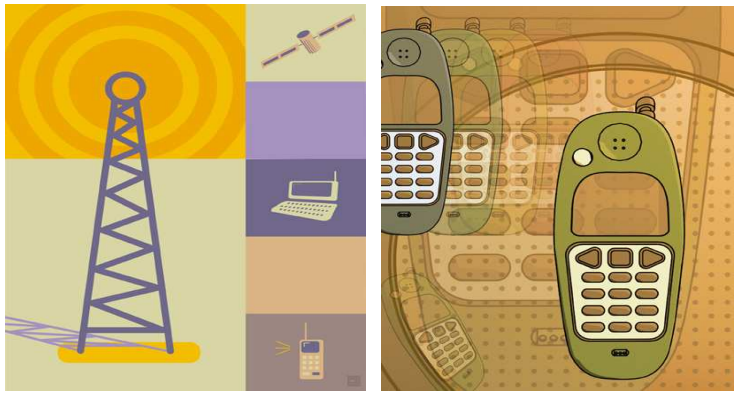
The E3 Architecture and Solutions for Cognitive Radio Networks



Jens Gebert
Alcatel-Lucent Bell Labs Germany

31. Meeting of VDE/ITG Group 5.2.4 “Mobility in IP-based networks”
Workshop “Cognitive Radio – Technical Challenges and Commercial Implications”

Presentation outline

- E3 Overview
- Architecture
- Self-Organization/Self-Optimization
- Flexible Use of Spectrum
- Prototyping Environment
- Cognition Enablers
- Standardization of Cognitive Systems
- Conclusions

E³ – Overview

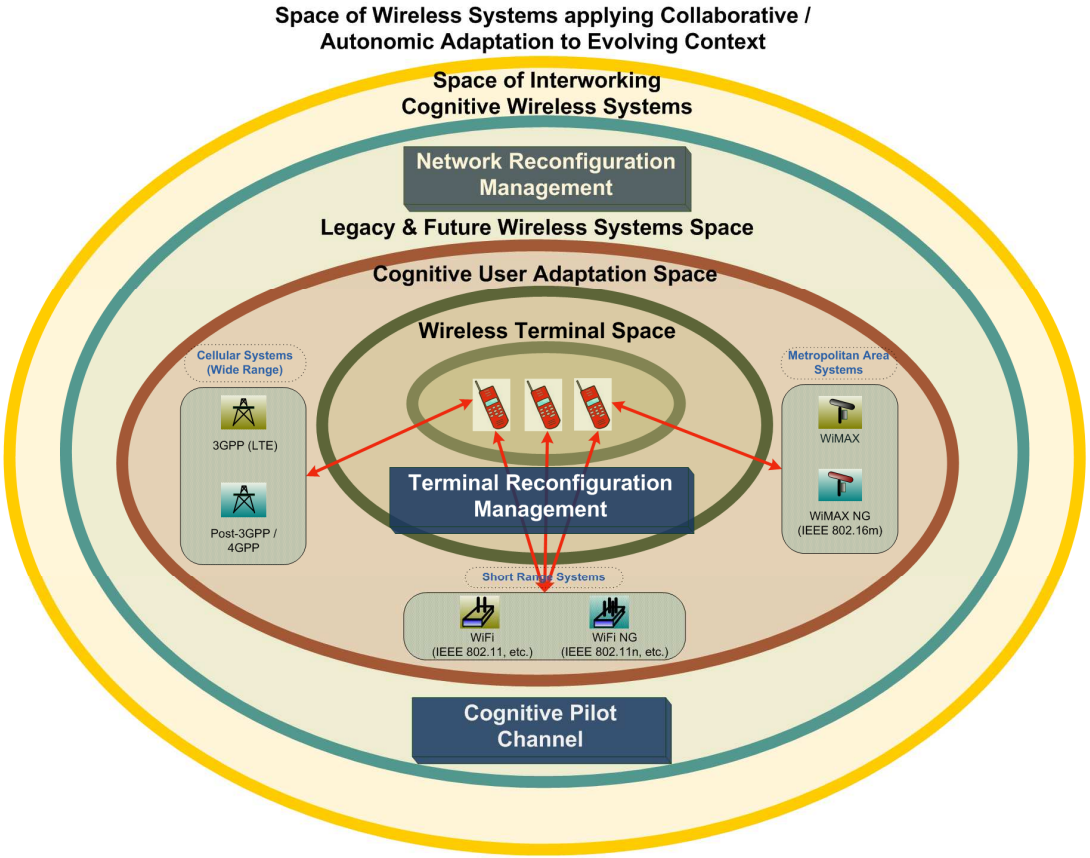
E³ is an European Project on End-to-End-Efficiency under the 7th Framework Program of the European Commission, addressing the core of the strategic objective "The Network of the Future"

Top Level Objectives:

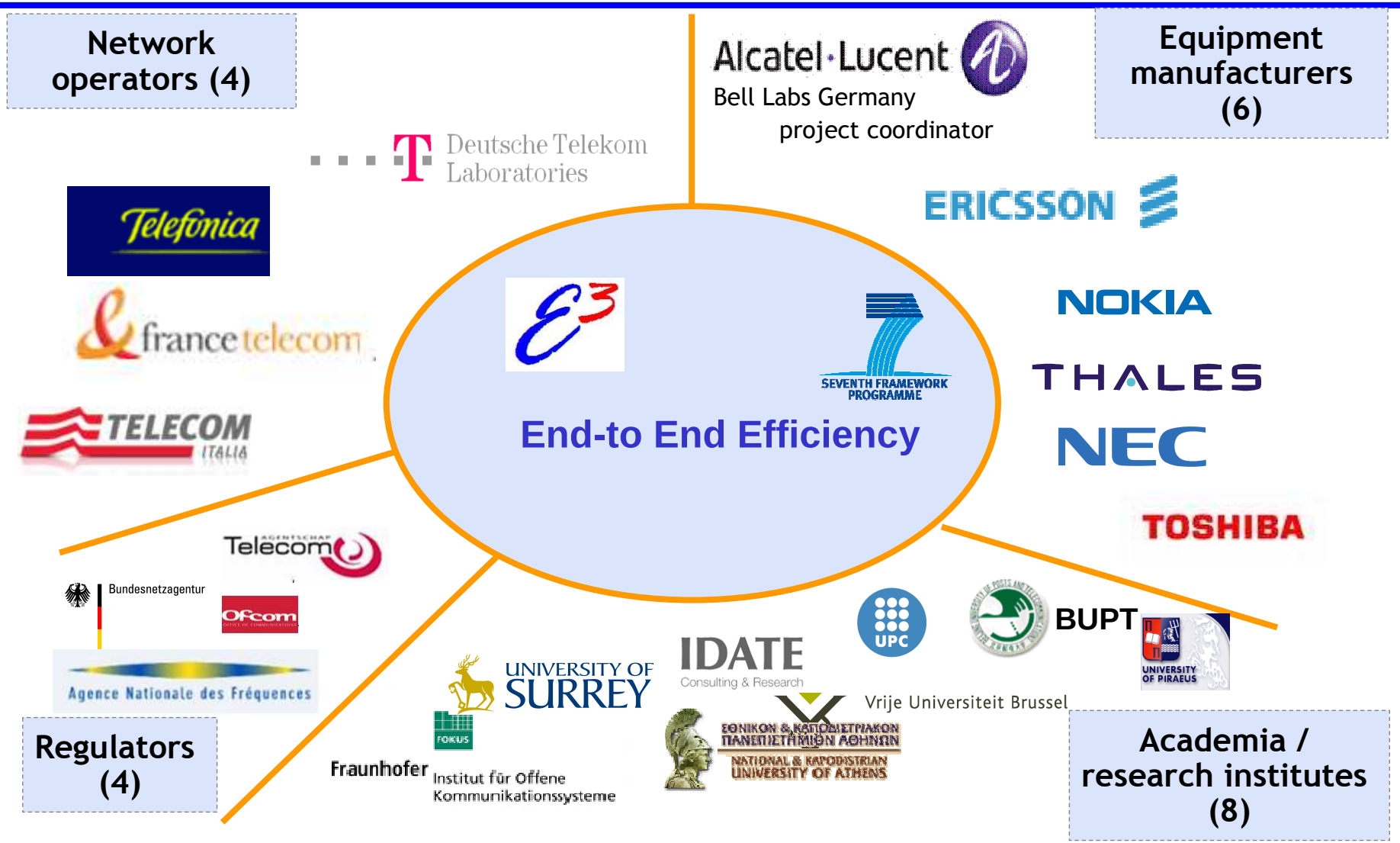
- *Cognitive Radio System design*
- *Gradual, non-disruptive evolution of wireless networks*
- *Increased efficiency of wireless network operations*

Project Duration:

- *Jan. 2008 – Dec. 2009*



E³ - Partners


Network operators (4)
Alcatel·Lucent
Bell Labs Germany
project coordinator
Equipment manufacturers (6)
Deutsche Telekom Laboratories
Telefonica
ERICSSON
france telecom
NOKIA
THALES
TELECOM ITALIA
NEC
TOSHIBA
End-to End Efficiency
SEVENTH FRAMEWORK PROGRAMME
Telecom
Bundesnetzagentur
Ofcom
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Regulators (4)
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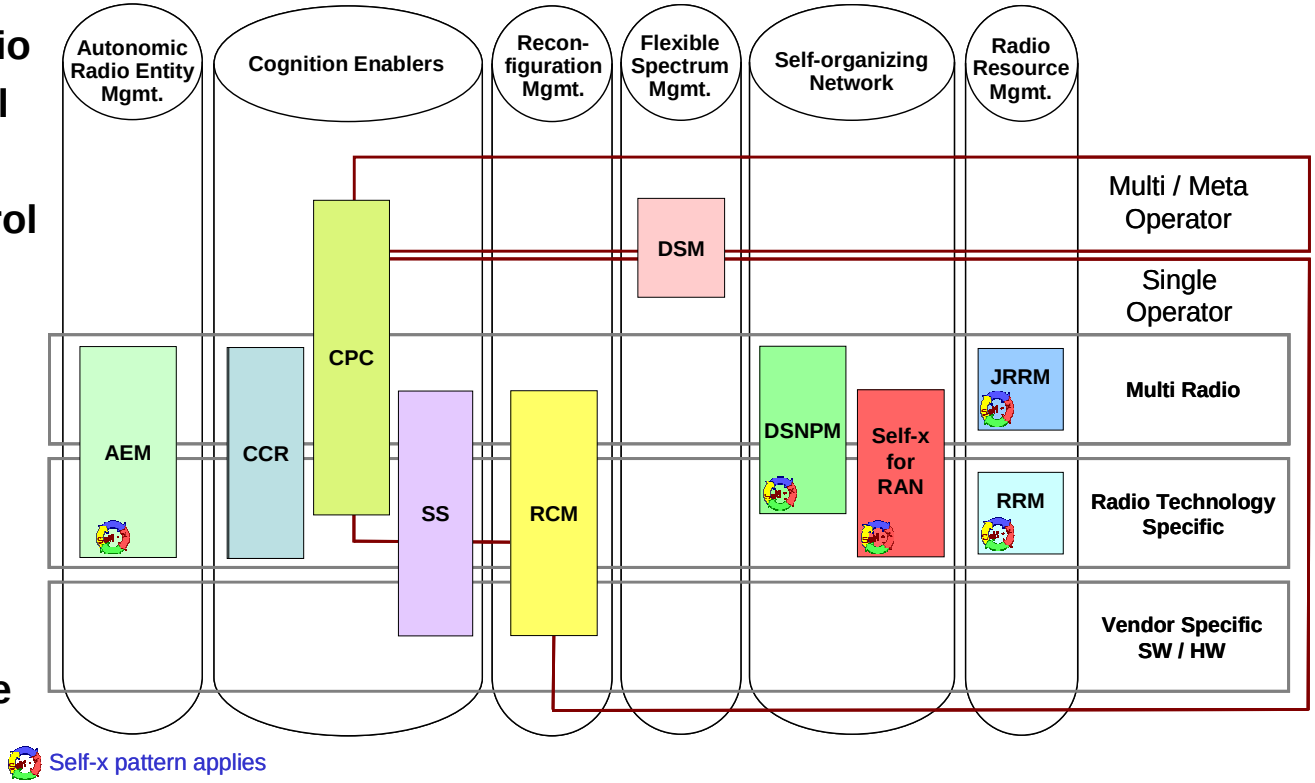
Cognitive Radio Aspects: Evolution

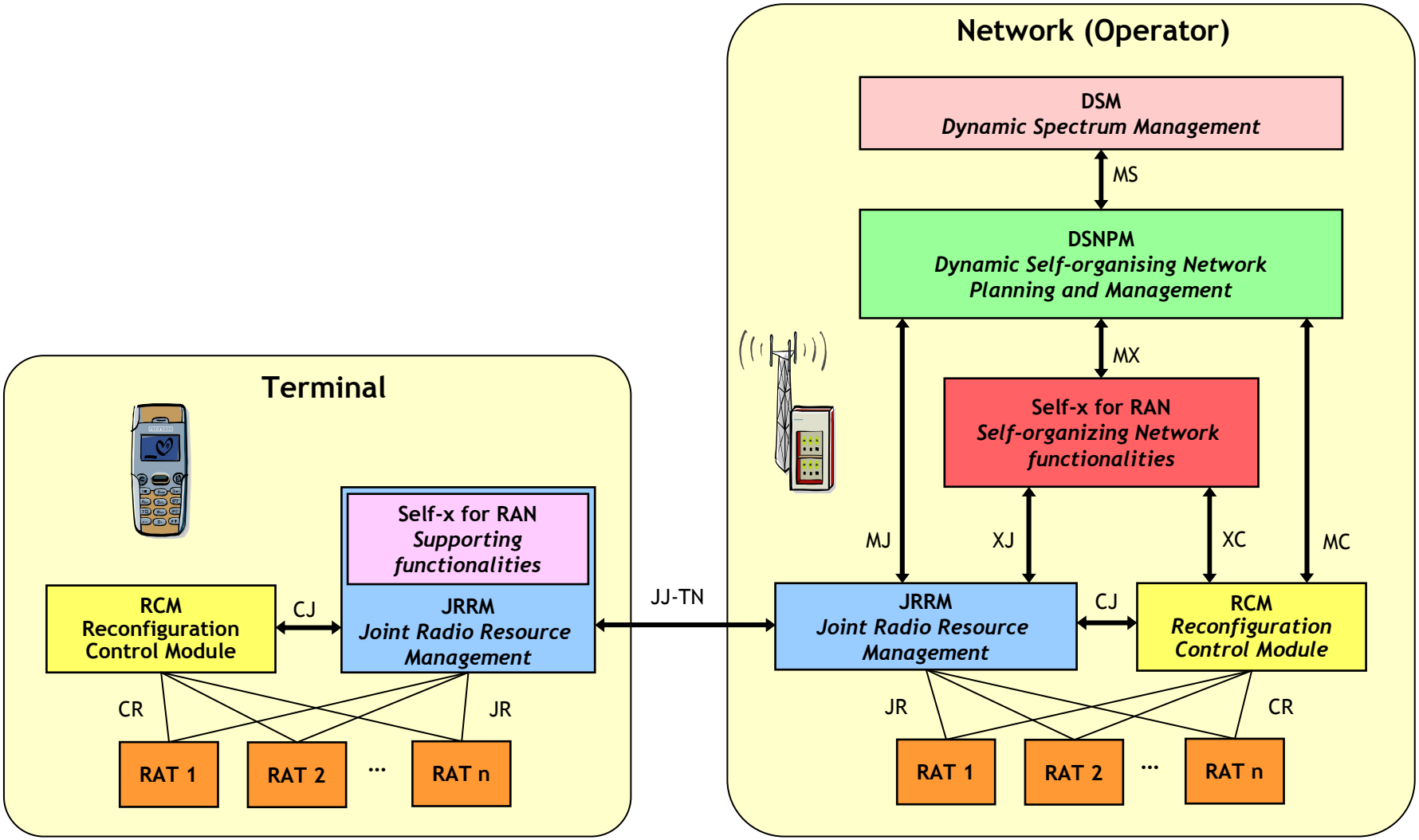
- Introducing Reconfigurable, Cognitive Systems in the B3G world:
- Evolution of B3G systems to Cognitive Radio Systems
- Improve utilisation of spectrum and radio resources
  - ⇒ Dynamic Spectrum Management
  - ⇒ Support of heterogeneous standards
  - ⇒ More efficient Joint Radio Resource Management (Short term)
- Reconfigurable Base Stations and Reconfigurable Terminals
- Self-Management and Self-Optimisation of
  - ⇒ Radio Network Infrastructure
  - ⇒ Cognitive Devices
- Cognition Support Mechanisms
  - ⇒ Cognitive Pilot Channel, Spectrum Sensing

The pillars of the architecture

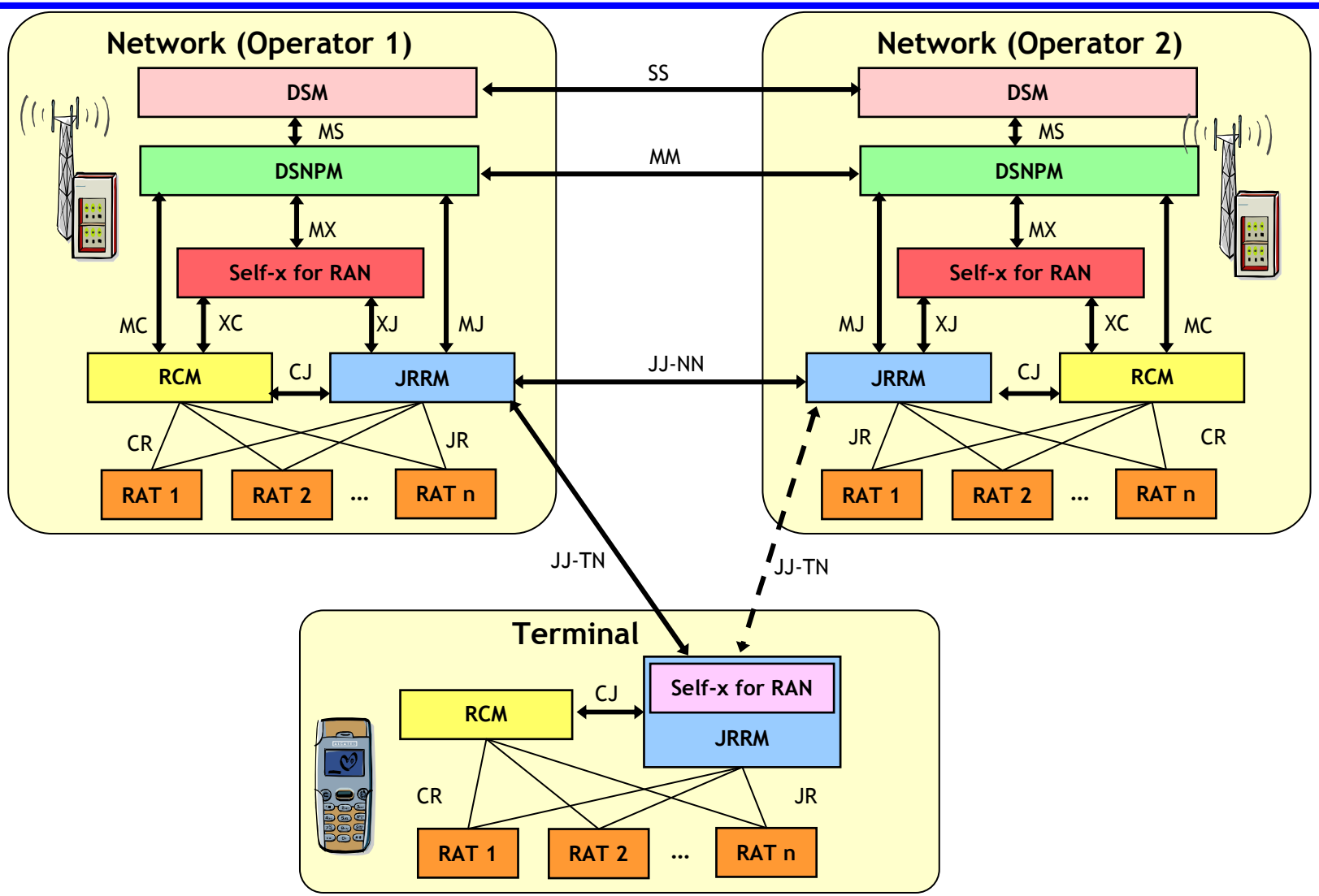
- **AEM - Autonomic Entity Management**
- **CCR - Cognitive Control Radio**
- **CPC- Cognitive Pilot Channel**
- **SS - Spectrum Sensing**
- **RCM - Reconfiguration Control Module**
- **DSM- Dynamic Spectrum Management**
- **DSNPM - Dynamic Self-organizing Network Planning & Management**
- **Self-x-for-RAN - Self-x for Radio Access Networks**
- **JRRM - Joint Radio Resource Management**
- **RRM - Radio Resource Management**



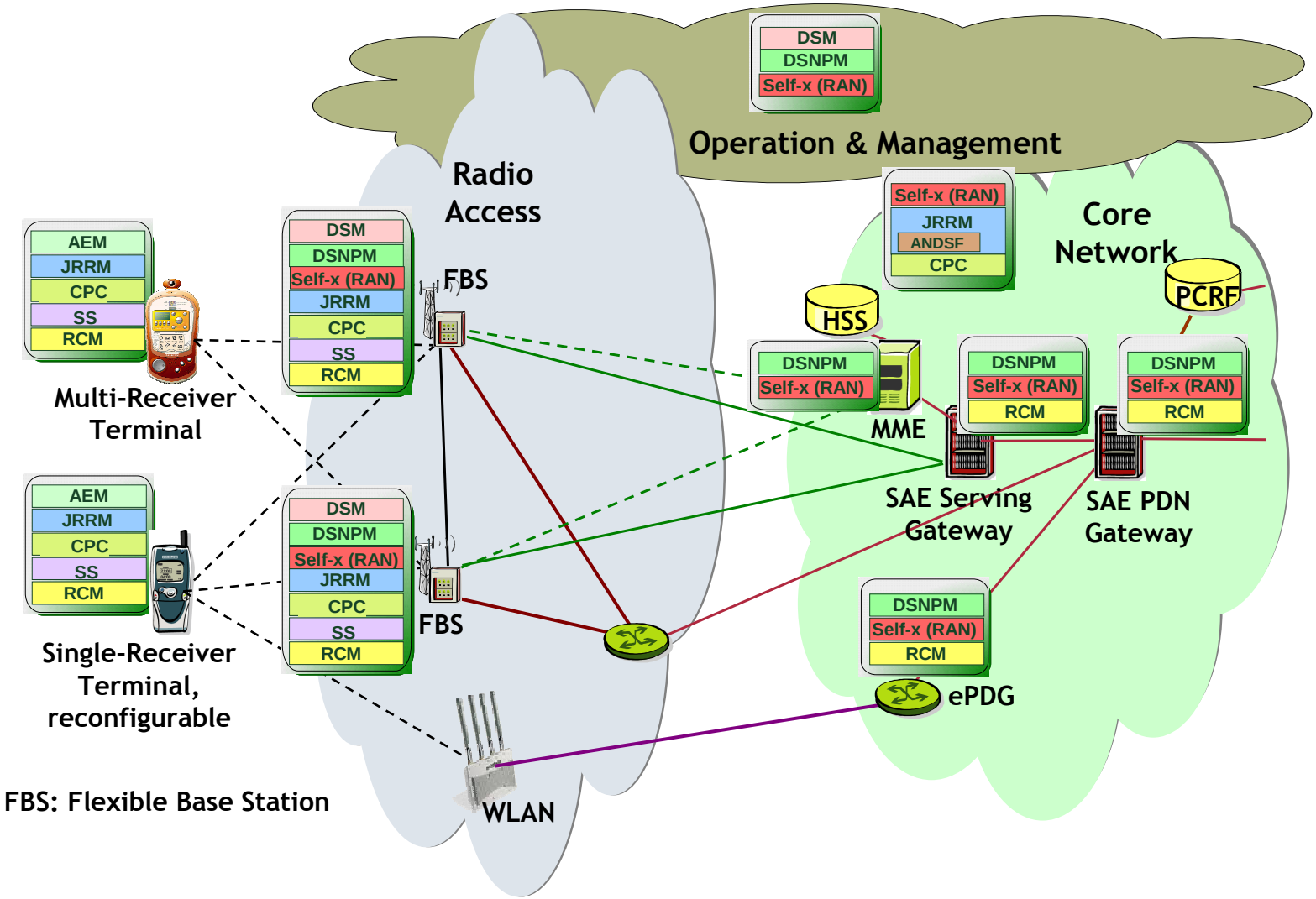
Functional Architecture (FA)
Single Operator Case



Functional Architecture (FA)
Multi Operator Case



Heterogeneous Wireless System and Functional Building Blocks



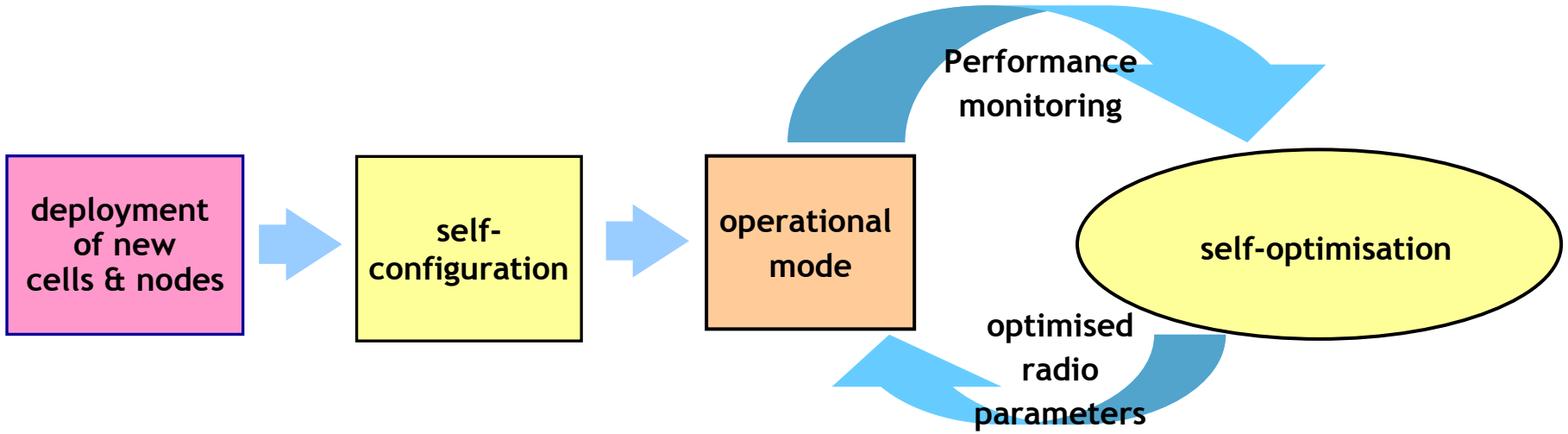
Self-Organization of Networks (1/4)

- Self-Management and Self-Optimisation of Cognitive Systems:
  - ⇒ Awareness of user, device and context information
  - ⇒ Policies derivation
  - ⇒ Decision making
  - ⇒ Reconfiguration
  - ⇒ Learning
- Cognitive Systems determine and configure their operation based on the knowledge and experience obtained through learning,
  - ⇒ In a reactive manner, i.e. responding to the detection of problematic situations
  - ⇒ Proactively to prevent issues undermining the optimal system function
- Simulation of new approaches & algorithms
- Recommendations for service-, network providers & equipment manufacturers

Self-Organization of Networks (2/4)

Self-X: Self-configuration, Self-optimisation, self-healing

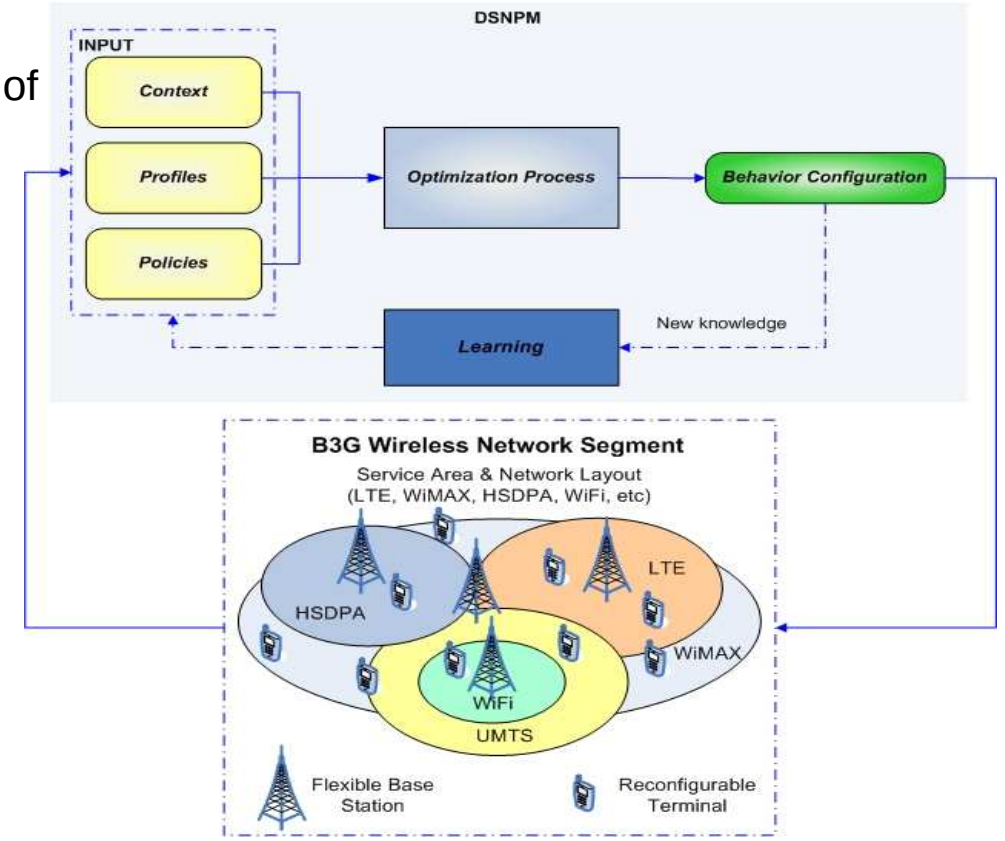
- ⇒ for single-RAT networks
  as well as heterogeneous networks
- ⇒ Spectrum selection, inter-cell interference coordination
- ⇒ Cell-outage compensation, cell self-reconfiguration
- ⇒ Handover optimisation, load balancing



Self-Organization of Networks (3/4)

Input:

- **Context: traffic, mobility, interference, element status**
  - ⇒ Change of element status, e.g., fault of some component
    like TRX → trigger for self-healing mechanisms
- **Profiles: equipment, application, user requirements and preferences**
- **Policies: optimization objectives, strategies, constraints**



Optimization mechanisms:

- **Algorithms for various time scales, optimal or near-optimal**
- **Short time scale: greedy, online**
- **Mid-term: simulated-annealing, taboo search, genetic algorithms**

Self-Organization of Networks (4/4)

Output:

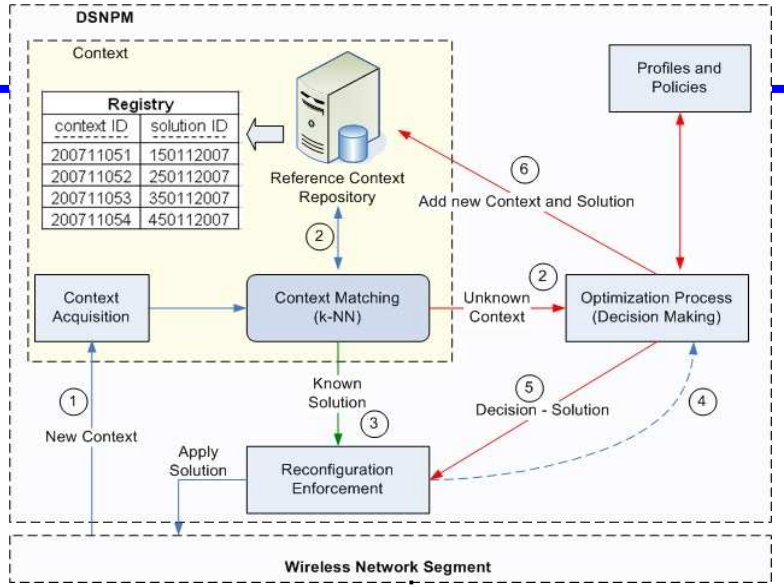
- **Configuration at various levels e.g.:**
  - ⇒ **RAT per transceiver**
  - ⇒ **Spectrum per transceiver**
  - ⇒ **QoS level determination per user class**

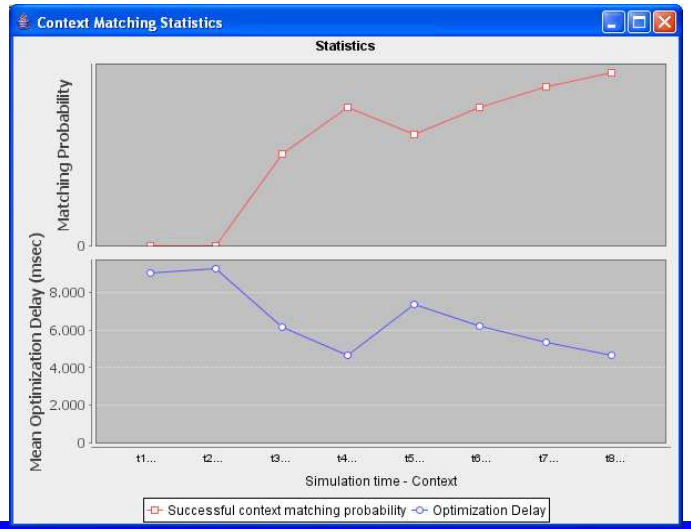
Learning:

- **Contexts encountered in time space**
- **Solutions applied and efficiency**

Impact:

- **Optimal QoS,**
  operational efficiency,
  automation of tasks,
  minimization of human involvement,
  reduction of operational expenditure (OPEX)

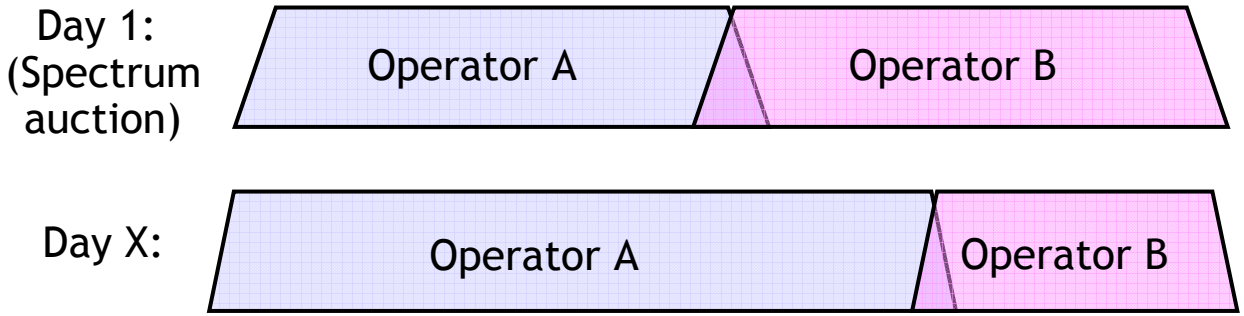




Flexible Use of Spectrum

Flexible use of spectrum

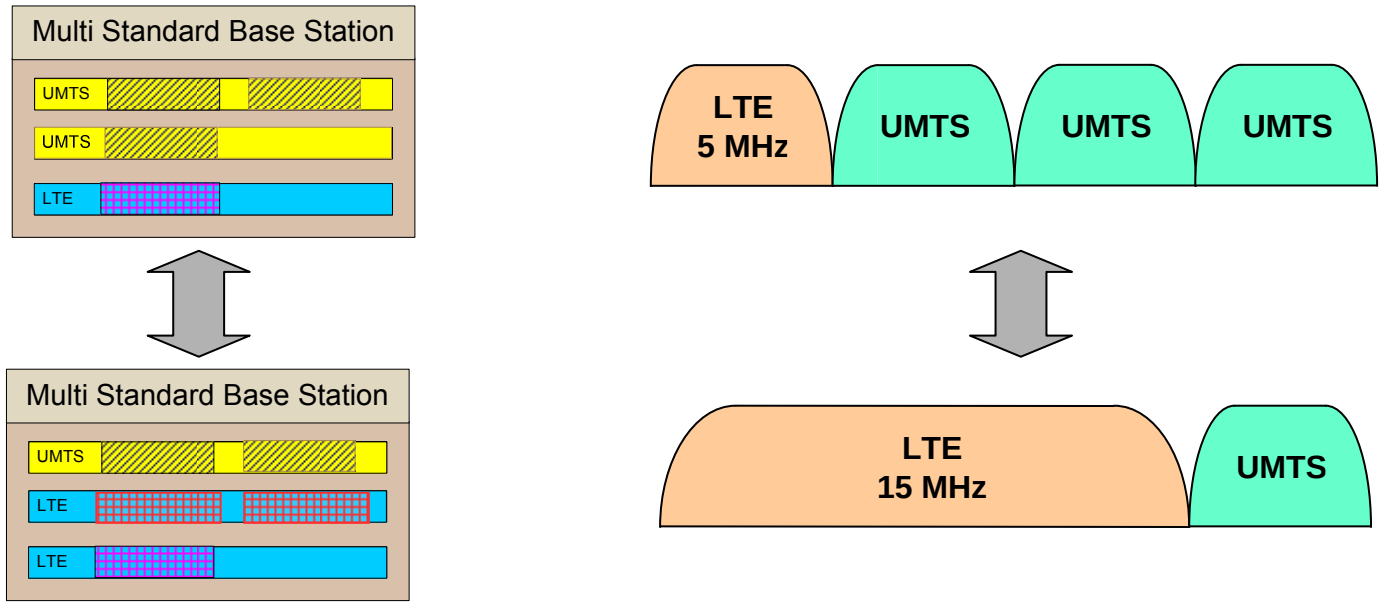
- Spectrum management for optimal spectrum usage
  - ⇒ Dynamic Spectrum Allocation (DSA):
    - Spectrum control in the network
    - Medium/long term radio resource optimisation



  - ⇒ Dynamic Spectrum Selection (DSS):
    - Spectrum control entity in the terminal
    - short term radio resource optimisation

Reconfigurable Base Stations and Terminals

- Reconfigurable base stations
  - ⇒ Base Station Configuration and Reconfiguration to maximise the networks efficiency



- **Reconfigurable terminals**

Cognition Enablers

Cognition enablers - Especially for environment with flexible spectrum management

⇒ Cognitive Pilot Channel

- Distributes information on available radio accesses and their spectrum

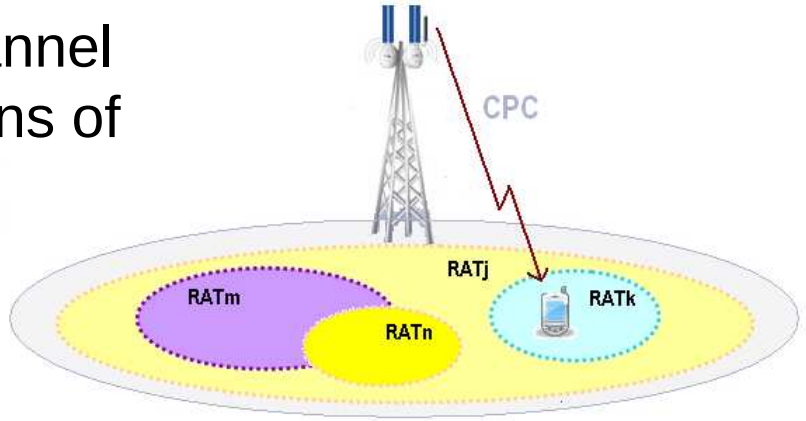
⇒ Cognitive Control Radio

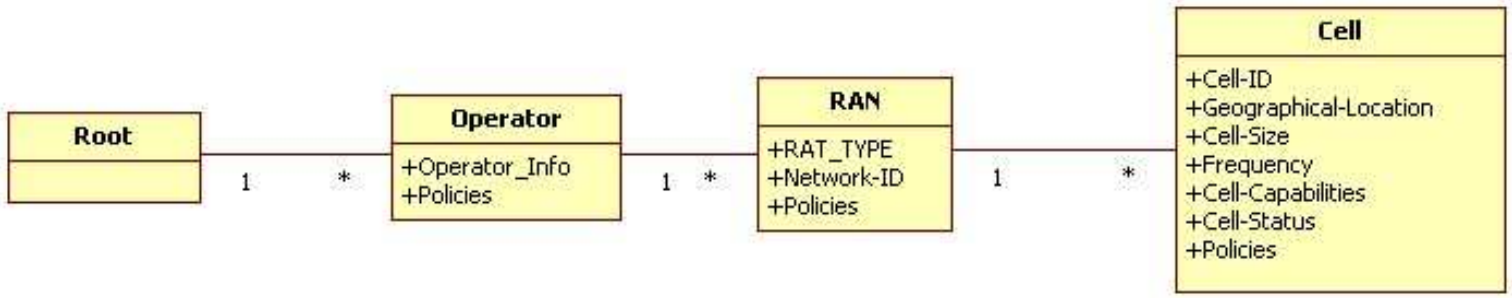
- Exchange of Cognitive Control information between terminals

⇒ Spectrum Sensing

Cognitive Pilot Channel (CPC)

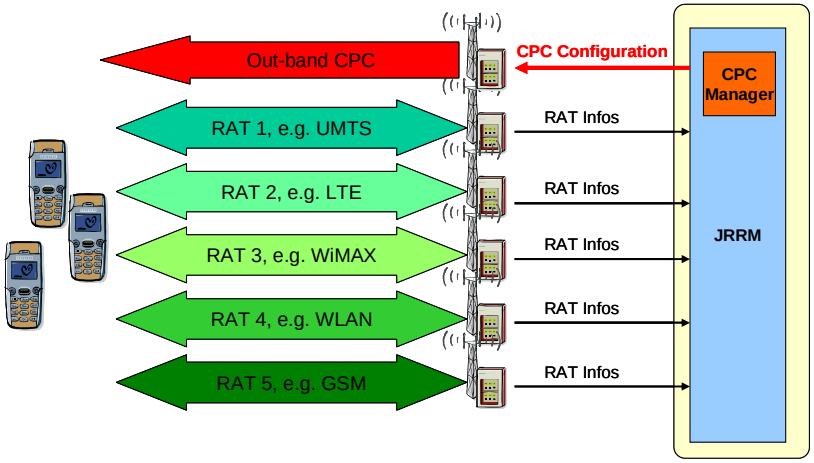
- Cognitive Pilot Channel (CPC): a channel providing information for the operations of Cognitive Radio Systems
- Use Cases
  - ⇒ Start-up scenario
  - ⇒ Secondary spectrum usage
  - ⇒ Radio resource optimisation
- Information model:



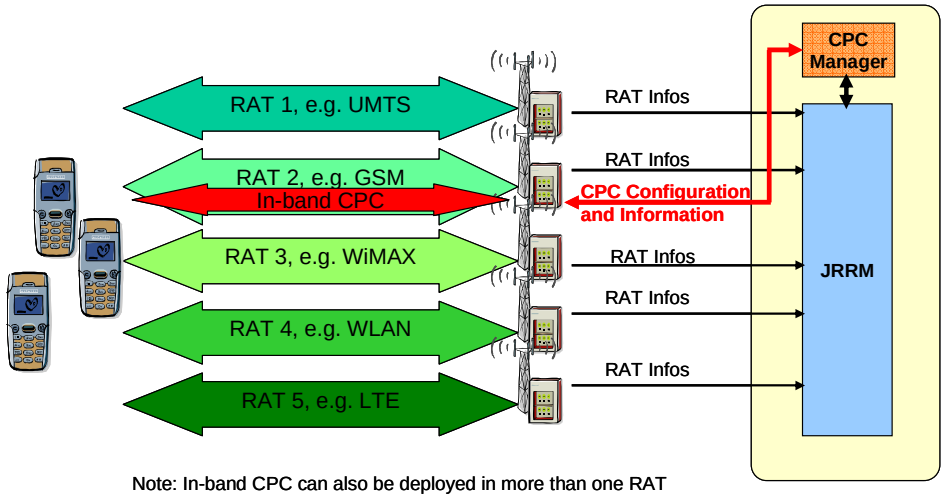


Out-band and In-band CPC

- Out-band CPC



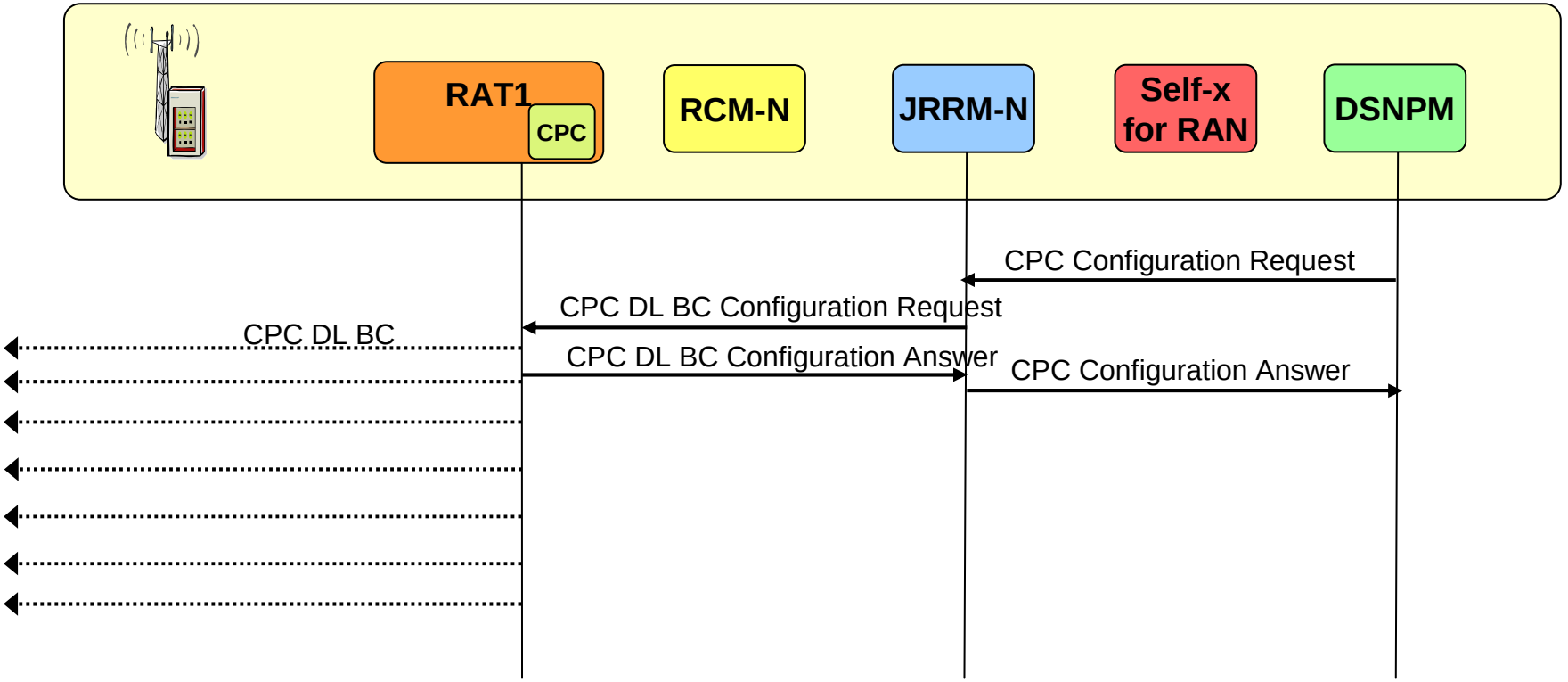
- In-band CPC



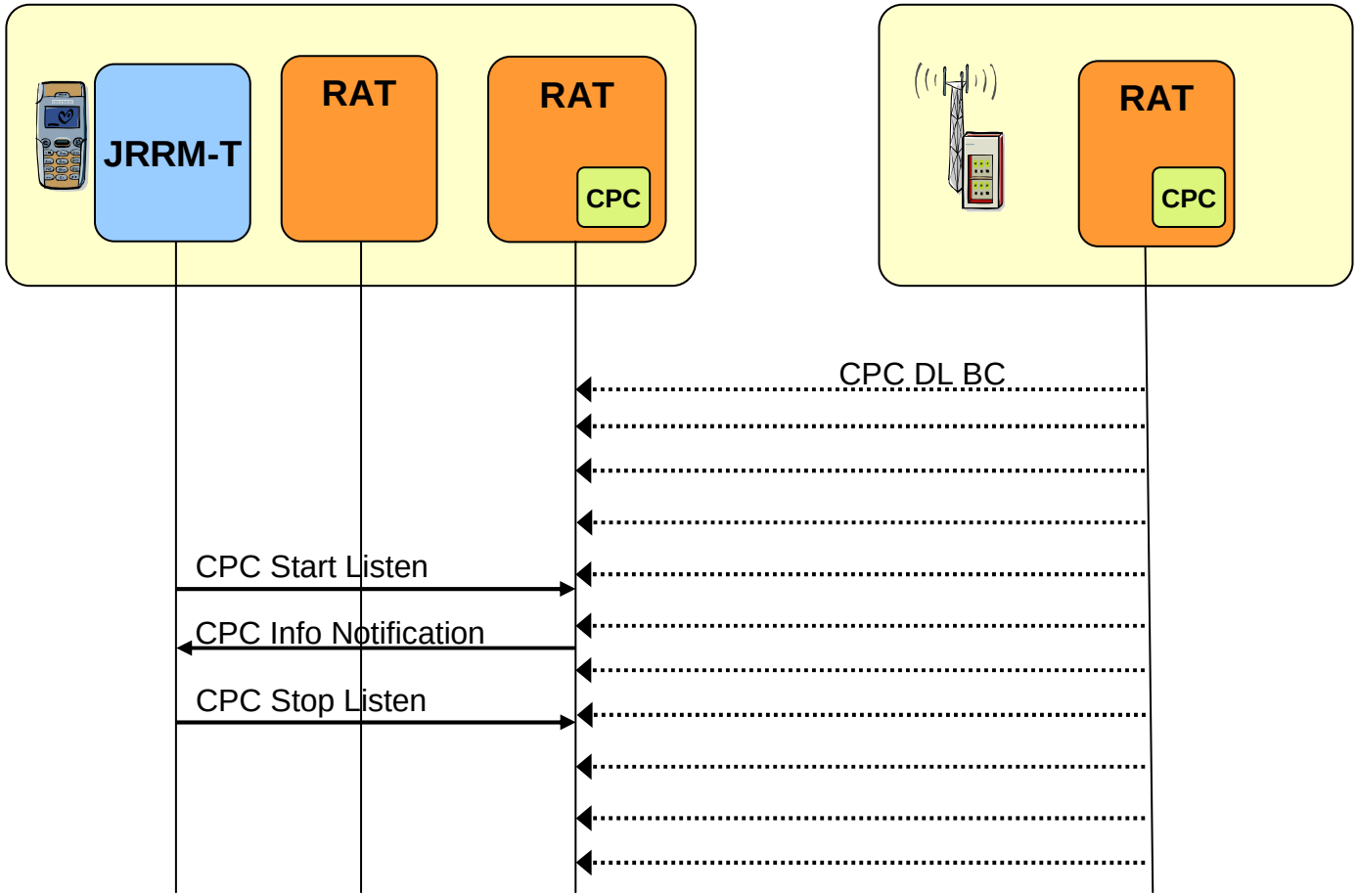
Note: In-band CPC can also be deployed in more than one RAT

- Combinations of Out-band CPC and In-band CPC are also possible

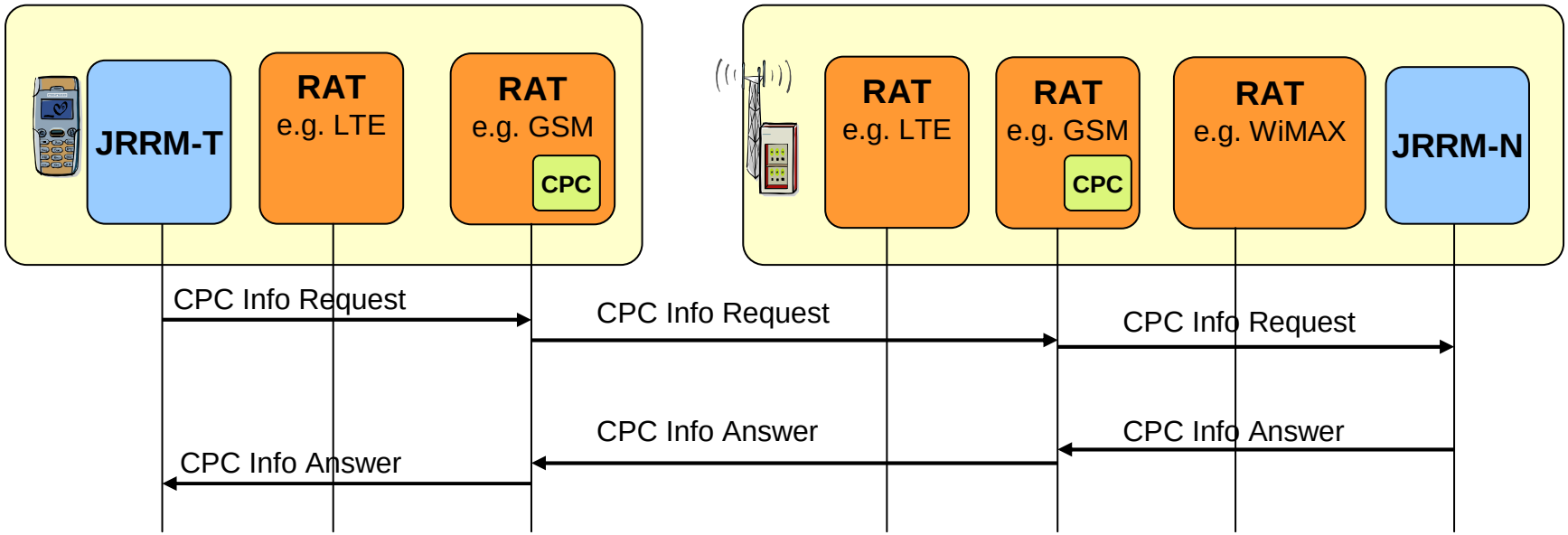
CPC configuration on network side
Here: Downlink in-band broadcast CPC



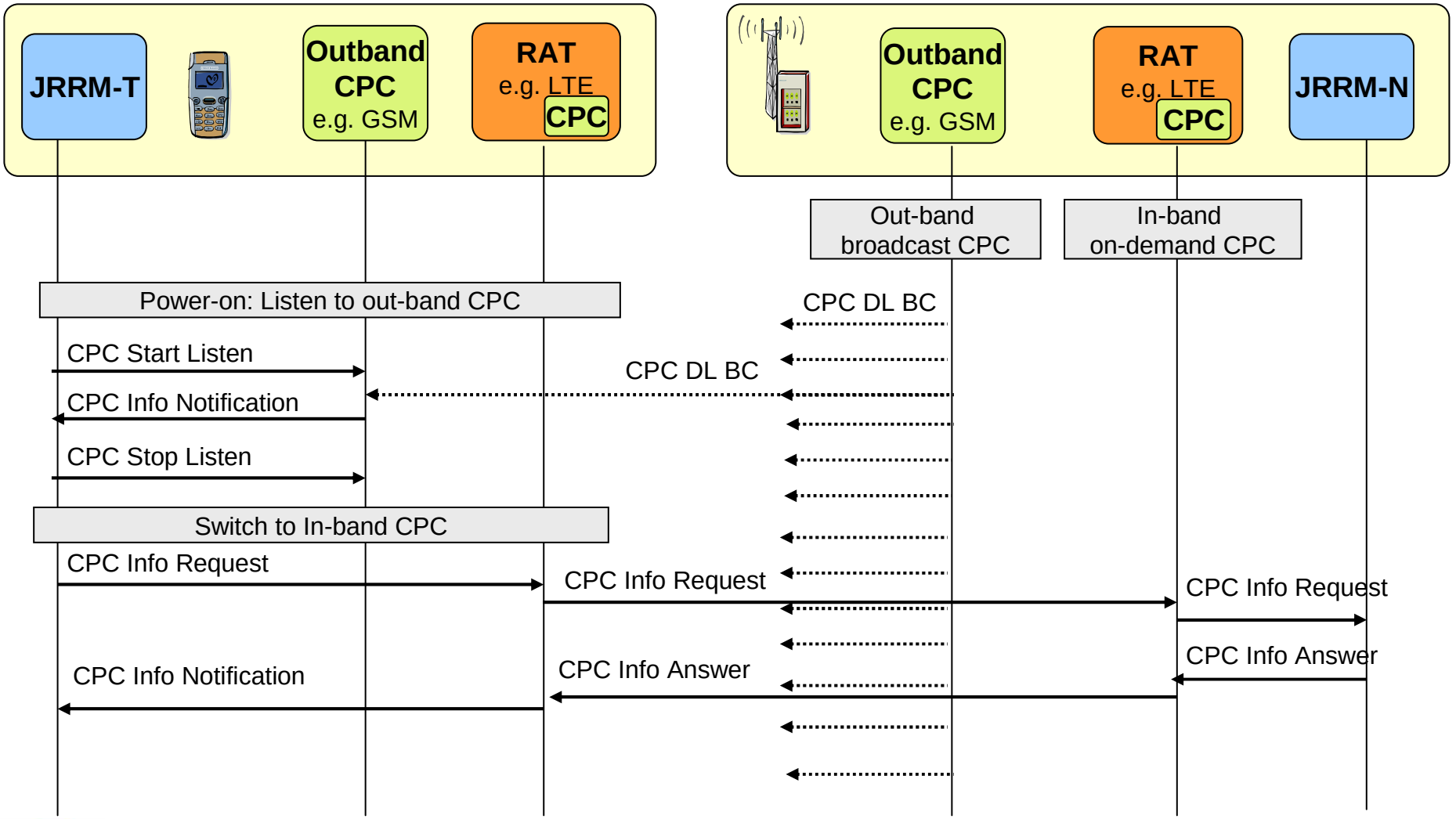
Listen on broadcast CPC on terminal side



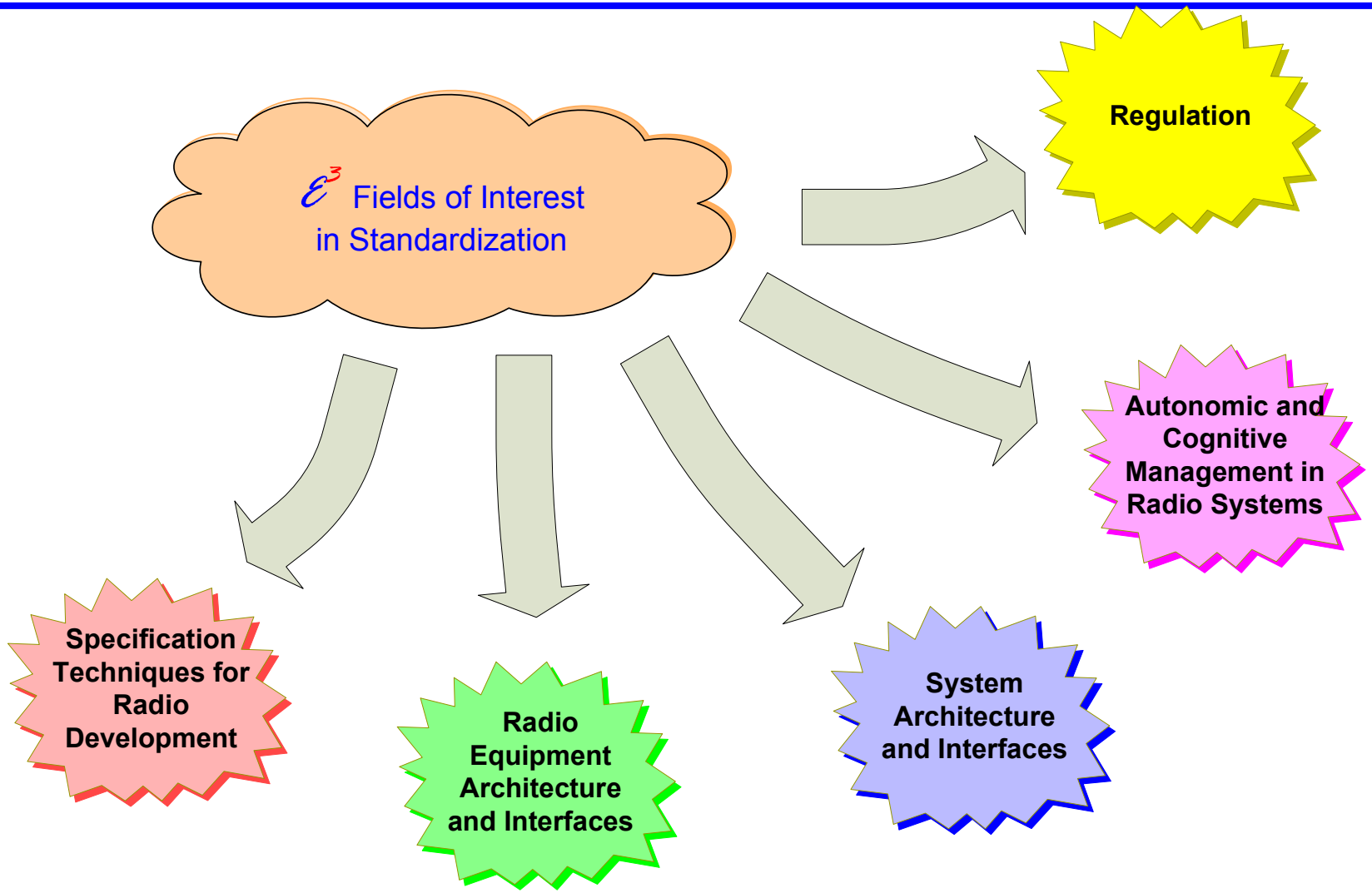
Alternative procedure: Dedicated CPC Information Request



Combined CPC procedures



Regulation/Standardization and E3



Standardization of Cognitive Systems (1/2)

- **Standardization activities to support global harmonization**
- **Activities in ETSI (European Telecommunications Standards Institute):**
  - ⇒ **E^2R II opened the path towards ETSI activities, and E^3 continued participating actively**
  - ⇒ **ETSI Technical Committee on Reconfigurable Radio Systems (TC RRS) has been created in 2008, extension of mandate in Sept. 2009.**
  - ⇒ **Several reports have been published in 2009, e.g.**
    - **ETSI TR 102 682 "Functional Architecture (FA) for the Management and Control of Reconfigurable Radio Systems"**
    - **ETSI TR 102 683 "Cognitive Pilot Channel"**
    - **ETSI TR 102 838 "RRS Standardisation Issues in the area of SDR and CR – results or RRS in 2009"**

Standardization of Cognitive Systems (2/2)

IEEE Standards Coordinating Committee 41 (SCC41) on "Dynamic Spectrum Access Networks":

- **IEEE P1900.4**
  - ⇒ **E3 project has been very active in the initiation, consolidation and successful finalization of the first P1900.4 version of the draft standard**
  - ⇒ **1900.4 "Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks", published in Feb. 2009**
  - ⇒ **Continuation in the area of**
    - ⇒ **detailed interface design (1900.4.1)**
    - ⇒ **DSA in White Space Frequency Bands (1900.4a)**
- **IEEE P1900.6 focuses on the interfaces between sensing and decision making mechanisms in cognitive radios, cognitive radio systems and in dynamic spectrum systems in general**

E³ involvement

Regulation:

ITU WP 1B on CR	*E³ monitors*
ITU-R WP5A on CR	*E³ contributes*

Autonomic and Cognitive Management:

ETSI RRS WG3 (CPC)	*E³ leads*
IEEE SCC41 P1900.6	*E³ contributes*

System Architecture and Interfaces:

IEEE SCC41 P1900.4	*E³ contributes*
ETSI RRS WG3 (FA)	*E³ leads*

Radio Equipment Architecture and Interfaces:

ETSI RRS WG2	*E³ contributes*
SDR-F (Digital RF)	*E³ leads*

Specification Techniques:

OMG, SDR-F, OMA, ACF	*E³ contributes*

Summary and conclusions

- E3 Functional Architecture including functionalities for
  - ⇒ Self-organizing networks and autonomous entities
  - ⇒ Reconfiguration of network elements and devices
  - ⇒ Dynamic Spectrum Management
  - ⇒ Joint Radio Resource Management
  - ⇒ Cognition Enablers (CPC, CCR, SS)
- Ongoing related standardization activities (ETSI RRS, IEEE SCC41) to support global harmonization
- E3 project has made fundamental design and development work for introducing cognitive systems into wireless communication infrastructures

Thank you!

Acknowledgement

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