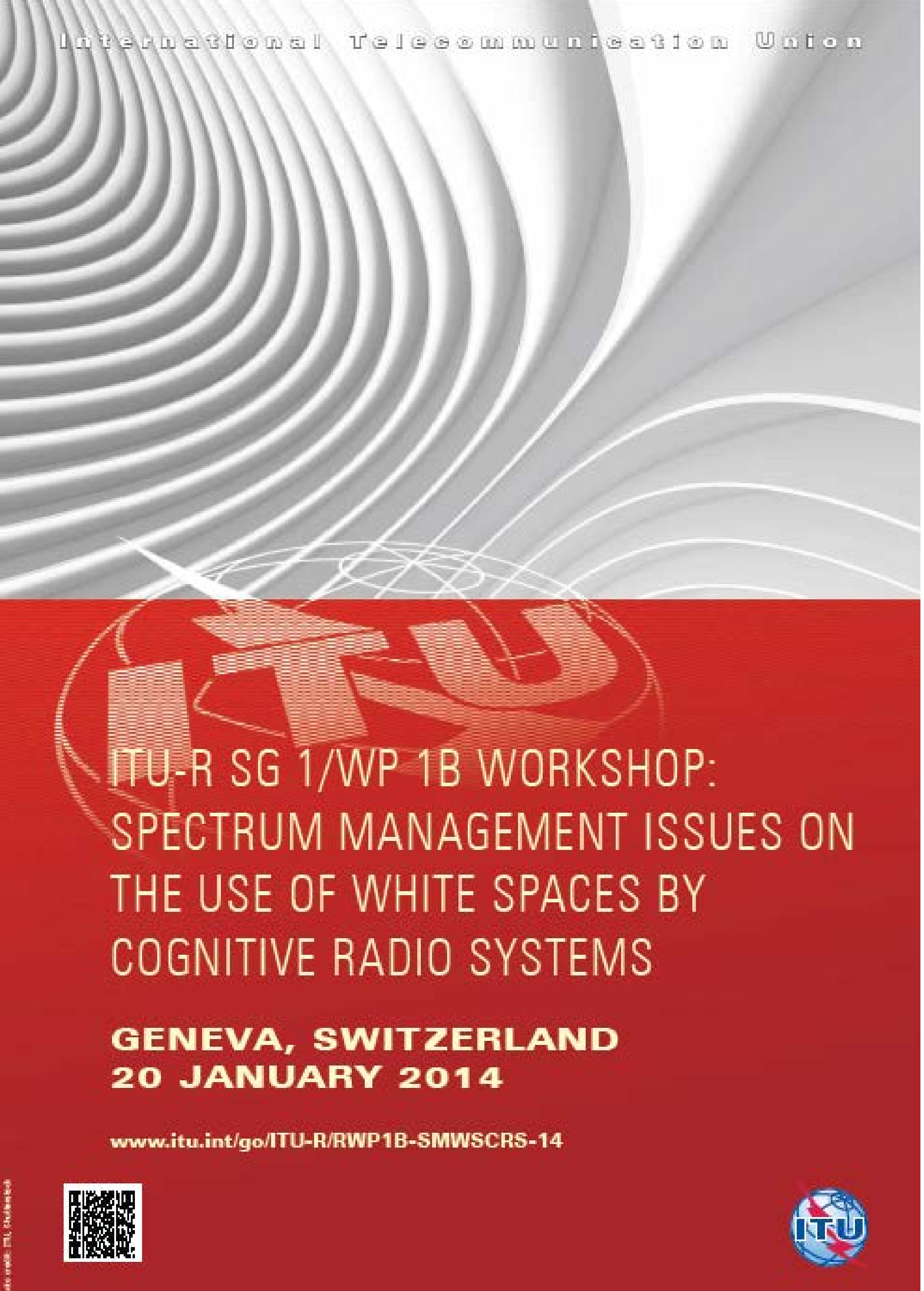

ITU-R SG 1/WP 1B WORKSHOP: SPECTRUM MANAGEMENT ISSUES ON THE USE OF WHITE SPACES BY COGNITIVE RADIO SYSTEMS
(Geneva, 20 January 2014)

Cognitive Cellular Systems in China

Challenges, Solutions and Testbed

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ITU-R WP 1B, Geneva, Switzerland
20 January, 2014

Outline

- **Background**
- **Challenges and Solutions in Cognitive Cellular System**
  - Cognitive Ability
  - Autonomous Decision Making
  - Adaptive Reconfiguration Ability
- **Practice of Cognitive TD-LTE System**
  - Cognitive TD-LTE System Operation in TV White Space
  - Cognitive TD-LTE Systems Operation in 230MHz

Spectrum Usage

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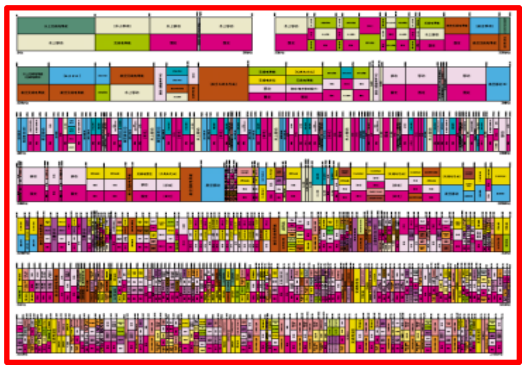
Current spectrum usage is experiencing coexistence of spectrum shortage and waste.

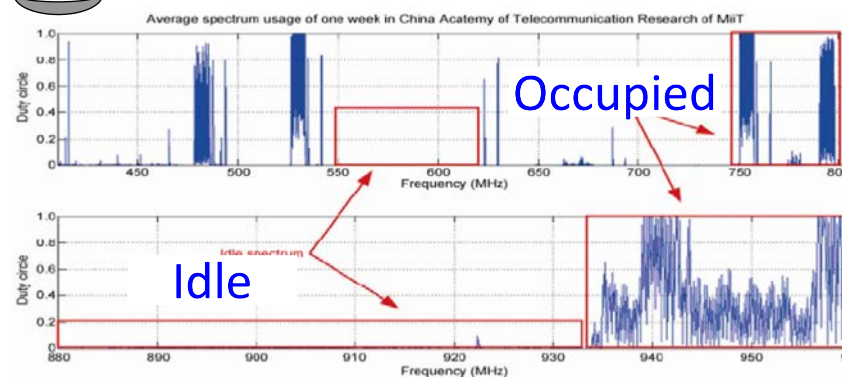
Spectrum Shortage



Existing bands have been exhausted

- There is a growing demand on spectrum resource due to the increasing demand on wireless transmission.
- The importance and scarcity of spectrum have become increasingly prominent.

Spectrum Waste



Spectrum is insufficiently used (e.g., TV WS)

- Field test of spectrum occupation shows that spectrum occupancy is less than 5%, similar to the results of FCC.
- Spectrum is insufficiently used in both time and frequency.
- Spectrum is insufficiently used due to outdated wireless transmission technology and rigid spectrum allocation mode.

Cognitive Cellular Systems in China

❖ How to efficiently utilize the vacant spectrum resource

- Requirement 1: Accurate and efficient vacant spectrum awareness
- Requirement 2: Dynamic spectrum management
- Requirement 3: Flexible and adaptive transmission and dynamic spectrum utilization

Solution: Cognitive Radio System !

❖ Cognitive TD-LTE System Operation

➢ **Network Selection: Cellular Network**

- Cellular network is the pillar of telecommunication industry. Utilizing cognitive technology to solve spectrum usage in cellular network is of great importance.

➢ **Mode selection: TD-LTE**

- LTE systems offer high peak data rates, low latency, high capacity and network simplicity.
- TDD can operate in unpaired spectrums, whereas FDD requires paired spectrums. Thus, TDD offers more flexibility in spectrum usage.

Cognitive TD-LTE System Operation - Band Selection

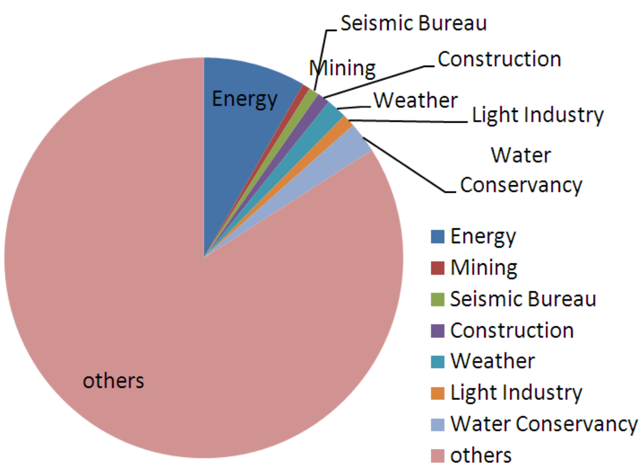
UHF Band

- Coexistence with broadcast TV services enables high efficiency of spectrum utilization.

TV White Space Spectrum Allocation		
TV Channels	**Spectrum**	**Band**
2, 3, 4	54 – 72 MHz	VHF – Low-band
5, 6	76 – 88 MHz	VHF – Low-band
7 – 13	174 – 216 MHz	VHF – High-band
14 – 51	470 – 698 MHz	UHF band

Based on the field test of spectrum occupation, 698-806MHz is selected.

Band 230MHz



- 230MHz is allocated to multiple industry services by fixed pattern, and the spectrum can not be used sufficiently for the data transmission characters.
- New data transmission requirements of the industry services can not be met, and the band is not widely and sufficiently used in all countries.

Coexistence among multiple systems on 230MHz to realize high efficiency of spectrum utilization.

Outline

❖ Background

❖ Challenges and Solutions in Cognitive Cellular System

Executing

- Cognitive Ability

Information Processing

- Autonomous Decision Making

Managing

- Adaptive Reconfiguration Ability

❖ Practice of Cognitive TD-LTE System

- Cognitive TD-LTE System Operation in TV White Space
- Cognitive TD-LTE Systems Operation in 230MHz

Technical Challenges

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Challenge 1： Obtaining accurate cognitive information

Cognitive information is the basis of cognitive TD-LTE system operation

- How to obtain cognitive information while guaranteeing the information transmission simultaneously?
- How to obtain cognitive information rapidly and accurately ?

Solution

- Re-design protocol : adding the cognitive functions
  Re-design frame format: UL-DL Guard Period and Uplink Time Slot are used to implement collaborative sensing
- Combine spectrum sensing and database to ensure both efficiency and accuracy of obtaining cognitive information.

Obtaining Cognitive Information

Methods for obtaining cognitive knowledge

	Spectrum sensing	Database
Advantages	• Suitable for dynamic changing environment • Fast local information update	• Global information management • Efficient information sharing • Accurate frequency information
Disadvantages	• Sensing time cost and hardware cost • Miss detection, false alarm, location difficulty for hidden node	• Slow response to rapid changing radio environment • Slow local information update

Both two methods of obtaining cognitive information have disadvantages

Combining these two methods is a good solution

- Obtain global information via database, and update local information via spectrum sensing. The efficiency and accuracy of cognitive information can thus be increased.
- Overcome the hidden node problem, improve the accuracy of spectrum sensing, avoid interference, and reduce the overhead.

➢ **Policy and Regulation Challenge 1 - Frequency authorization**

Description: The *sensitivity of the spectrum utilization information* could be very high. The information should not be obtained via spectrum sensing or database. Possible frequency band(s) for the systems or services implementing CRS should be authorized first while accounting for existing uses on the band(s).

Technical Challenges

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Challenge 2: Efficient spectrum management

Spectrum management complexity increases with management scope

- How to guarantee cognitive information transmission and basic data transmission?
- How to solve the contradiction between global spectrum planning and local dynamic spectrum management?

Solution

- Allocate dedicated frequency for a cognitive cellular system
- Static and dynamic combined spectrum management
- Two-level spectrum management mechanism

Result

Validated in the lab, the proposed mechanism has a 30% growth of spectrum utilization compared to fixed spectrum management.

Spectrum management

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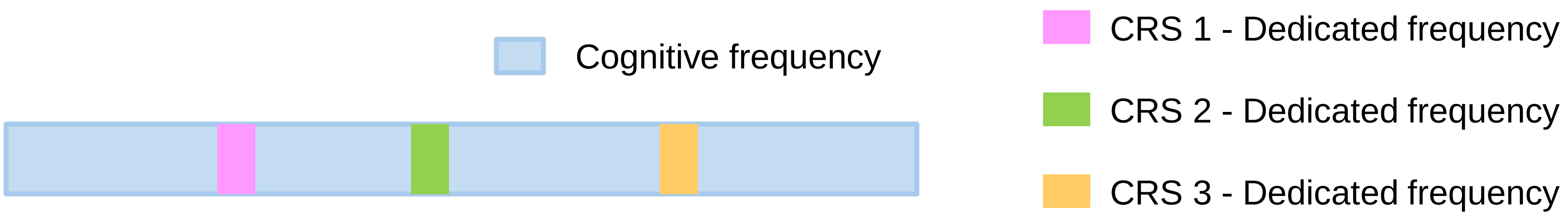
➢ Dedicated frequency:

Dedicated frequency is allocated to a certain cognitive cellular system to guarantee cognitive information transmission and basic data transmission. Different dedicated frequencies are allocated to multiple cognitive cellular systems to work together without interference to each other.



It is challenging to design dynamic spectrum management for the cognitive cellular system with **statically utilized dedicated frequency** and **dynamically utilized cognitive frequency**.

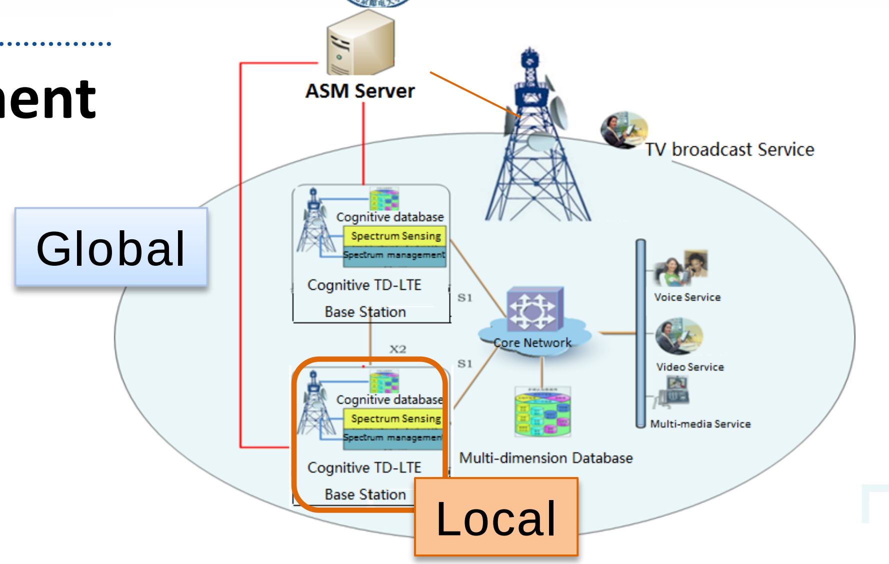
➢ **Policy and Regulation Challenge 2 - Frequency allocation**

- **Description:** Frequency allocation is supposed to follow the radio regulations by ITU. It is hard to find *harmonized dedicated frequency band(s)* worldwide or even nationwide. On the other hand, when multiple cognitive cellular systems coexist on the same spectrum band, each of them shall have *equal right to access* the spectrum.

Policy and Regulation Challenges

❖ Two-level spectrum management

- Global:
  inter-cell spectrum management,
  large time granularity
- Local:
  intra-cell spectrum management,
  small time granularity



➢ **Policy and Regulation Challenge 3 – Cross-border coordination**

- **Description:** Radio frequency allocation regulations are different among countries and regions. How to conclude agreement on *cross-border coordination* related to CRS is a big challenge.

➢ **Policy and Regulation Challenge 4 - Interference coordination**

- **Description:** Cognitive radio system is more likely to be operated on unlicensed spectrum band(s). *Interference risk* for operators of wireless networks is highlighted.
- **Candidate Solution:** Regulatory models must be based on clear definitions of rights and responsibilities of both licensed and unlicensed spectrum users.

Technical Challenges

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Challenge 3： Adaptive to the changing environment

Adaptive reconfiguration is the key to deal with the changing environment

- How to realize the reconfiguration of parameters, protocols and working modes of different cognitive nodes in heterogeneous networks

Solution

- **Service reconfiguration**: service split (with multiple QoS requirement)
- **Protocol and parameter reconfiguration**: simultaneous transmission

- **Policy and Regulation Challenge 5 - Type approval**

  Description: All radio devices require type approval before they can be imported, installed, sold or used. Each jurisdiction that regulates communications requires devices to be tested for conformance to local regulations before it is approved for use in that jurisdiction. For reconfigurable devices, the *reconfigurability in operation frequency and transmission mode calls for new method for type approval*.

Summary

- **Policy and Regulation Challenge 1 - Frequency authorization**

  Possible frequency band(s) for the systems or services implementing CRS should be authorized first while accounting for existing uses on the band(s).

- **Policy and Regulation Challenge 2 - Frequency allocation**

  It is hard to find harmonized dedicated frequency band(s) worldwide or even nationwide. When multiple cognitive cellular systems coexist on the same spectrum band, each of them shall have equal right to access the spectrum.

- **Policy and Regulation Challenge 3 – Cross-border coordination**

  Radio frequency allocation regulations are different among countries and regions. How to conclude agreement on cross-border coordination related to CRS is a big challenge.

- **Policy and Regulation Challenge 4 - Interference coordination**

  To decrease interference risk, regulatory models with clear definitions of rights and responsibilities of both licensed and unlicensed spectrum users are needed.

- **Policy and Regulation Challenge 5 - Type approval**

  For reconfigurable devices, the reconfigurability in operation frequency and transmission mode calls for new method for type approval.

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Cognitive TD-LTE System Operation in TV White Space

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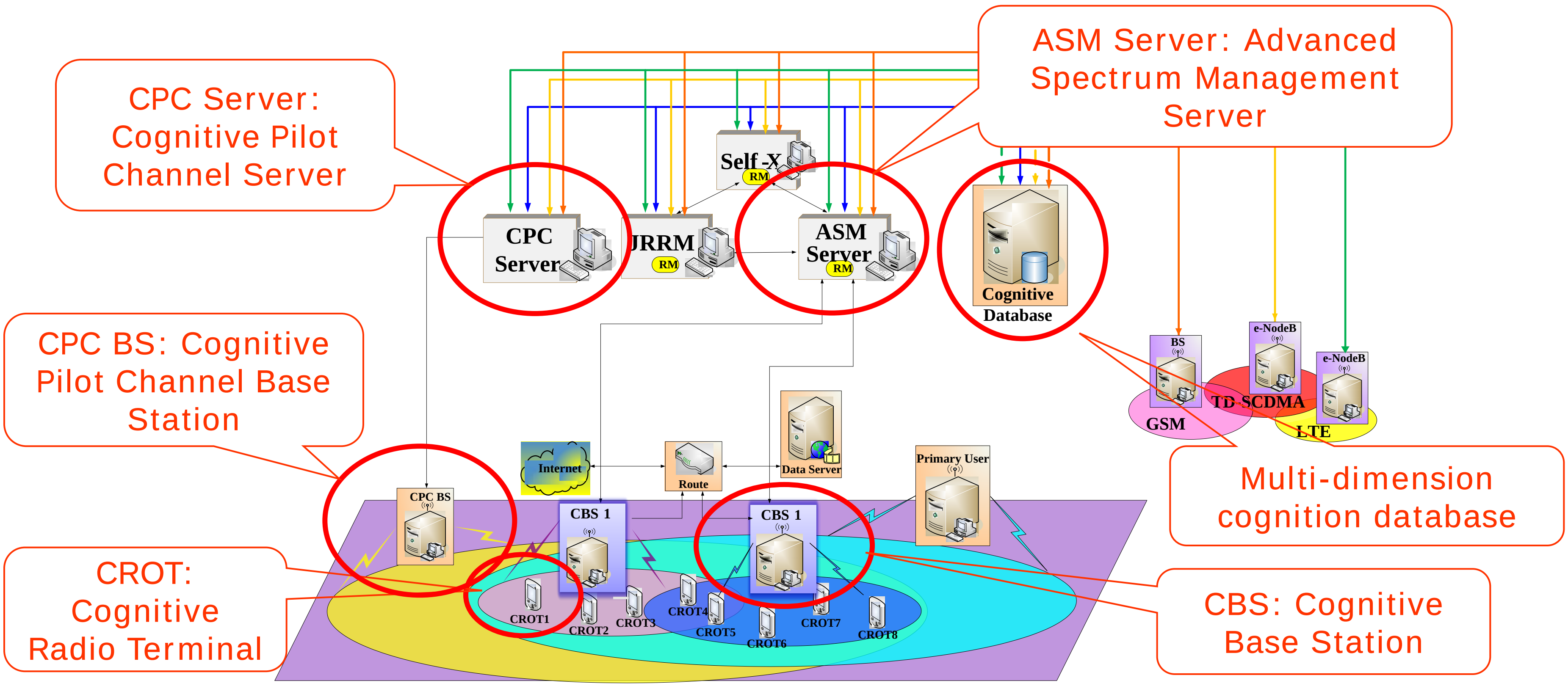
❖ System Architecture

The platform is mainly composed of the wireless access side and network side. It is designed to implement a cognitive network to improve the spectrum efficiency and verify the heterogeneous network convergence.



Cognitive TD-LTE System Operation in TV White Space

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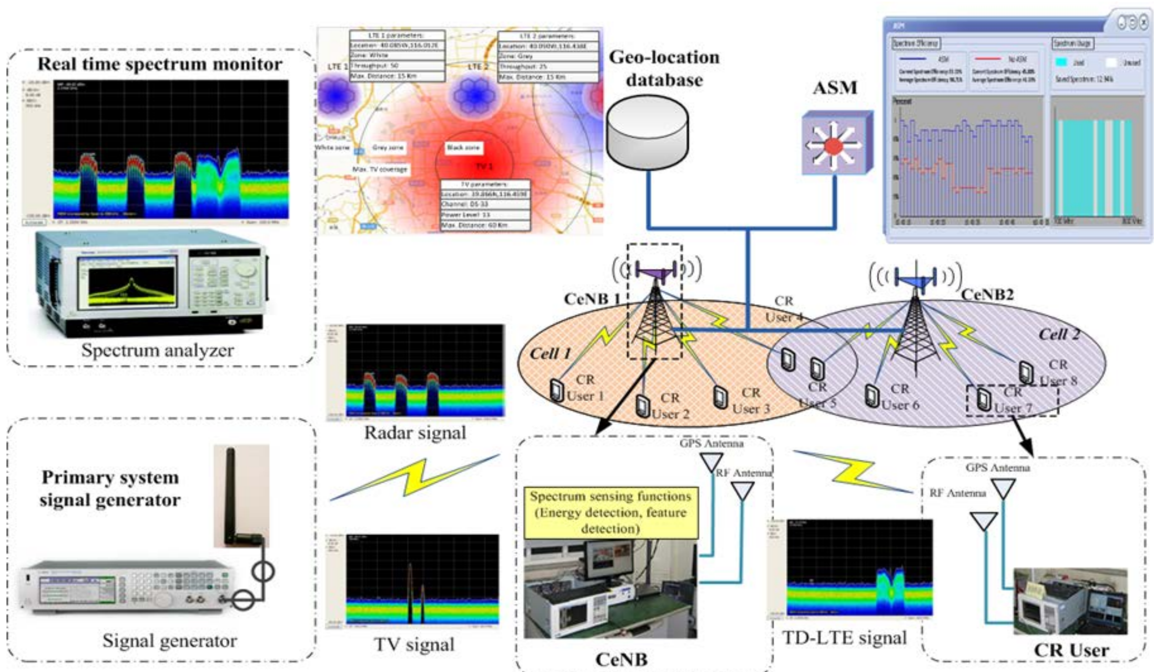
❖ Testbed characteristics

- **Spectrum Range of Testbed**
  - 698-806MHz scalable spectrum range
  - Bandwidth: 1.25-20MHz
  - Frequency point switch time: <5ms
- **High Computing Ability**
  - 9 DSP cores with 1.2GHz high speed, 86.4G MIPs, 86.4G MACs
  - Support 2-4 antennas MIMO, support 100Mbps LTE standard
  - Satisfy various signal and protocol processing requirements of different wireless communication standards
  - Satisfy real time requirement of spectrum cognition in large scale

Key functions	Platform Indications
Sensing granularity	TV -120dBm Radar -113dBm
Sensing period	10ms
Sensing rate	TV 4ms Radar 3ms
Handover time	50ms



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Cognitive TD-LTE System Operation in 230MHz

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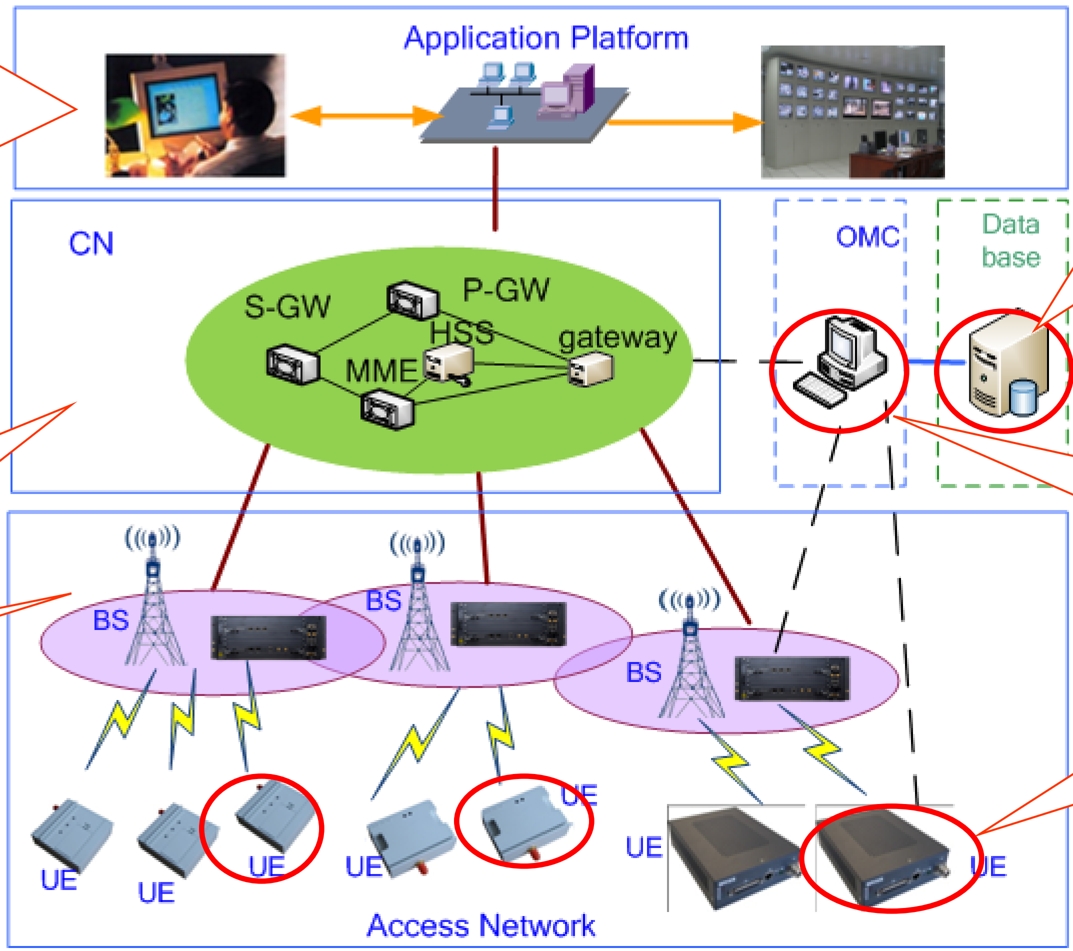
The system is mainly composed of **access network, Core Network (CN), Operation and Maintenance Center (OMC), data base and application platform.**

Application Platform: main control station for user, providing data statistics, analysis,etc.

CN: core network

BS: Base station



Data base: Frequency allocation information

OMC: Operation and Maintenance

UE:User Equipment

Cognitive TD-LTE System Operation in 230MHz

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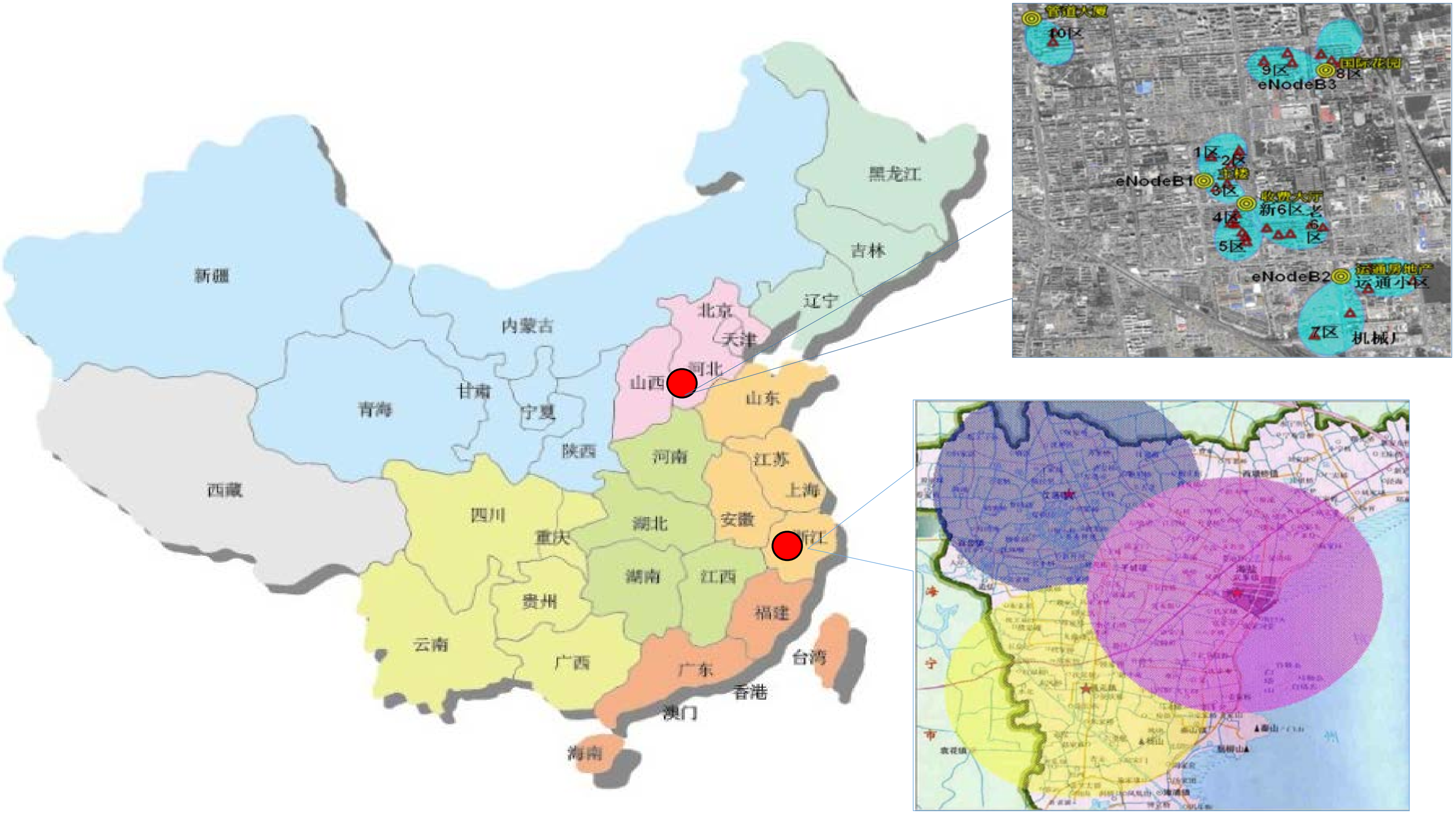

Field trials are being developed in Hebei and Zhejiang province , to verify the performance of the cognitive radio system in 230MHz.

Thank you for your attention!

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