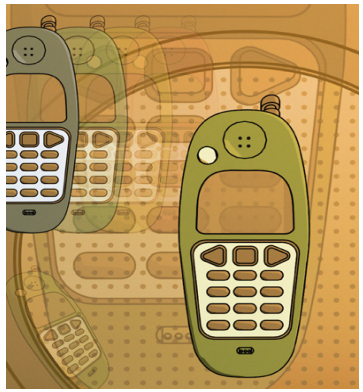
Functional Architecture for Efficient Control of Cognitive Radio Systems



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Outline

- Introduction
- Governance of Cognitive Radio Systems
- Collaborative Autonomous Control
- Functional Architecture
- Conclusion

Introduction

- **Cognitive Radio Systems:**
  - ⇒ **Dynamic and flexible usage of spectrum bands**
  - ⇒ **Flexible choice of radio technology**

- **Opportunistic spectrum access:**
  - ⇒ **Care about incumbent systems**
  - ⇒ **Sufficient fast hand-off in case of occurrence of primary users**

- **Examples for Cognitive Radio Systems**
  - ⇒ **Ad-hoc networks**
  - ⇒ **Meshed networks**
  - ⇒ **Operated networks**

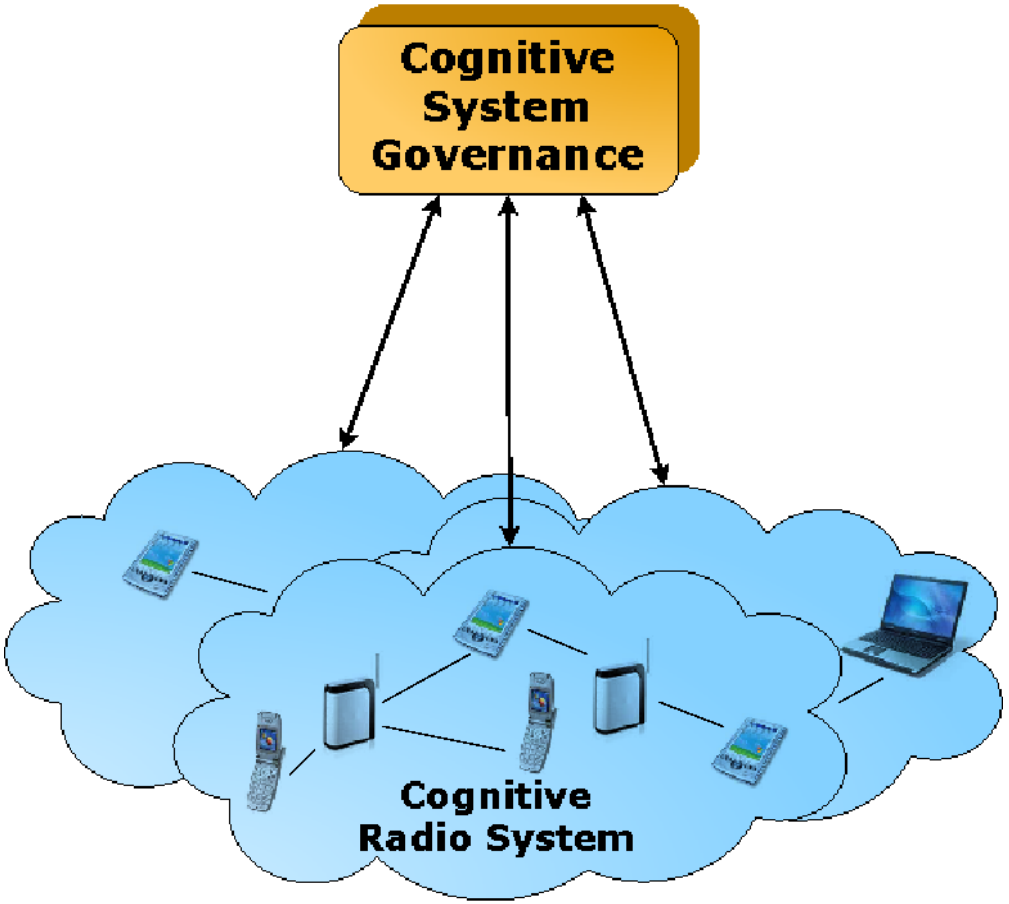
- **New types of control required**
  - ⇒ **Network/System overarching**
  - ⇒ **Operator to Operator**
  - ⇒ **Operator to Ad-hoc**

Governance of Cognitive Radio Systems

Why Governance?

- Cognitive Radio Systems will not replace incumbent radio systems in one shot
- Limitations in frequency bands + radio technologies used within, space and time
- Limitations may be subject of changes (regulation, technical problems, business agreements, emergency etc. may be reasons for that)
- Governance is the way of keeping Cognitive Radio Systems aware of current restrictions at their location

Governance at a Glance



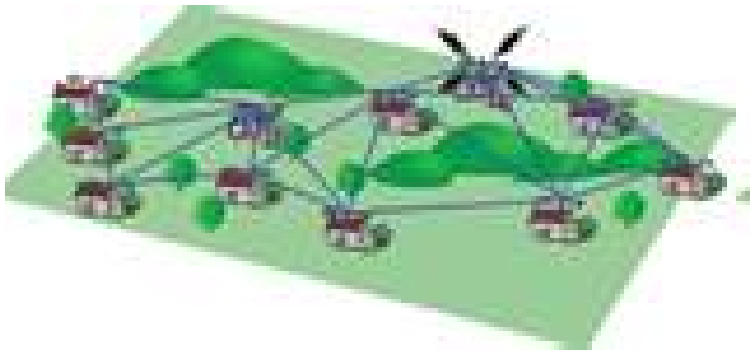
CSG Tasks:

- *Provide info:* WHERE and WHEN certain spectrum bands MUST NOT be used, excluded technologies, power constraints
- Ensure information consistency, contradiction avoidance
- Help detect opportunistic spectrum usage possibilities
- CSG awareness of radio resource usage
- Help organizing sensing tasks

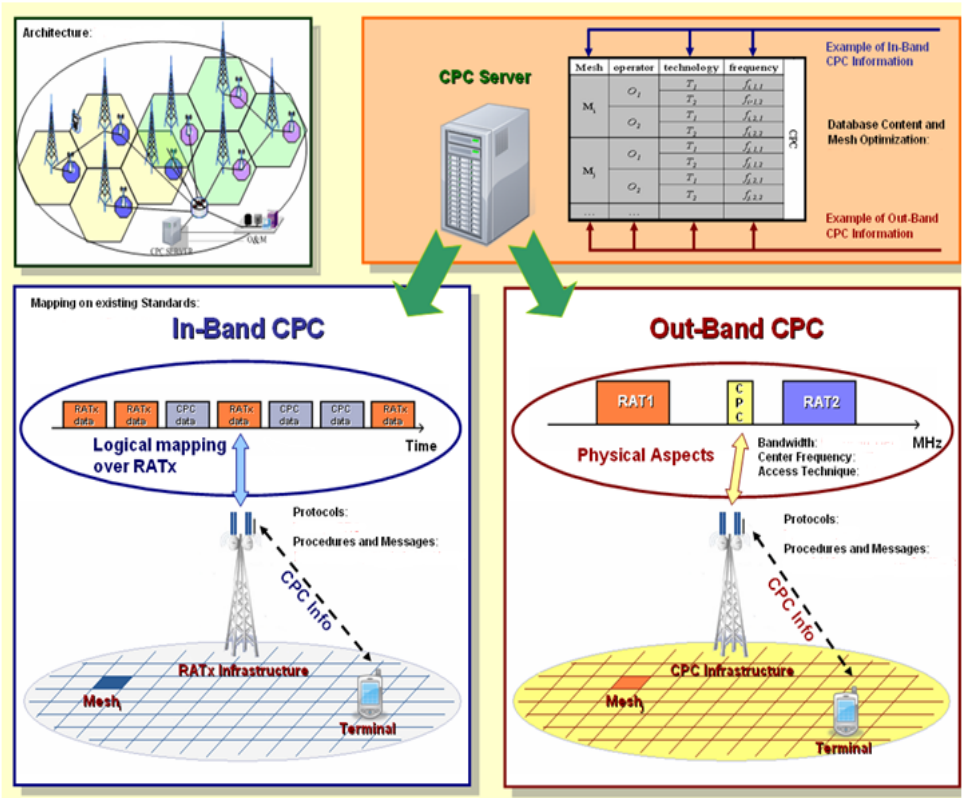
Governance Examples

TV White Space Data Base

Consult regularly



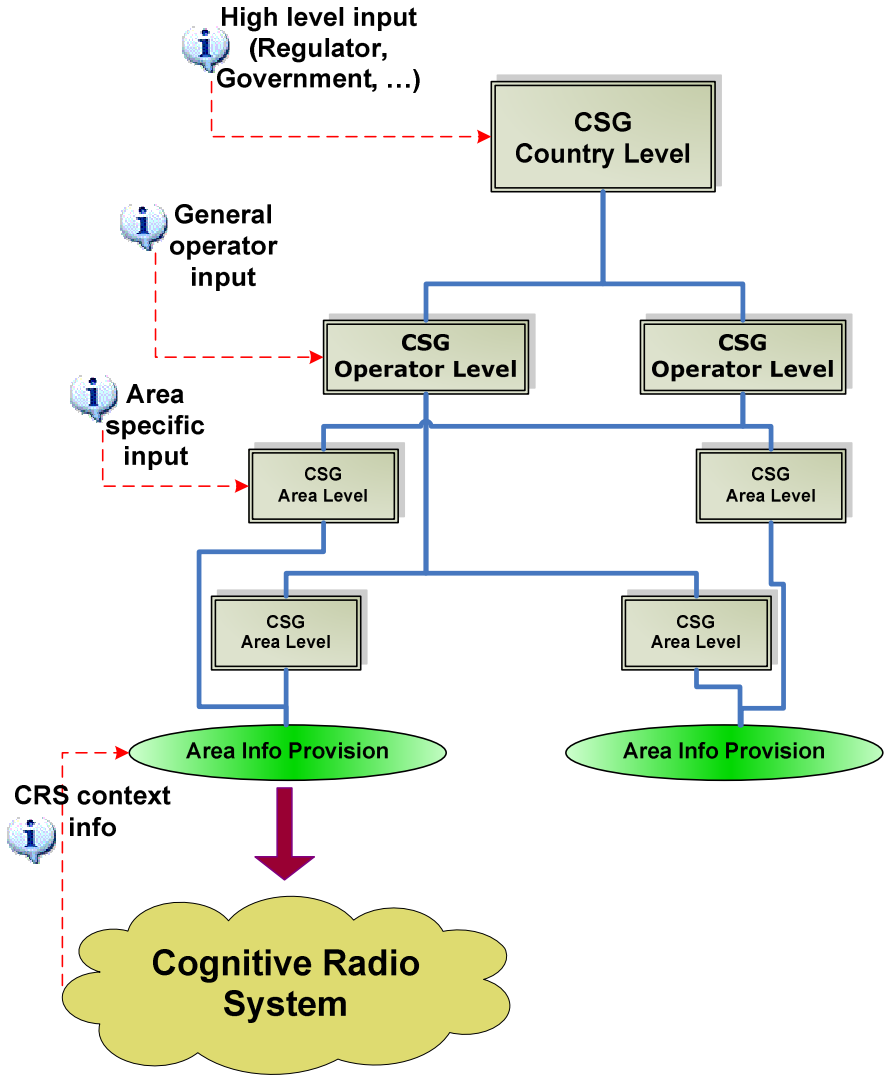
Cognitive Pilot Channel



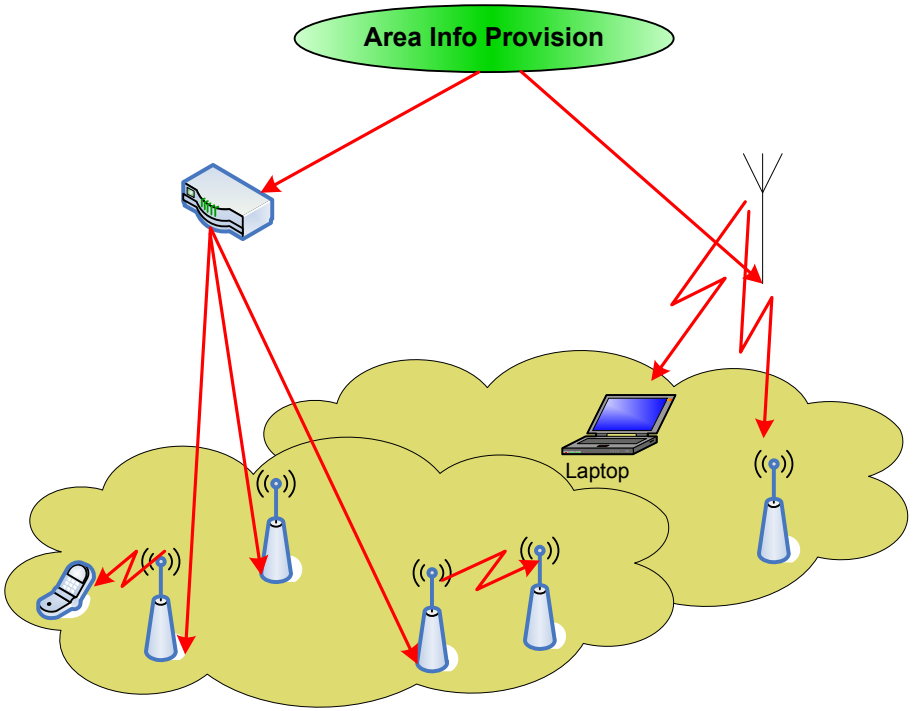
- Common concept
- Extendable for governance of CRS

Distribution of Governance Information (DL)

Information Collection



Distribution to CRS



Information delivery:

- On demand
- On event
- Scheduled
- Broadcast, multicast, P2P

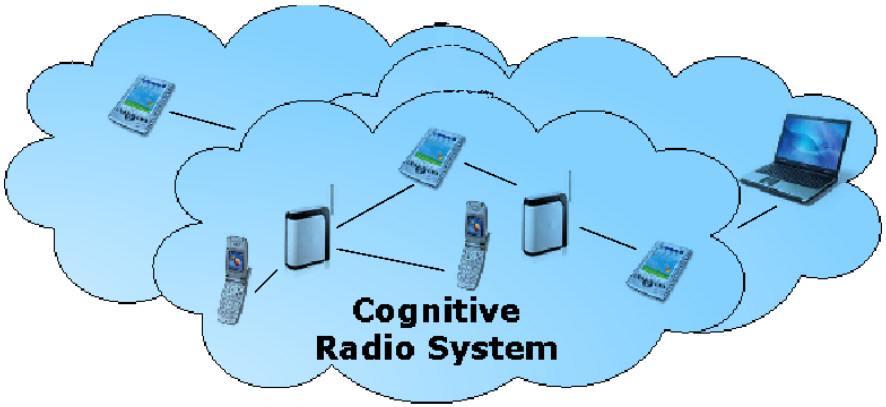
Collaborative Autonomous Control

Why Collaborative Autonomous Control?

- Coordinated spectrum access between the nodes of a Cognitive Radio Systems
- Coordinated spectrum access between multiple Cognitive Radio Systems in an area
- Collaborative Sensing
- Protection for hidden nodes
- Further distribution of CSG information
- Coordination of system re-organization

⇨ *Terminology:* Cognitive Control Radio (CCR)

CCR at a Glance



Cognitive Control Radio

CCR Tasks:

- **Support spectrum usage negotiations**
- **Sharing spectrum sensing results**
- **Sharing radio usage parameters**
- **Initiation of sensing activities**
- **Support nodes to enter into a network**
- **Distribute CSG rules to all radio nodes**

Types of communication in CCR

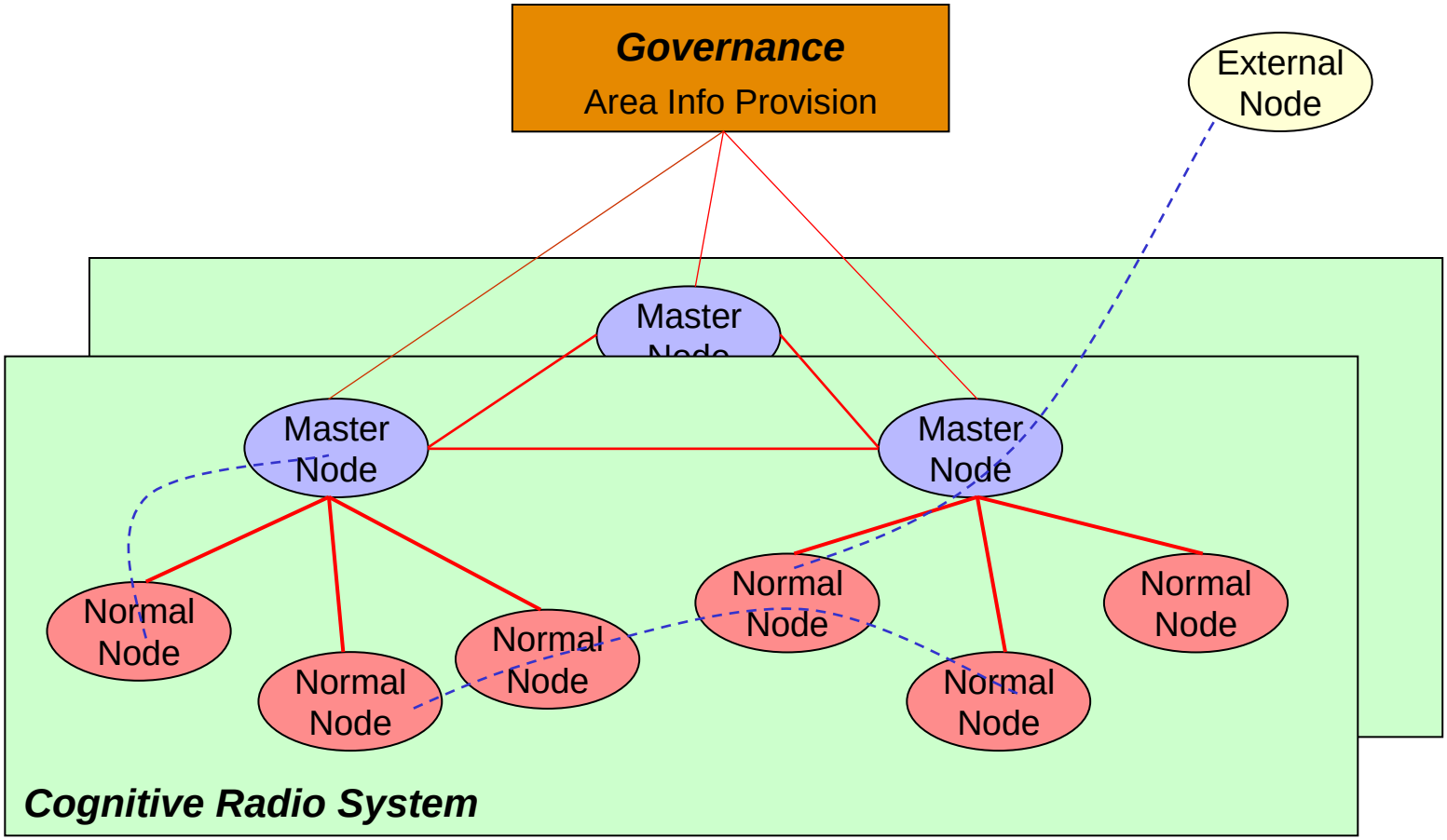
- Broadcast to neighbors
  - ⇒Stop if limited number of hops reached
  - ⇒Stop if given signal energy loss reached
- Acknowledged packet transmission to a one-hop neighbor
- Transmission over multiple hops to an individual destination
  - ⇒Routing needed
  - ⇒In mobile environment finding and keeping up routes consumes a lot of resources

CCR Channel Options

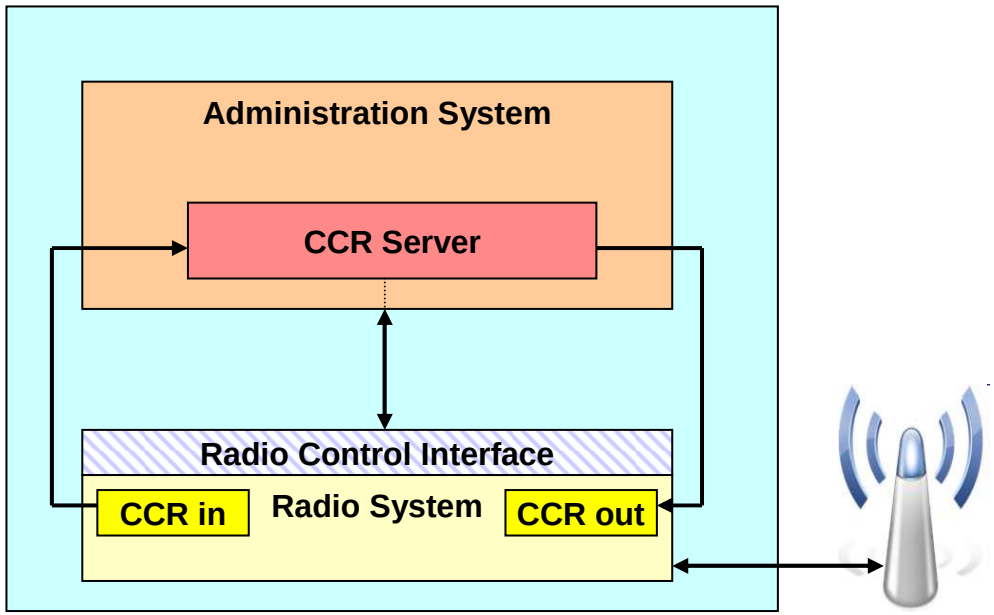
- One fixed CCR Channel
- CCR Channel Propagation for multiple available CCR Channels
- CCR Channel Selection Procedure

Functional Architecture

Architecture Overview



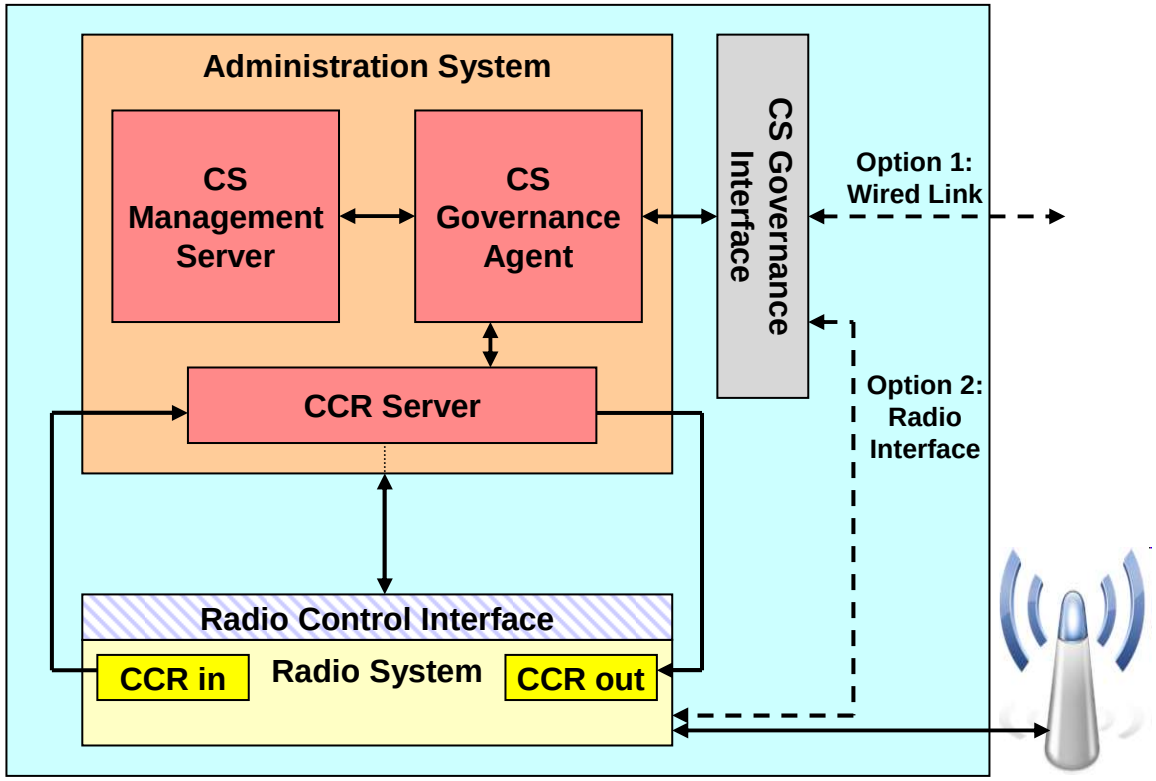
Normal Node



Tasks:

- Forward incoming CCR messages to CCR Server
- CCR Server acts on incoming messages
- Re-distribute incoming CCR messages if appropriate
- Enforce sensing requests
- Collect and summarize sensing results
- Generate and broadcast sensing requests
- Broadcast detected interference

Master Node



Specific tasks of Master Node:

- Communicate with Cognitive Governance System (CSG)
- Distribute CSG Info to normal nodes
- Follow CSG rules
- Define and forward sensing schemes
- Event detection and forwarding to CS Management Server

Conclusion

- **Cognitive Radio Systems need additional control**
- **Dynamically changing radio environment is subject to the control**
- **Well-balanced external governance and system internal control is key to the success of Cognitive Radio Systems**
- **Obtaining and sharing of measurement results as well as other dynamic context data have potential for overwhelming the system with control messages → care in design is highly important**

Acknowledgements

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Thank You!