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Cognitive TD-LTE System Operating in TV White Space in China

Challenges, Solutions and Testbed

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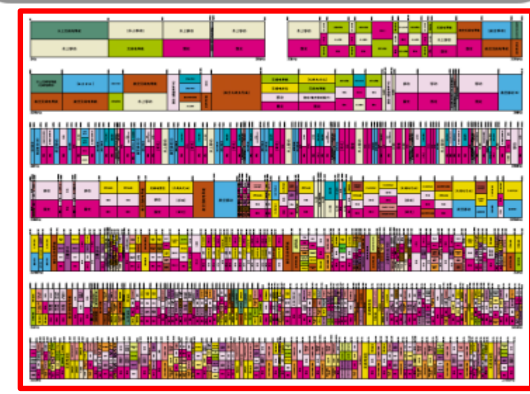
Outline

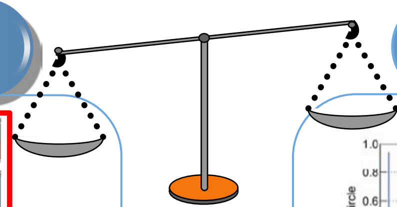
- **Background**
- **Challenges and Solutions in Cognitive TD-LTE System**
  - Cognitive Ability
  - Autonomous Decision Making
  - Adaptive Reconfiguration Ability
- **Testbed for Cognitive TD-LTE System**

Spectrum Usage

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

Spectrum Shortage

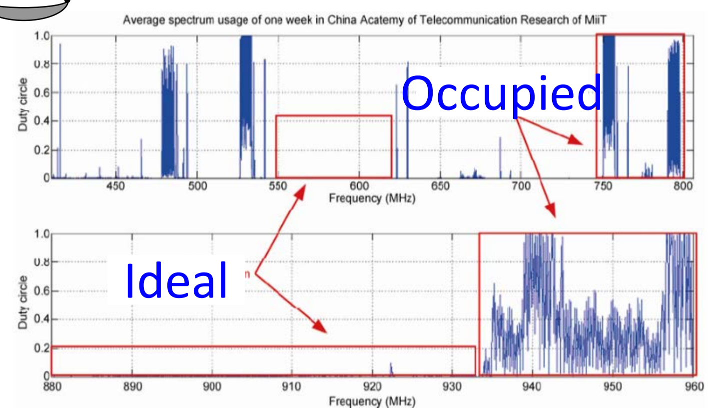




Existing bands have been exhausted

- 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



TV white space is insufficiently used

- Field test of spectrum occupation at BUPT campus in China shows that spectrum efficiency is Less than 5%, surprisingly similar to the data released by FCC.
- Spectrum is insufficiently used in both time and frequency.

CRS Operating in TV White Space in China

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❖ How to efficiently utilize the vacant spectrum resource

- Requirement 1: Flexible transmission bandwidth
- Requirement 2: Dynamic spectrum management

Solution: Cognitive Radio System！

❖ Why operate cognitive TD-LTE system in TV White Space

➢ **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**

- Broadband China Strategy requires the deployment of 3G/LTE networks.
- TDD can operate in unpaired spectrum, whereas FDD requires paired spectrum. Thus, TDD offers more flexibility in spectrum usage.

➢ **Band Selection: UHF Band**

- Coexist with broadcast TV services to realize high efficiency of spectrum utilization.

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Technical Challenges

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Challenge 1：Obtaining accurate cognitive information

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

- Obtaining cognitive information simultaneously with transmitting information
- Obtaining cognitive information rapidly and accurately

Solution

- Re-design protocol and frame format to support acquiring cognitive information simultaneously with transmitting information
- Combine spectrum sensing and database to ensure both efficiency and accuracy

Obtaining Cognitive Information

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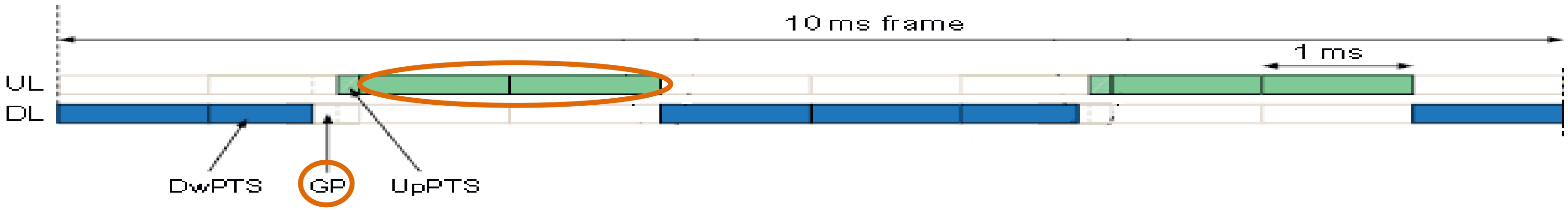
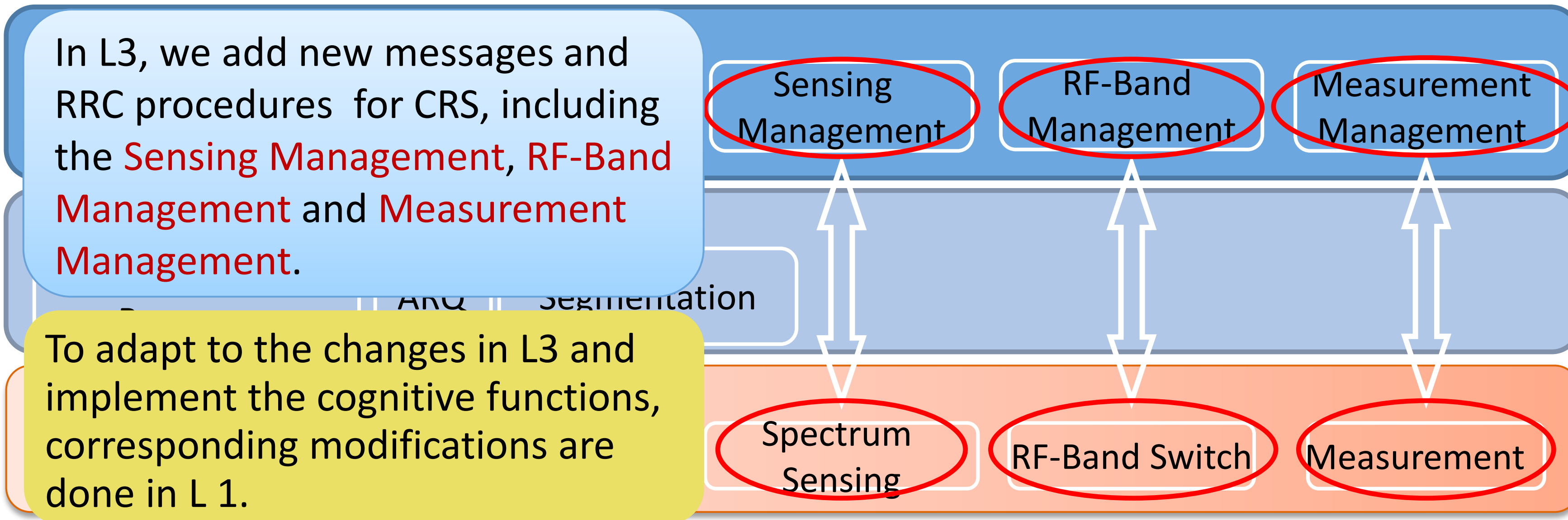
❖ Frame Format Design and Protocol Design

- **Frame Format Design:** UL-DL Guard Period and Uplink Time Slot are used to implement collaborative sensing. It enables real-time cognitive information transmission and breaks the limitation of conventional silence duration.



- **Protocol Design:** The cognitive communication protocol is designed based on TD-LTE-Advanced protocol, by adding the cognitive functions.



In L3, we add new messages and RRC procedures for CRS, including the Sensing Management, RF-Band Management and Measurement Management.

To adapt to the changes in L3 and implement the cognitive functions, corresponding modifications are done in L 1.

Obtaining Cognitive Information

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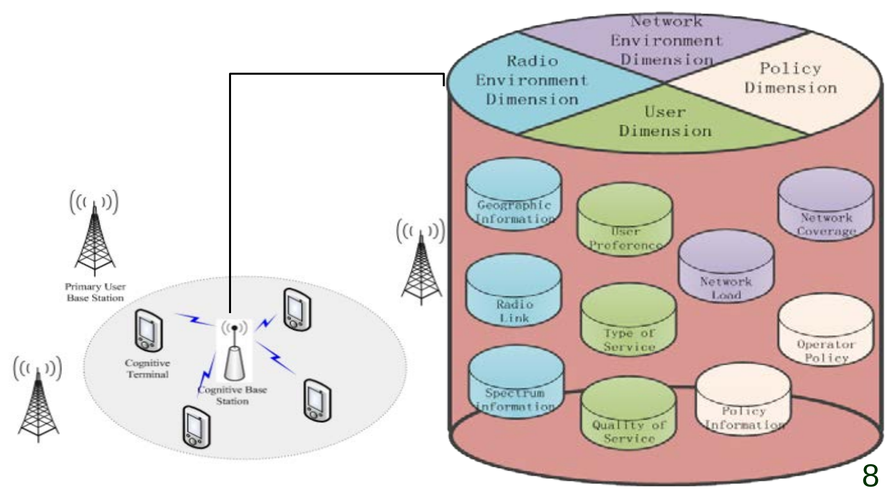
❖ Methods for obtaining cognitive knowledge

	Spectrum sensing	Database
Advantages	• Suitable for dynamic changing environment • Fast local information update	• Global information management • Efficient information sharing
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

Combine the two methods

- **Advantages**
  - Obtain global information via database, and update regional (local) information via spectrum sensing.
  - Overcome the hidden node problem, improve the accuracy of spectrum sensing, avoid interference, reduce the overhead



Obtaining Cognitive Information

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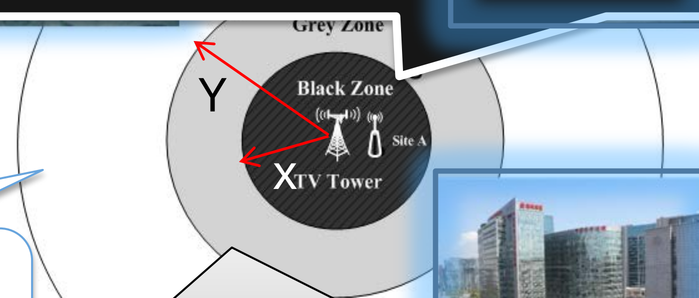
❖ Three zones use case

- Database stores accurate information, such as locations and borders of white zone, black zone and grey zone.
- The secondary users access database first and implement spectrum sensing only when necessary.

It is difficult to coexist with TV system in black zone, and orthogonal frequency can be used by checking the **database information**.



The secondary users in white zone can utilize the vacant spectrum freely **without spectrum sensing**.

Users in gray zone can utilize the vacant spectrum opportunistically through **spectrum sensing**.

Name	Meaning	Comment
White Zone Range	Distance between PU and SU>Y km	Secondary users beyond this range can deploy freely without spectrum sensing function.
Black Zone Range	Distance between PU and SU<X km	Secondary users within this range can't work on the same spectrum as PUs absolutely, check the database.
Grey Zone Range	X km<Distance between PU and SU<Y km	Secondary users within this range should perform spectrum sensing before transmission.

Technical Challenges

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Challenge 2：Efficient spectrum management

Spectrum management complexity increases with management scope

Spectrum management should be applied:

- For both inter-cell and intra-cell
- Rapidly and efficiently

Solution

Two-level spectrum management mechanism

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

Result

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

Technical Challenges

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Challenge 3：Adaptive to the changing environment

Adaptive reconfiguration is the key to deal with the changing environment

- Reconfiguration should be applied among heterogeneous networks
- Reconfiguration should improve QoS

Solution

- Service reconfiguration
- Protocol and parameter reconfiguration

Result

	Packet Loss Probability	Transmission latency
Before Reconfiguration	5.36%	90.9965ms
After Reconfiguration	0.27%	27.9953ms

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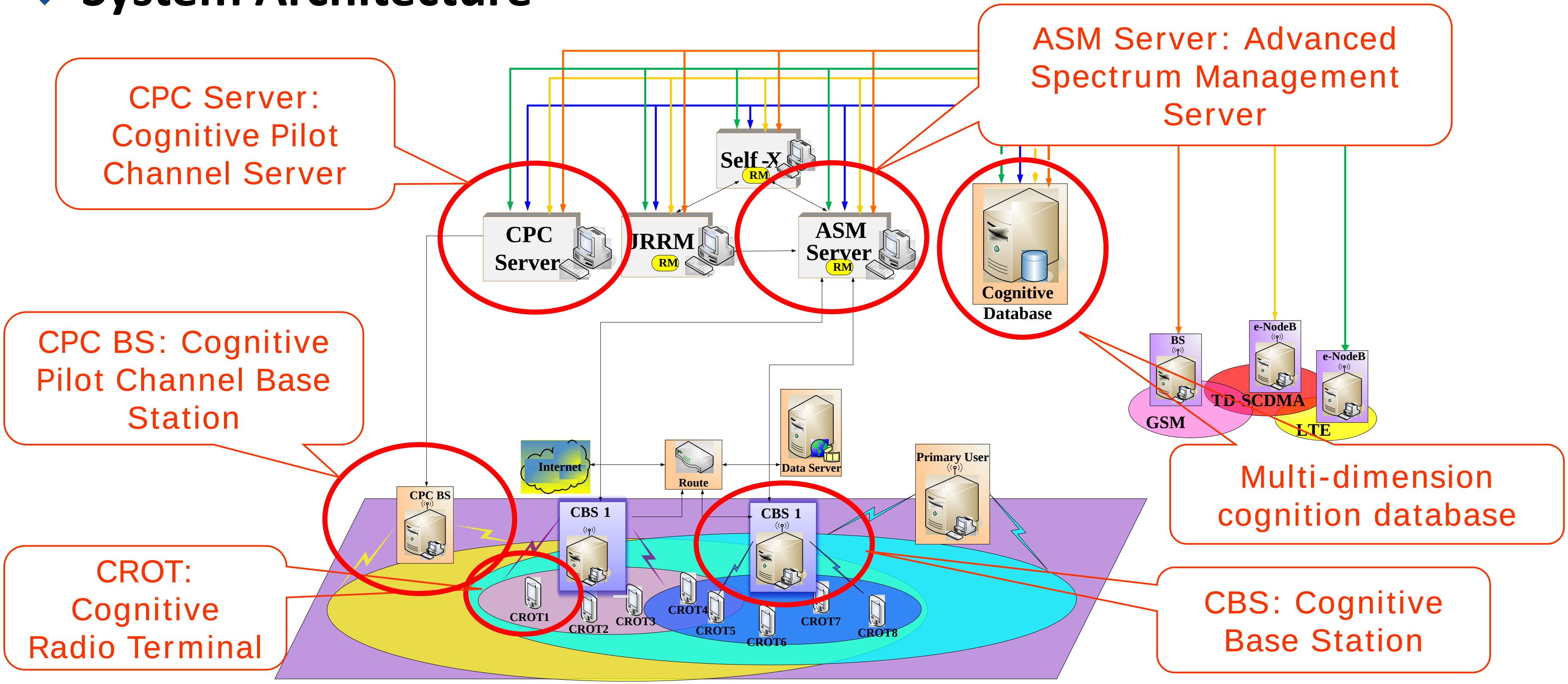
Testbed for Cognitive TD-LTE System

❖ System Architecture



The platform is mainly composed of the Wireless Access side and Network side. It is designed to implement a cognitive network with centralized dynamic spectrum allocation to improve the spectrum efficiency and verify the heterogeneous network convergence.

Testbed for Cognitive TD-LTE System

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❖ Testbed characteristics

- **Spectrum Range of Testbed**
  - 700MHz-2.8GHz scalable spectrum range
  - Bandwidth: 1.25-20MHz
  - Frequency point switch time: <5ms
- **Support Multiple Standards**
  - 2G: GSM, CDMA
  - 3G: TD-SCDMA, WCDMA, CDMA2000
  - 3G+: LTE
  - IEEE: 802.11b/g/n, WiMAX

	FCC standards	Platform Indications
Sensing granularity	-114dBm	TV -120dBm Radar -113dBm
Sensing period	Off service：30s On service：60s	10ms
Sensing rate	N/A	TV 4ms Radar 3ms
Handover time	2s	50ms

- **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

Thank you for your attention!

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