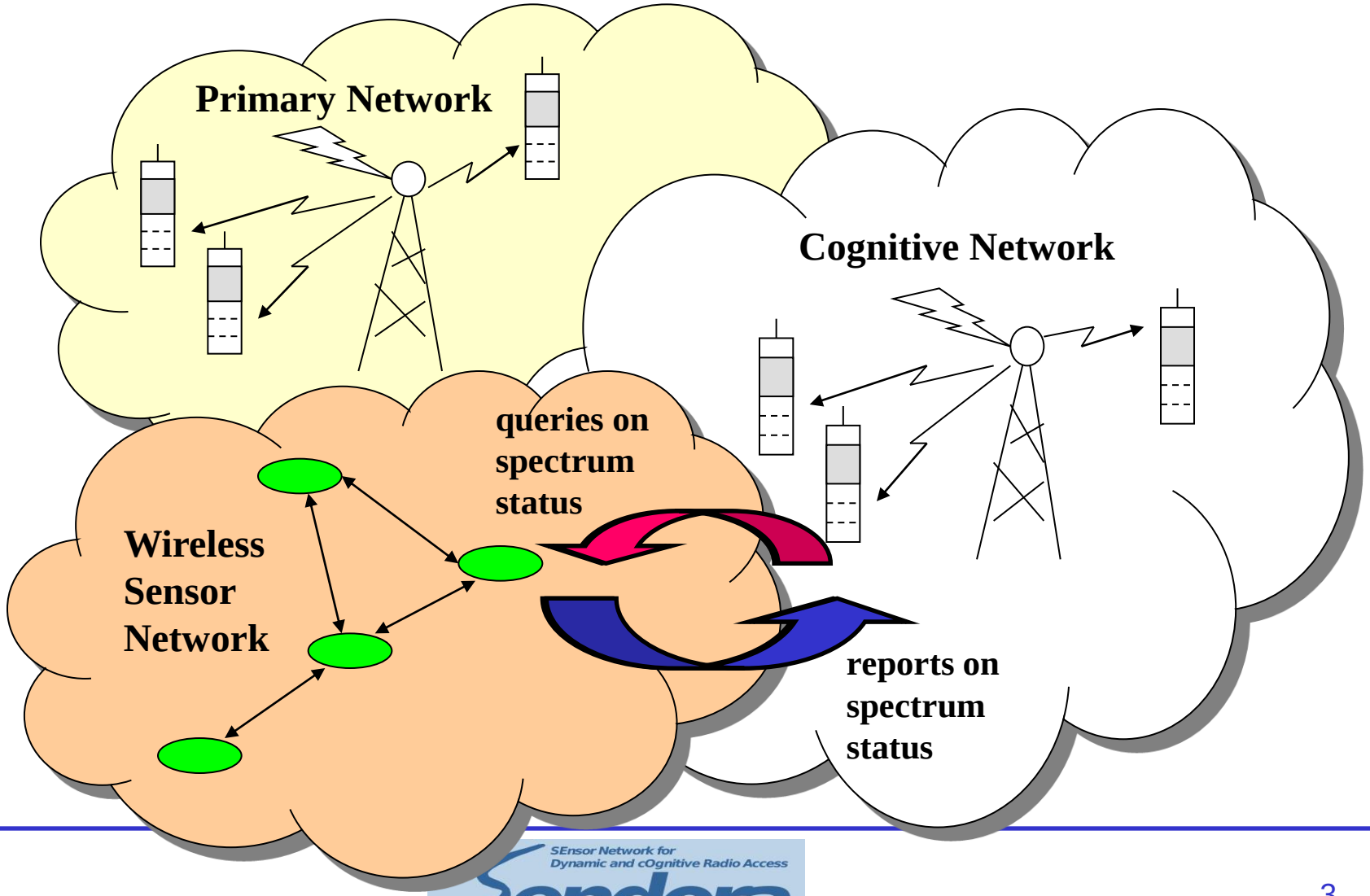
SENDORA overview

- **Motivation:** radio spectrum is a scarce resource that is paradoxically under-utilized
- **Objective:** develop a technology able to reuse the licensed but unused spectrum in an opportunistic manner
- **Challenge:** detect and use spectrum holes, without interfering harmfully with the licensed network, with fine granularity of allocation in time and frequency
- FP7 ICT Call 1 project
- From January 2008 to December 2010

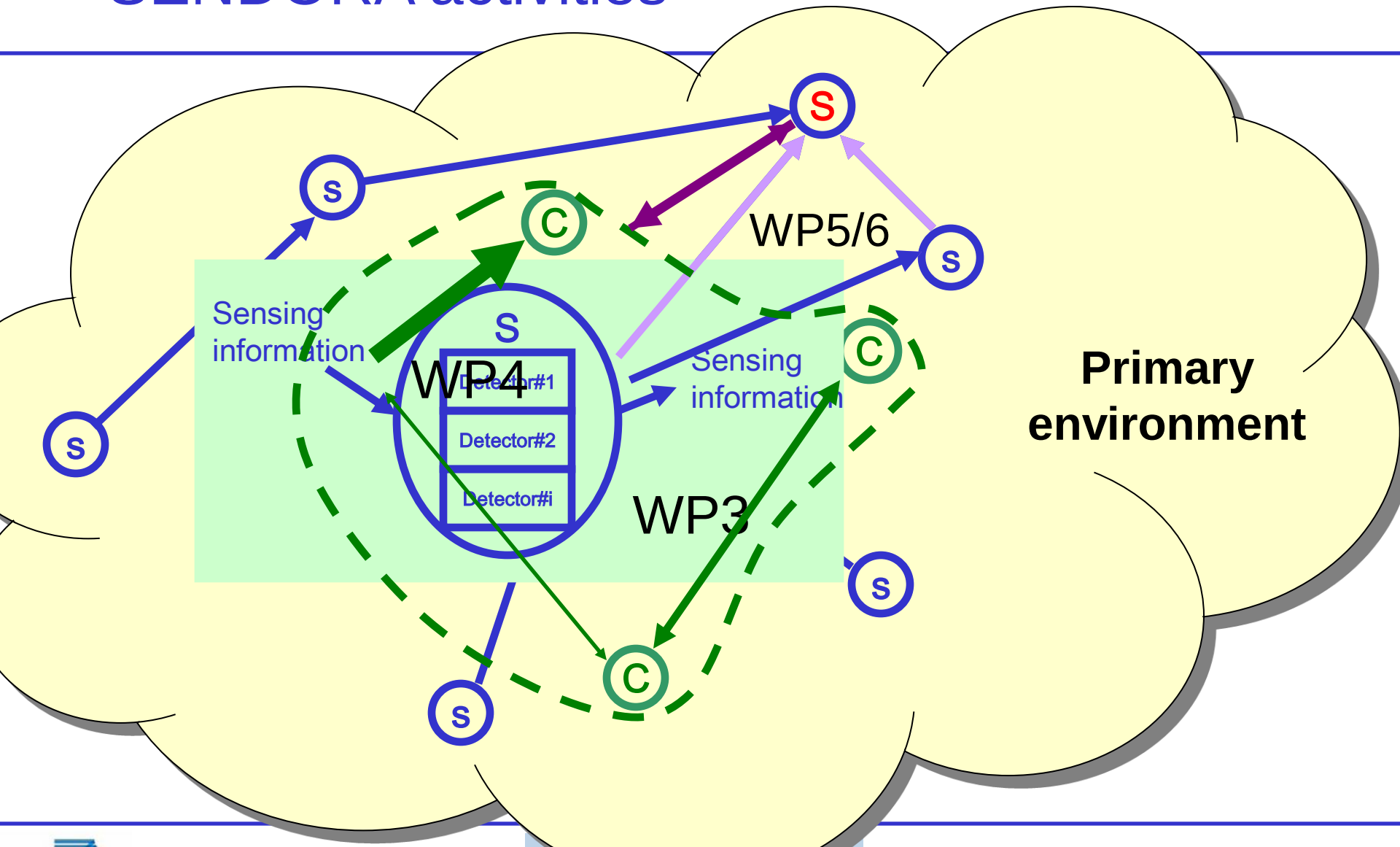


"Sensor Network aided Cognitive Radio"

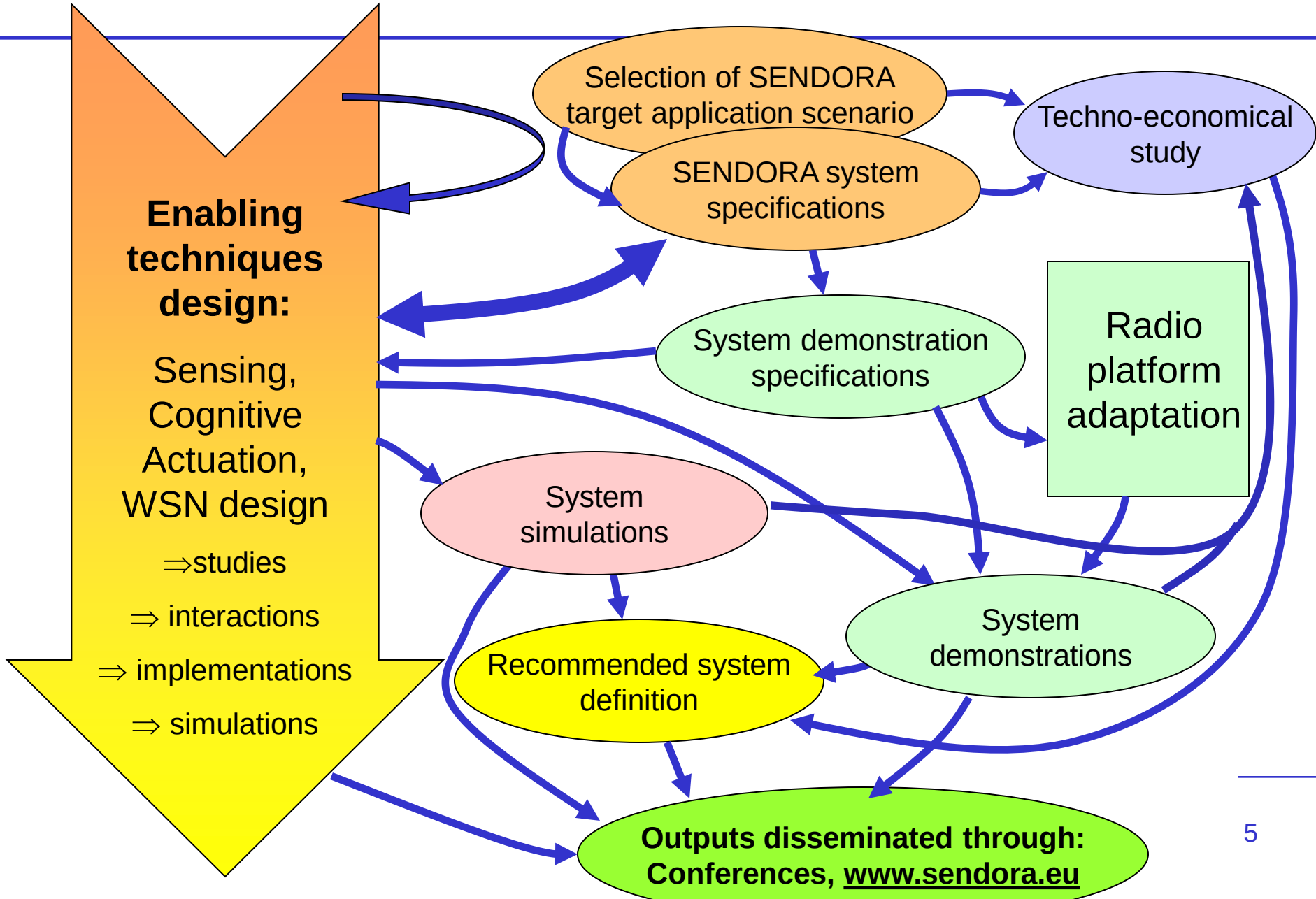
SENDORA: Sensor Network Aided Cognitive Radio System



SENDORA activities



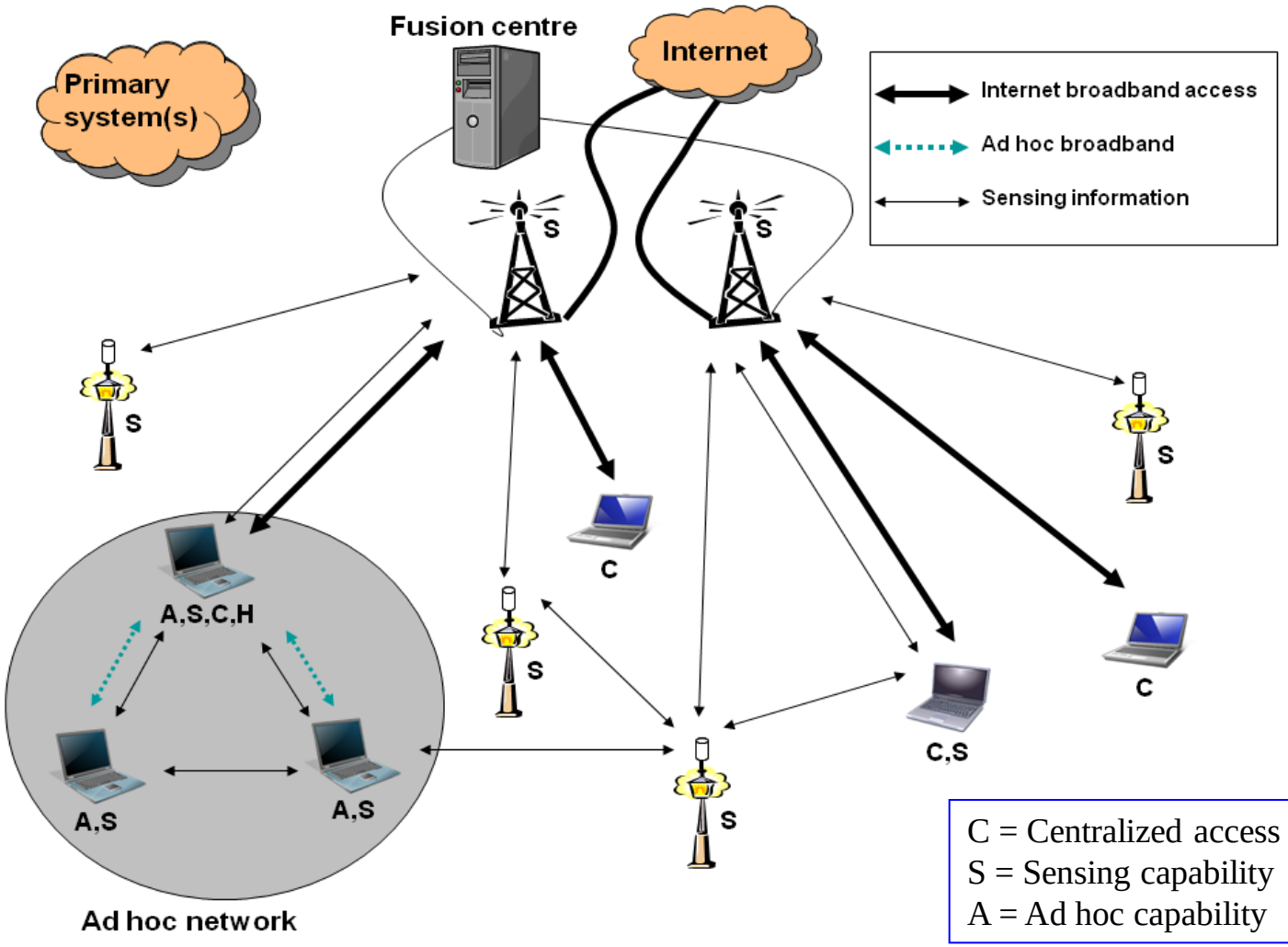
SENDORA general approach



System Specifications

- Selected scenario:
  Cognitive **Nomadic broadband in urban and suburban areas**
- Non real-time services: web browsing, video download;
  Real time services provided on a best-effort basis
- Scenario evaluated to both have high market potential and be the best solution compared to other technologies
- A hybrid architecture is proposed with an external sensor network and sensors integrated in user terminals

System Architecture



C = Centralized access capability
S = Sensing capability
A = Ad hoc capability

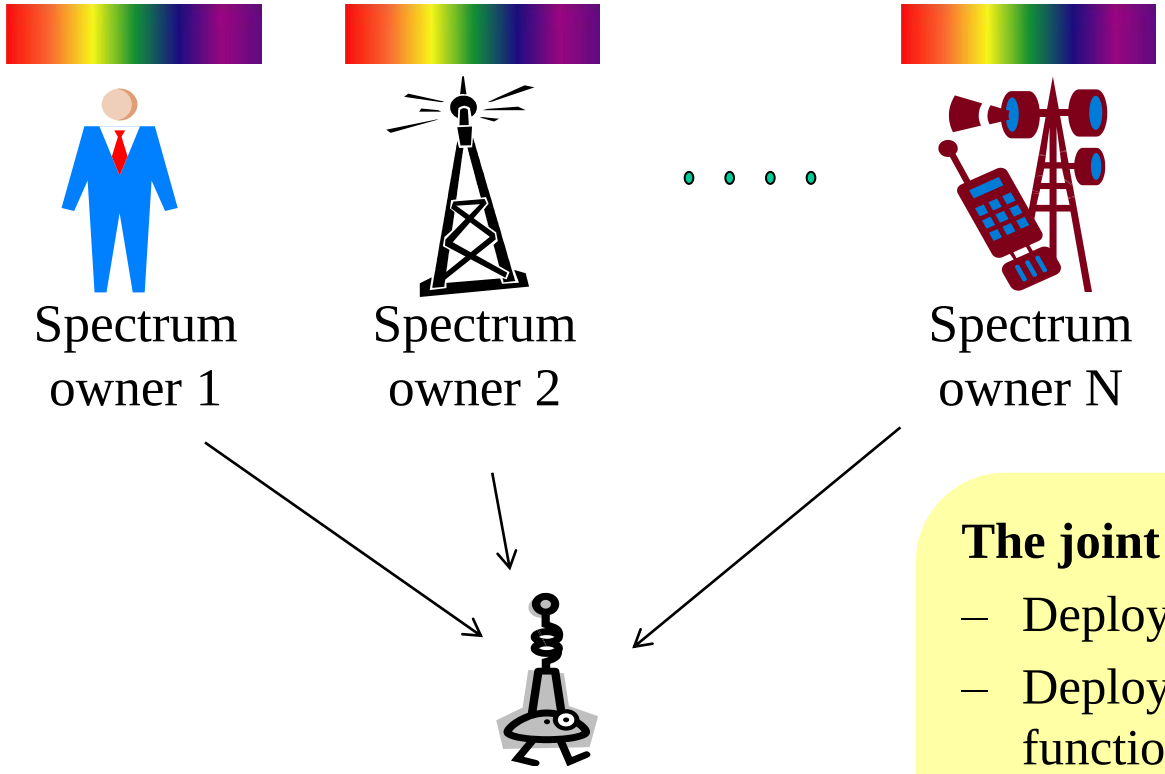
Studied techniques

- Sensing
  - Detection algorithms
  - Collaborative sensing
  - Effect of non-idealities
  - Hardware implementation aspects
- Cognitive actuation
  - Interference management techniques dedicated to
    - Cognitive system capacity maximization
    - Primary systems protection
- WSN design
  - Cooperative communications techniques
  - Network dimensioning
  - Dedicated protocol design

Benefits of the WSN aided CR approach

- The sensor network has two main functions:
  - To identify ”spectrum holes”
  - To protect the primary systems
- The sensor network provides improved protection of primary networks
  - Improved primary user detection confidence
  - Calibration of the interference generated by the cognitive radio network gives good interference control
- The capacity of the cognitive radio network is improved
  - Better detection of spectrum holes
  - Better interference control

Business Case : Spectrum Sharing



At least one of the owners is an operator having a cellular infrastructure in the area

The joint venture will:

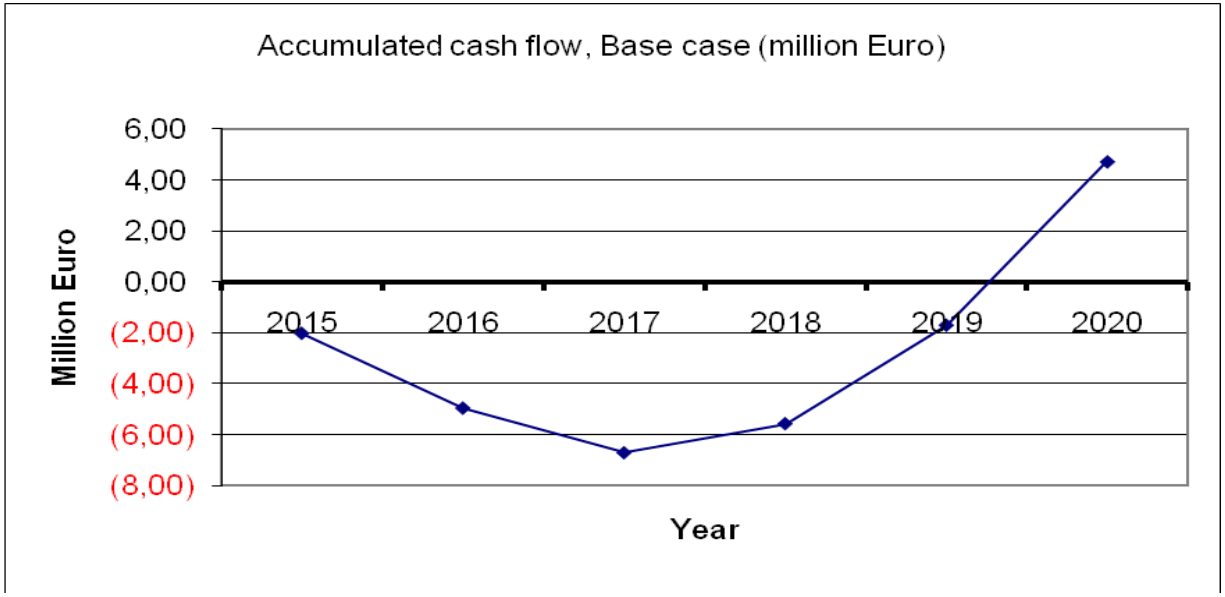
- Deploy a fixed sensor network
- Deploy cognitive base station functionality and pay rent for maintenance and backhaul to the BS owners
- Offer a nomadic broadband service

Key Assumptions for Business Case

- **Scenario:** Hypothetical European city with 1 million inhabitants, covering an area of 200 km^2 (incl. downtown area of 50 km^2). Study period: 2015 – 2020.
- **Revenues**
  - Subscription fee: 20 €/month
- **CAPEX Costs**
  - Fixed sensor price: 300 € (sensor density = 65 sensors/km^2)
  - Fixed sensor installation cost: 50 €/sensor
  - Fusion centre costs: 150,000 € (price) + 10,000 € (installation)
  - Cognitive functionality in BSs: 5,000€
  - Cost for establishing new BS sites: 60,000€ (no new BS sites assumed in the base case)
- **OPEX Costs**
  - General OPEX: 8€/subscriber/month
  - Fixed sensor operational costs: 15 €/month/sensor
  - BS maintenance and rental costs: 1,000€/month/site

All numbers are estimates for the year 2015

Business Case Results



Results are quite similar to many other tele-communication infra-structure projects.
It's a long-term business case, where the joint venture must have financial strength to wait a longer period for the return on investment.

Business case : Sensitivity analysis (1)

ARPU [€/month]	NPV [million Euro]
15.0	-9.33
18.0	-2.92
19.4	**0**
20.0	**1.36**
25.0	12.04

The attractiveness of the service is crucial

Base case

Low power and very reliable sensors required

Fixed sensor OPEX [€/month/sensor]	NPV [million Euro]
5.0	6.82
10.0	4.09
15.0	**1.36**
17.5	**0**
20.0	-1.37
25.0	-4.10

Base case

Number of fixed sensors per km^2	NPV [million Euro]
10	11.44
30	7.77
65	**1.36**
72	**0**
120	-8.72

Base case

R&D efforts should focus on ways to reduce the required fixed sensor density

Business case : Sensitivity analysis (2)

Share of new sites	NPV [million Euro]
0 %	**1.36**
6 %	**0.00**
10 %	-0.89
20 %	-3.03
30 %	-5.28
40 %	-7.43
50 %	-9,67

Base case

New sites should be avoided.

It will be a challenge to produce sufficiently cheap and reliable outdoor sensors.

Fixed sensor price [Euro]	NPV [million Euro]
50	3.98
150	2.93
300	**1.36**
430	**0**
500	-0.74
700	-2.84
1000	-5.99

Base case

Project outcomes

- SENDORA has generated valuable foreground of many kinds:
  - A system approach and associated design methodology
  - Architectural studies
  - Advanced enabling techniques in detection, collaborative sensing, protocol stack design, network dimensioning
  - First business case studies in close relationship with technical studies
  - System simulations at different levels (NS2)
  - Hardware implementations
  - Demonstration based on radio platform prototypes (Eurecom OpenAirInterface)
- The achievements are in line with expectations, in particular from regulators, as shown by an analysis of the RSPG report on cognitive technologies

Thanks for your attention !

More details and results can be found at www.sendora.eu

Main system requirements

- Common system requirements have been defined for the different parts of the system:
  - Regarding the Cognitive Network:

    Network topology (both centralized and ad hoc), Usage model (nomadic), Terminal types (laptop typically), Required capacity (DL: 5 Mbit/s, UL: 1.3 Mbit/s), Services and QoS (Internet Access, best effort), Operating Frequency range (<3GHz), Coverage (indoor and outdoor), Ranges (100m (ad hoc) to 1km (centralized)), Power (battery, dynamic power control)

  - Regarding the Wireless Sensor Network:

    Mobility (fixed infrastructure), Power (mains or battery), Communication (dedicated narrow licensed band), Coverage (area of cognitive operation), Detection probability of Primary communications (0.95)

  - Regarding the Primary Networks to consider:

    Considered Primary Technologies (WiFi, LTE, DTT, UMTS)