# ITU-R Cognitive Radio Tutorial

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Base Contribution:

None

Purpose:

For discussion in the ITU-R Liaison group

# Outline

- Background of Cognitive Radio
- Standardization activities on Cognitive Radio in ITU-R
  - WP1B, WP5A and WP5D
- Study of Cognitive Radio in KDDI R&D Laboratories
- Considerations for a new study item on multi-network in IEEE 802.16WG

# Background of Cognitive Radio System (CRS)

- Expectation for Cognitive Radio
  - Shortage of frequency resources as a background (especially bellow 6GHz)

- What is Cognitive Radio?
  - Technology to use radio intelligently by recognizing radio environment
  - Studying various aspects to realize

    (e.g., selecting or bundling system)
  - Different approaches taken by universities, study organizations, operators

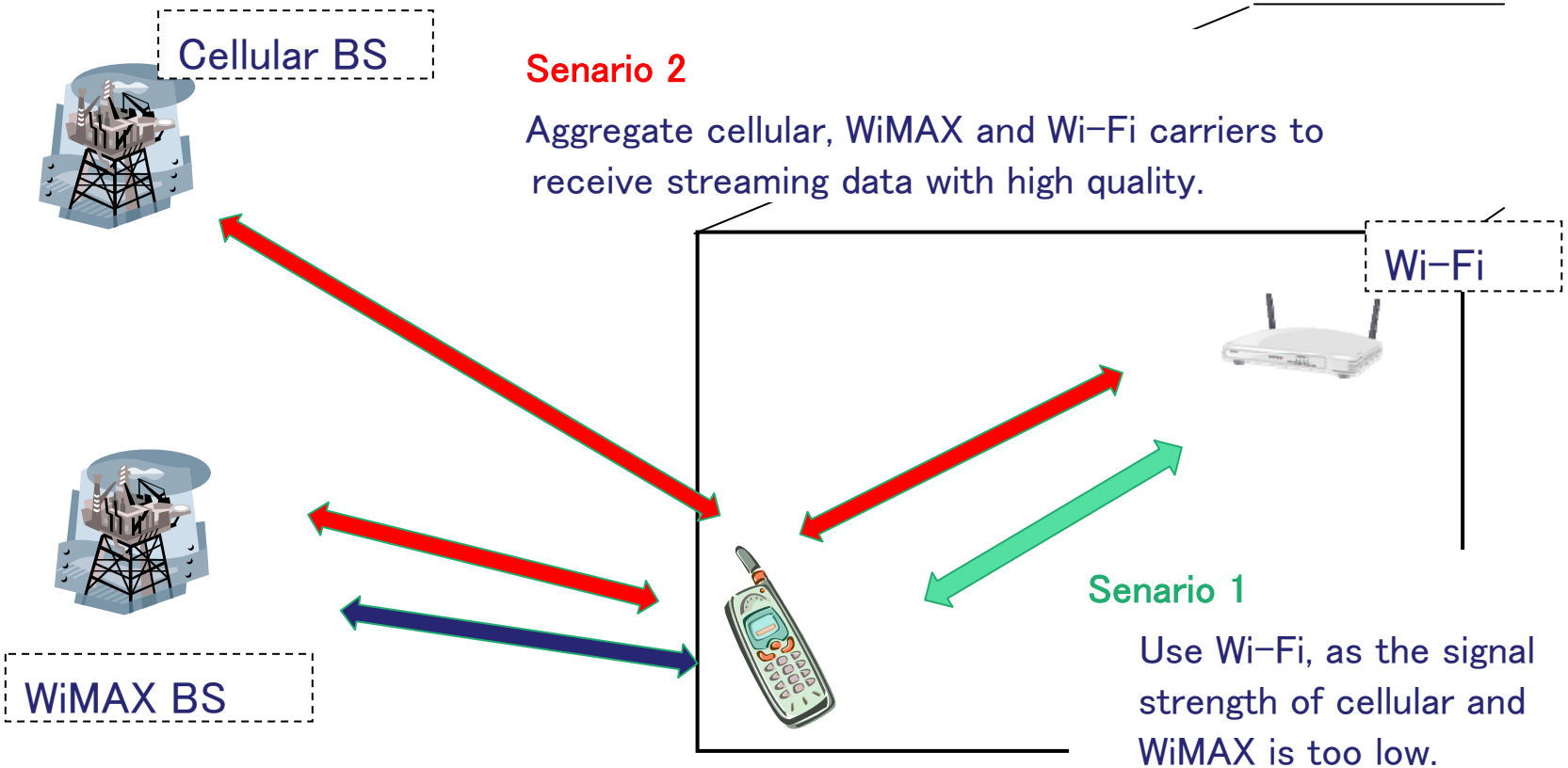
    (primary service, secondary service, etc.)
  - Regulatory issues require further study

# Various Cognitive Radio Systems (CRS)

- Various opinions from various people
  - Coexistence between macro cells and femto cells (in the same system)
  - Coexistence between a current system and an advanced system (in the same frequency band)
  - Smaller guard band
  - Mobile routers (with intelligent selection of public network)
  - Heterogeneous network (with multiple radio interfaces)
  - Frequency sharing
- What can we do? (from users' side and from operators' side)
  - Auto system selection based on a user's preference
  - Improvement of reliability
  - Effective use of frequency resource and power resource

# Example of CRS

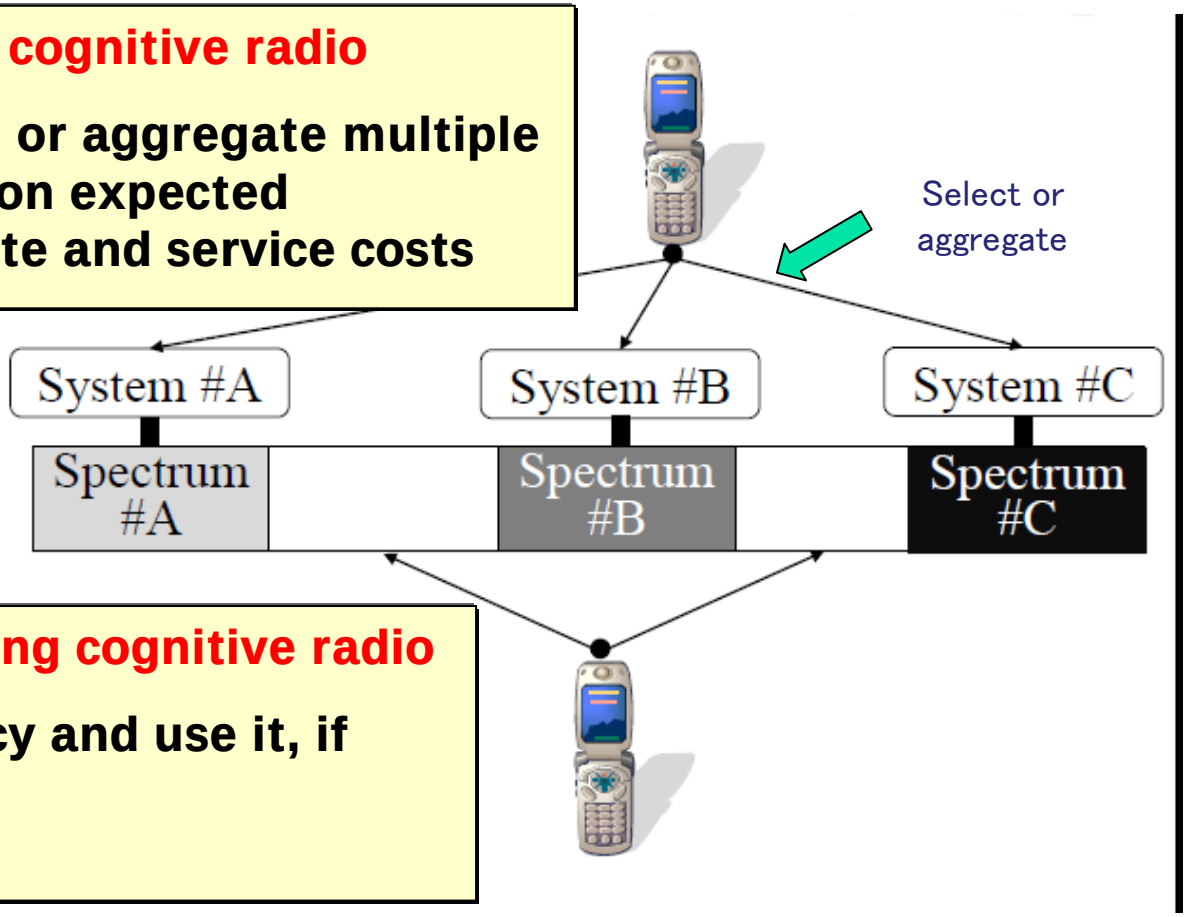
- Selecting system depending on the environment



# Typical two examples

**Heterogeneous cognitive radio**

**Select a system or aggregate multiple systems based on expected transmission rate and service costs**

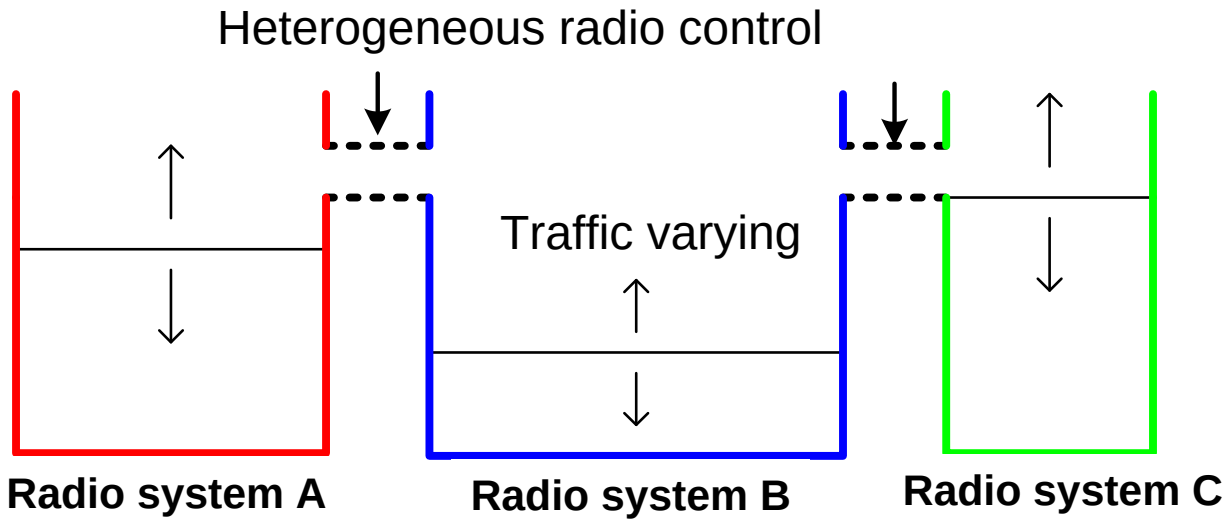



**Frequency sharing cognitive radio**

**Search frequency and use it, if available**

# Load balancing by heterogeneous radio

- Efficient use of radio resources by load balancing




- Cooperative control of multiple radio systems in accordance with environmental change

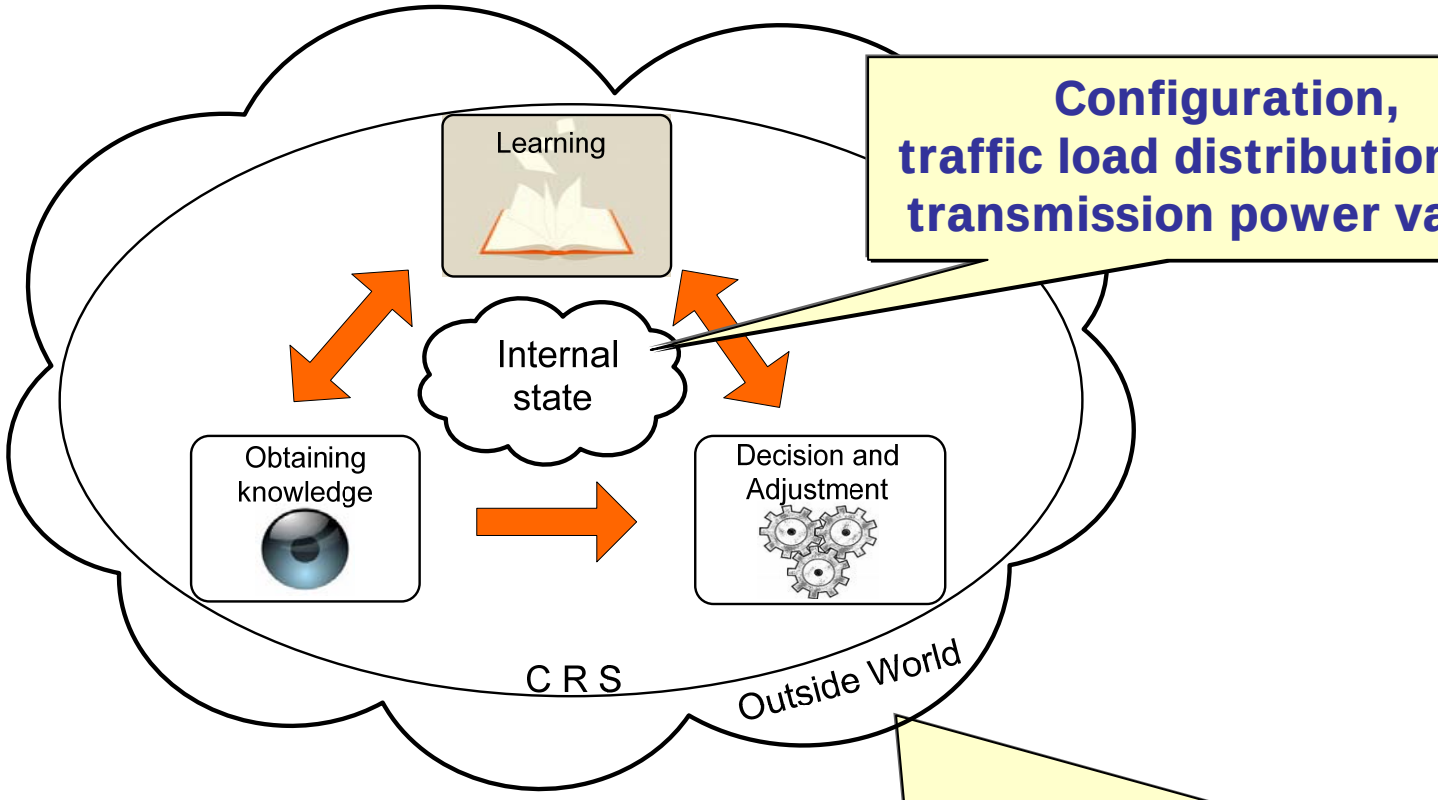
# Concept of Cognitive Radio

- Dr. J. Mitola: proposed concept of Cognitive Radio, introducing the cognition cycle.

  "Cognitive Radio: Making Software Radios More Personal," IEEE Personal Com., Vol. 6, No. 4, pp. 13–18, Aug. 1999.

- Definition in ITU-R
- IEEE SCC 41 and P1900
- FCC
- SDR Forum (Wireless Innovation Forum), etc.

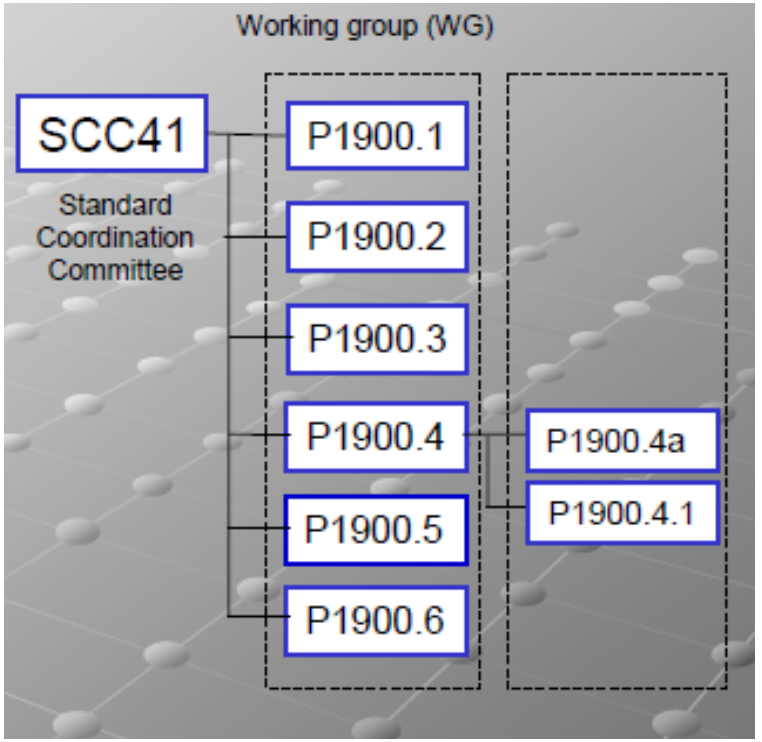
# Concept of CRS in ITU-R Report




CRS concept based on Dr. Mitola's
(Extracted from Doc. 5A/TEMP/306)

# IEEE SCC 41 and P1900

**IEEE 1900.1**: Standard Definitions and Concepts for Spectrum Management and
Advanced Radio System Technologies
**IEEE 1900.2:** Recommended Practice for Interference and Coexistence Analysis
**IEEE 1900.3:** Standard for Assessing the Spectrum Access Behavior of Radio Systems Employing Dynamic Spectrum Access Methods
**IEEE 1900.4**: Standard for Architectural building blocks enabling network-device distributed decision making for optimized radio resource usage in heterogeneous wireless access Networks
**IEEE 1900.4a**: Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks – Amendment: Architecture and Interfaces for Dynamic Spectrum Access Networks in White Space Frequency Bands
**IEEE 1900.4.1**: Standard for Interfaces and Protocols Enabling Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Networks
**IEEE 1900.5:** Standard on Policy Language and Policy Architectures for Managing Cognitive Radio for Dynamic Spectrum Access Applications
**IEEE 1900.6:** Standard on interfaces and data structures for exchanging spectrum sensing information for dynamic spectrum access systems




Doc. 5A/497 (IEEE Standards Coordinating Committee 41 briefing to ITU-R WP 5A))

# Current study results of CRS in ITU-R

- WP1B
  - CPM text on WRC-12 agenda item 1.19
  - Draft WRC Resolution [A119-B2] for WRC-12 agenda item 1.19
- WP5A
  - Working document towards a draft new Report ITU-R M.[LMS.CRS1] (Doc. 5A/TEMP/306)
  - Working document towards a draft new Report ITU-R M.[LMS.CRS2] (Doc. 5A/TEMP/309)
- WP5D
  - Preliminary draft new Report ITU-R M.[IMT.CRS] (Doc. 5D/TEMP/542)

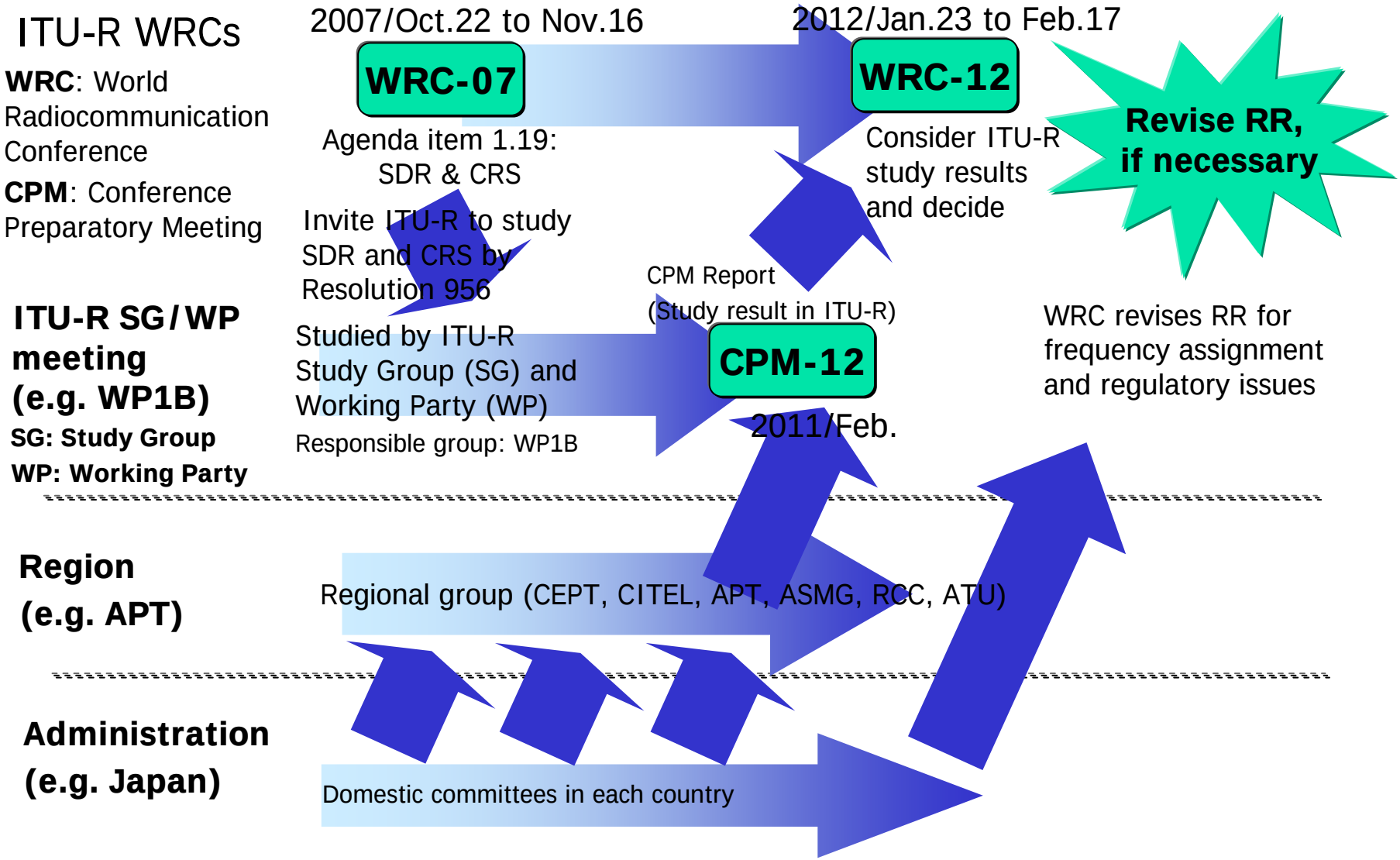
# How did the ITU-R study of cognitive radio start?

- Mar, 2006: Canada proposed Question for cognitive radio in ITU-R WP8A
  - Characteristics, performance, application -> WP8A
  - Concept, frequency management, regulation -> WP1B
- Sep, 2006: Question for cognitive radio (Q.241/5) was approved
  - WP8A technically studies CR, and WP1B studies regulatory issues.
- Jun, 2007: Start drafting Report on CR@WP8A
- Nov, 2007: Agenda item 1.19 (SDR and CR) @WRC-07
- Nov, 2007: CPM (Conference Preparatory Meeting)
  - Responsible group: ITU-R WP1B
- Jun, 2008: Start study in WP1B
  - Work on draft CPM text (definition, regulatory issues)
- Jun, 2010: Finalize draft CPM text in WP1B
- Jun, 2011: Finalize ITU-R Resolution in WP1B
- Jan, 2012: RA-12
- Jan, 2012: WRC-12

# World Radiocommunication Conferences (WRC)

- Review, and, if necessary, revise the Radio Regulations
- RR is the international treaty governing the use of the radio-frequency spectrum and the satellite orbits
- Held every three to four years
- Conference period is about four weeks (longest in ITU-R)
- ITU-R member nations decide domestic frequency allocation based on RR

# Schedule toward ITU-R WRC-12 on CRS



# WRC-12 agenda item 1.19

- to consider regulatory measures and their relevance, in order to enable the introduction of software-defined radio and cognitive radio systems, based on the results of ITU−R studies, in accordance with Resolution 956 (WRC−07);

# Resolution 956 (WRC-07)

(Title) Regulatory measures and their relevance to enable the introduction of software-defined radio and cognitive radio systems

resolves to invite ITU-R

1 to study whether there is a need for regulatory measures related to the application of cognitive radio system technologies;

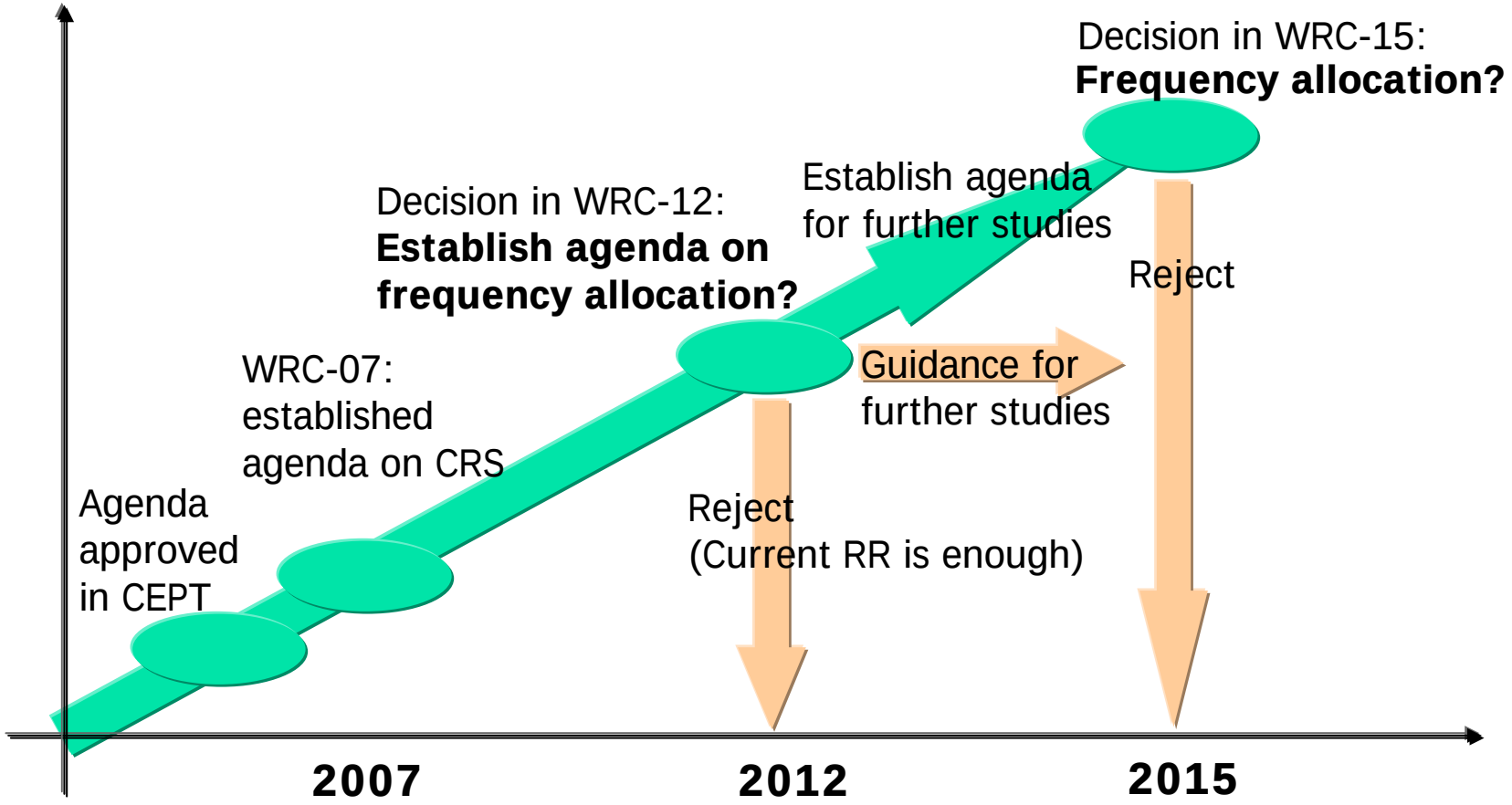
2 to study whether there is a need for regulatory measures related to the application of software-defined radio,

resolves further

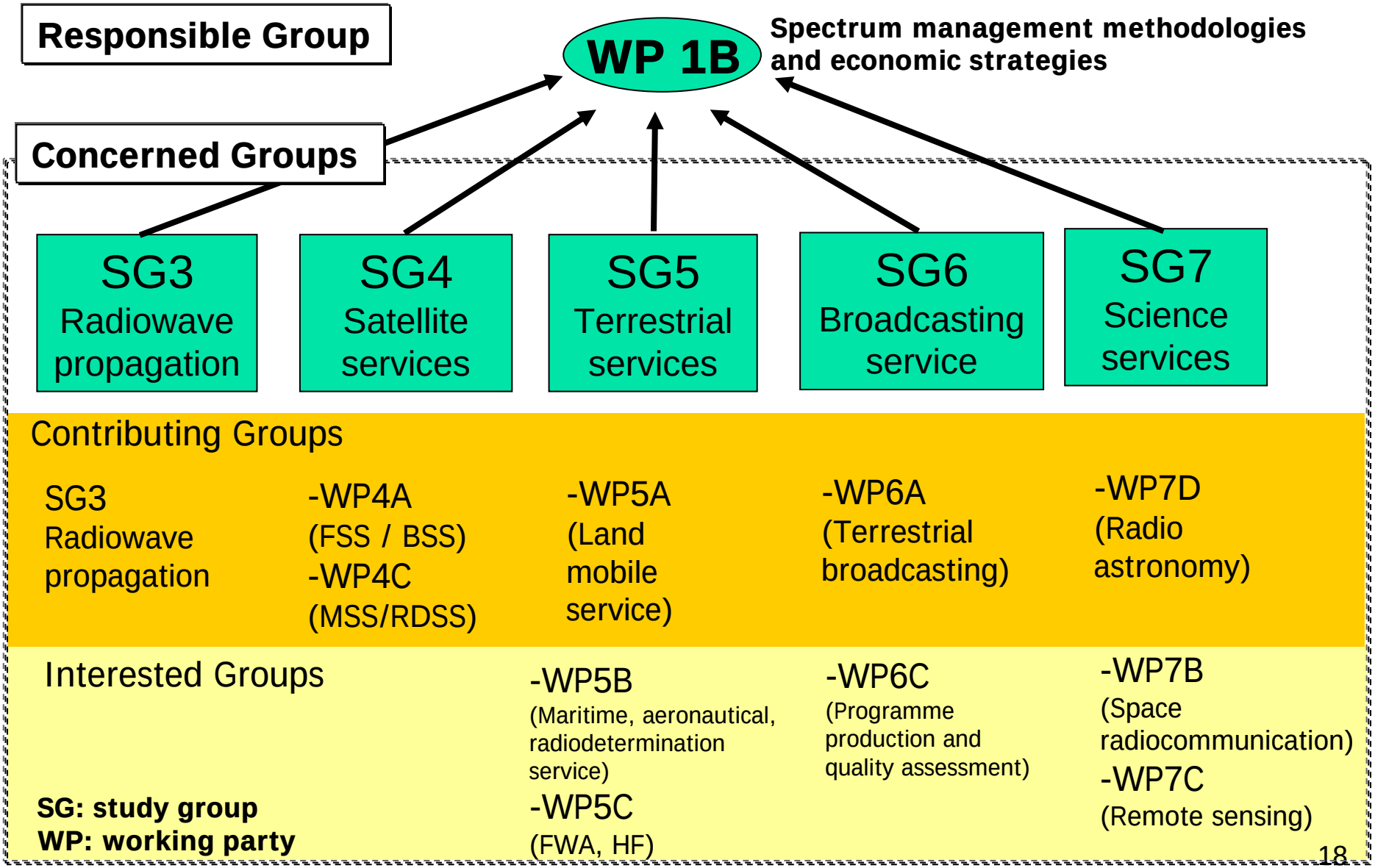
that WRC-11 consider the results of these studies and take the appropriate actions.

# Assumed two-step approach as a result of WRC-07

- Postponed the consideration of new frequency allocation to CPC in WRC-12 agenda item 1.19
- 'Is new regulatory issue necessary' will be discussed in WRC-12



# Study structure for agenda item 1.19 (WRC-12)



# CPM Report

- Outline of CPM Report to WRC-12 agenda item 1.19
  - Executive summary
  - Background
  - Summary of technical and operational studies and relevant ITU-R Recommendations
  - Analysis of the results of studies
  - Methods to satisfy the agenda item
    - Method B1: No change to the RR
      - Option A: No change to the RR
      - Option B: No change to the RR and an ITU-R Resolution providing guidance for further studies on CRS
    - Method B2: No change to the RR and add a WRC Resolution providing guidance for further studies and guidance for the use of CRS
  - Regulatory and procedural considerations

# Results of ITU-R study

- Definition of Cognitive radio system (CRS)
  ***"Cognitive radio system (CRS)*** *is a radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained."*
  (quoted from CPM Report to WRC-12)

# Results of ITU-R study

- In the case of LMS, CRS technologies may yield significant benefits by providing increased spectral efficiency of existing spectrum and mitigate the problem of congestion.
- Common concern within the ITU-R
  - the protection of existing services from potential interference from the services implementing CRS technology, especially from the dynamic spectrum access capability of CRS
  - Any system of a specific service using CRS should be operated in accordance with the provisions of the Radio Regulations and administration rules.

# Results of ITU-R study

- CRS challenges and opportunities
  - Some concerns with respect to the use of the CRS technology to dynamically access the spectrum
    - Satellite operators in the EESS using passive sensors
    - Interference avoidance to FSS and BSS (detection of receive-only terminals and use of database)
    - Any use of CRS technologies for safety-of-life operations
    - The hidden node problem by fading and shadowing effects
  - a CRS station to obtain the proper authorization from the relevant Administration prior to the use of the spectrum.

# Results of ITU-R study

- CRS capabilities and their applicability to facilitate coexistence in shared bands
  - The capabilities of CRS:
    - spectrum sensing capability including collaborative and cooperative sensing;
    - positioning capability of the transmitters and receivers (geo-location);
    - access to information on the spectrum usage, local regulatory requirements and policies, e.g. through access to a database or access to a logical or physical cognitive pilot channel;
    - capabilities to adjust operational parameters based on the obtained knowledge.
- These capabilities of CRS may help improve coexistence amongst radiocommunication systems deployed under the current regulatory regime (predetermined allocation and assignment).

# Consideration to results of ITU-R study

- Issues on CRS
  - The implementation of CRS will have to be in accordance with the Radio Regulations and with national regulations.
  - Whether CRS technology is used as an enabler of cooperative spectrum access amongst system operators or of opportunistic spectrum access, administrations issue the authorization for a station to use a radio frequency.
  - Further studies required on CRS technology, addressing especially dynamic and/or opportunistic spectrum access.
- Regulatory implications for CRS
  - No need for modification to the Radio Regulations
  - The use of CRS in some bands used by particular radiocommunication services may require the development of ITU-R Recommendations and Reports to address these issues.

# Methods to satisfy agenda item

- Method B1
  No change to the Radio Regulations
  - Option A: No change to the Radio Regulations
  - Option B: No change to the Radio Regulations and an ITU-R Resolution providing guidance for further studies on CRS
- Method B2
  - Add a WRC Resolution providing guidance for further studies and guidance for the use of CRS
  - No other changes to the Radio Regulations
  - This method does not propose a new agenda item at the next conference.

# Draft WRC Resolution for WRC-12 agenda item 1.19

- Resolution [A119-B2] (WRC−12)
  - Title: Studies on deployment and use of cognitive radio systems (CRS)
- *recognizing*
  - a) that CRS is a technology, not a radiocommunication service;
- *resolves*
  - 1 that any radio system implementing CRS technology within any radiocommunication service shall operate in accordance with the provisions of the RR applicable for that specific service in the related frequency band;
- 2 that when authorizing operation of CRS within a service, Administrations should take all possible measures to avoid harmful interference in bands shared with radiocommunication services such as space services (space-to-Earth), radiodetermination service, passive services (radio astronomy, Earth Exploration-Satellite Service and Space Research Service) and safety services,

# Draft WRC Resolution for WRC-12 agenda item 1.19

- Resolution [A119-B2] (WRC−12) (cont.)
- *resolves to invite ITU−R*
  - 1 to study the implementation and use of CRS in any radiocommunication service that intends to employ CRS, addressing requirements, technical characteristics, performance and benefits;
  - 2 to study the applicability of the cognitive capabilities and technical conditions to facilitate sharing between the services intending to deploy CRS and other radiocommunication services and the radio astronomy service;
  - 3 to develop relevant Recommendations and/or Reports based on the aforementioned studies as appropriate,

# Study result in ITU-R WP5A

- Working document towards a preliminary draft new Report ITU-R M.[LMS.CRS1]
(Document 5A/TEMP/306)
  - “Cognitive radio systems in the land mobile service (Part 1) ”
- Working document towards a preliminary draft new Report ITU-R M.[LMS.CRS2]
(Document 5A/TEMP/309)
  - “Cognitive radio systems in the land mobile service (Part 2) ”

# Two split Reports in ITU-R WP5A

Finalize before WRC-12

Extracted for Report ITU-R M.[LMS.CRS1]

- 1 Scope
- 2 Introduction
- 3 Related documents
- 4 Definition and terminology
- 5 General description of cognitive radio systems
- 6 Approaches and scenarios of cognitive radio systems

Extracted for Report ITU-R M.[LMS.CRS2]

- 7 Coexistence
- 8 [Impact on spectrum management]
- 9 Conclusion
- Annex A *Radio technologies closely related to CRS*
- Annex B *Relationship between SDR&CRS*
  - B.1 Conceptional Relationship between SDR and CRS
  - B.2 Method of adjustment based on SDR reconfiguration

(Outline of Doc. 5A/TEMP/224 Rev.1)

Further study required after WRC-12

# Deployment scenarios

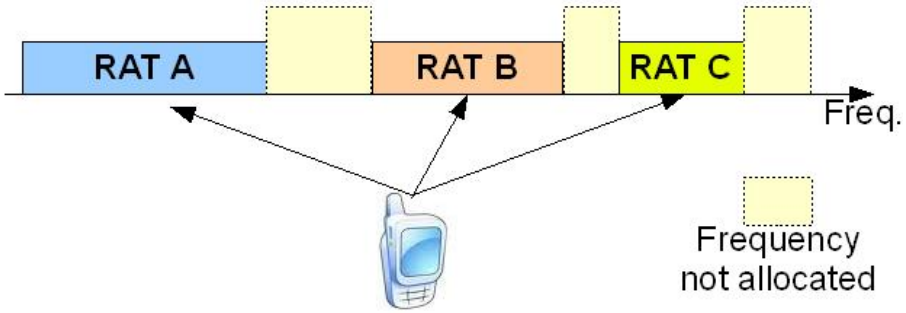
- The following four scenarios have been identified:
  - Use of CRS technology to guide reconfiguration of connections between terminals and multiple radio systems
  - Use of CRS technology by an operator of radiocommunication systems to improve the management of its assigned spectrum resources
  - Use of CRS technology as an enabler of cooperative spectrum access
  - Use of CRS technology as an enabler of opportunistic spectrum access

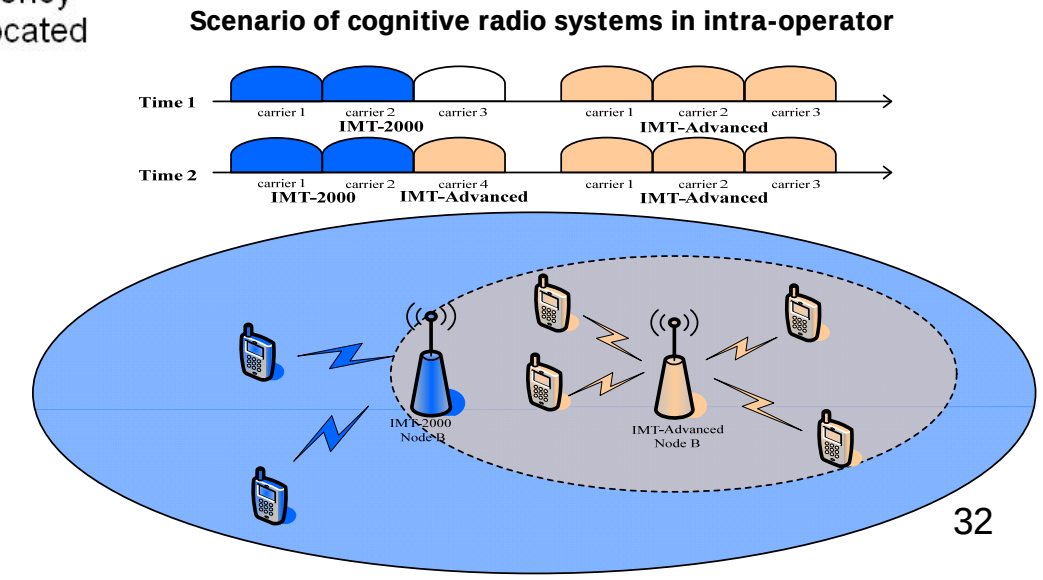
# Study result in ITU-R WP5D

- Preliminary draft new Report ITU-R M.[IMT.CRS] (Document 5D/TEMP/542)
  - “Cognitive radio systems specific for IMT systems”

# Scenarios of cognitive radio systems specific for IMT systems

- Update of a network for optimized radio resource usage
- Upgrade of an existing radio interface

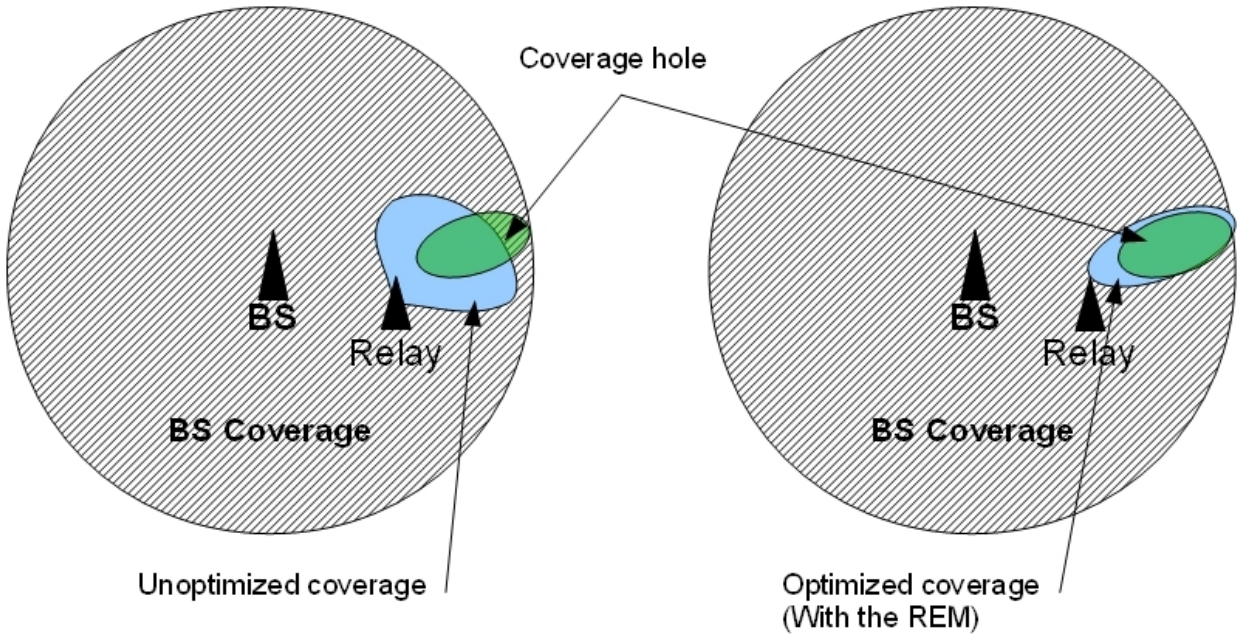


## Scenarios of cognitive radio systems specific for IMT systems

- In-band coverage/capacity improvement by relays

**Relay scenario**



## Scenarios of cognitive radio systems specific for IMT systems

- Self-configuration and self-optimization of femtocells
- Multi-modes coexistence and simultaneous transmission

# Summary of ITU-R study on CRS

- WRC-12 agenda item 1.19 on cognitive radio
  - Process to revise Radio Regulations
  - WRC-12 agenda item 1.19 -> Concluded by Feb. 2012
- Study activities on CRS in ITU-R
  - Study structure in ITU-R
  - Study results in ITU-R -> CPM Report and ITU-R Reports
- ITU-R study results towards WRC-12
  - No change to the Radio Regulations
    -> No discussion for frequency allocation
  - The use of CRS may require the development of ITU-R Recommendations and Reports
    -> No discussion necessary in future WRC

# Study in KDDI R&D Lab. and KDDI strategy

- Study of CRS in KDDI R&D Laboratories
  - Outline of the study and development project
  - Various technologies for CRS
- KDDI Strategy
  - Multi-Network

# Study and development project

- A research contract on cognitive radio technology organized by the Ministry of Internal Affairs and Communications
  - The 1st phase: F.Y.2005–F.Y.2007 (for 3 years)
  - The 2nd phase: F.Y.2008–F.Y.2011 (for 4 years)

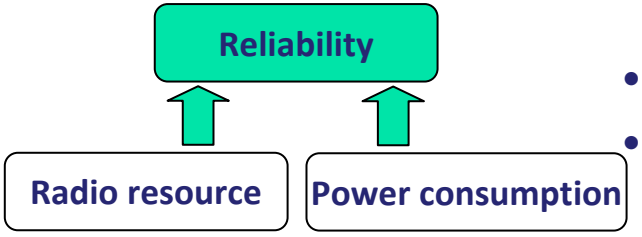
# Outline of study and development

Study and development for the technology to improve reliability by dynamical usage of different radio systems (Heterogeneous radio)

To realize high reliability and efficient use of radio resources by cooperative controlling multiple radio systems in different frequency bands

The target

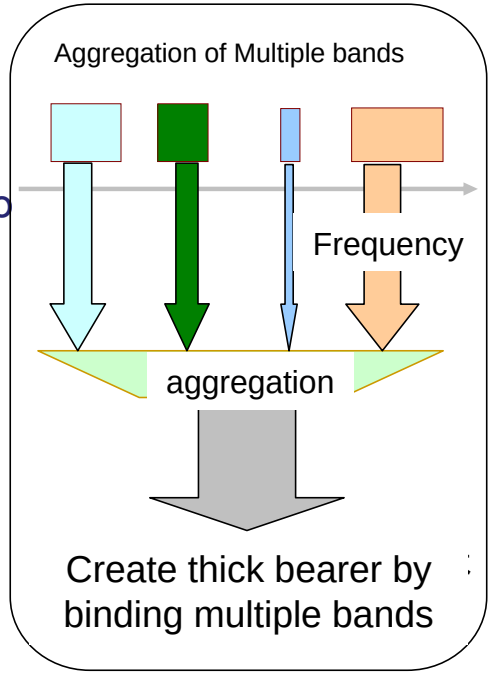
Compatible merits of terminals (reliability) and network (efficient use of radio resources)




- Secured reliability, if enough resources available
- Challenge to secure reliability by less resources

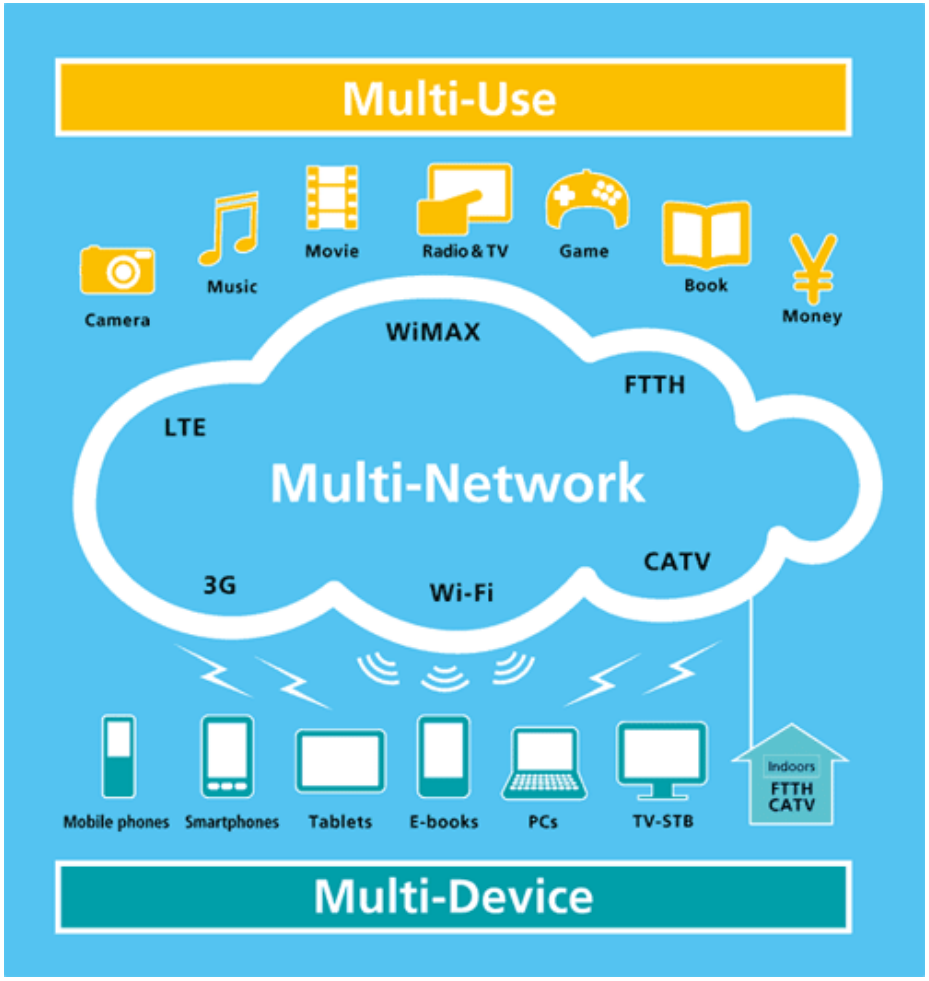
# Technical elements of cognitive radio

1. Sensing
   - Technology to sense environment for obtaining radio resource
   - Accuracy and time of detection, power of consumption to be evaluated
2. Communication system and resource control
   - Method to cooperate and coexist between radio systems and users for efficient utilization of radio resources
   - Protocol for spectrum aggregation
3. Database access
   - Utilize database to improve efficiency and accuracy of sensing as well as communication system and resource control
4. Device
   - RF device and processor targeted to multiple radio frequency bands
   - Performance indices: frequency bandwidth, device size, processing capacity, power consumption, costs, etc.



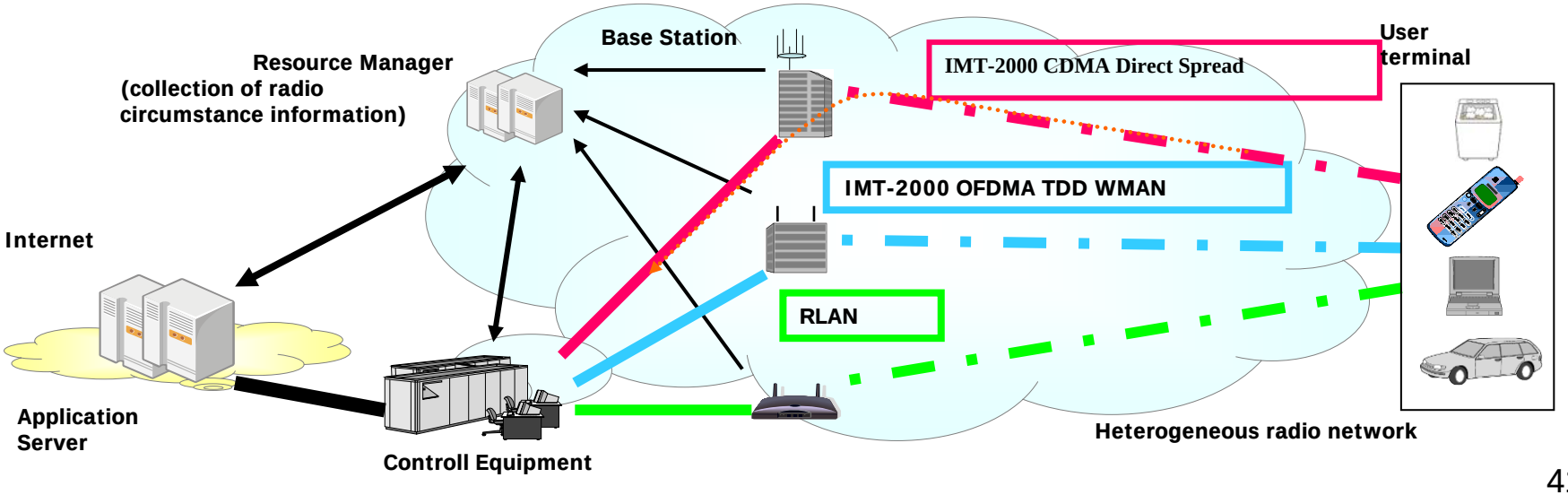
# Multi-Network in KDDI

- KDDI combines its fixed networks with mobile networks (3G/LTE, WiMAX and Wi-Fi).
- KDDI will accommodate skyrocketing traffic with low cost and high quality by multi-network.



# Considerations for a new study item on multi-network in IEEE 802.16WG

- Heterogeneous wireless network
  - Simultaneous use of multiple radio access technologies, e.g., LTE(-Advanced), WiMAX and Wi-Fi
  - Monitoring and collecting radio information in both terminal and network side
- Control utilization of radio access technologies based on radio environment
  - "Link aggregation" for high throughput
  - "Link selection" with consideration of application characteristics
  - Offload traffic



# Summary

- Expectation to Cognitive Radio
  - Shortage of frequency resource as a background
  - Concept, definition and an example of Cognitive Radio
  - Intelligent radio technology recognizing environment
- Standardization activities in ITU-R
  - WP1B: Regulatory study (towards WRC-12)
  - WP5A: Technical study on LMS except IMT (to develop CRS Report)
  - WP5D: Technical study on IMT system (to develop CRS Report)
- Study of Cognitive Radio in KDDI R&D Laboratories
  - Heterogeneous network
- Considerations for new study item on multi-network in IEEE 802.16WG