Cognitive Wireless Communications -A Solution for Efficient Multiple Networks Coexistence

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Outlines

- Multiple Networks Coexistence: Opportunities and Challenges
- Cognitive Wireless Communications
    - Components
    - Key Technologies
- Dynamic Spectrum Sharing Network (DySNet): A developing prototype for Cognitive Wireless Communication system

Multiple Networks Coexistence: Opportunities and Challenges

Mobile Telephone

Mobile Internet

Mobile Multimedia

- 1990s, 1G/2G
- Voice and SMS only

- 2000s, 2G/3G
- Voice, SMS, MMS, email, Web, ……

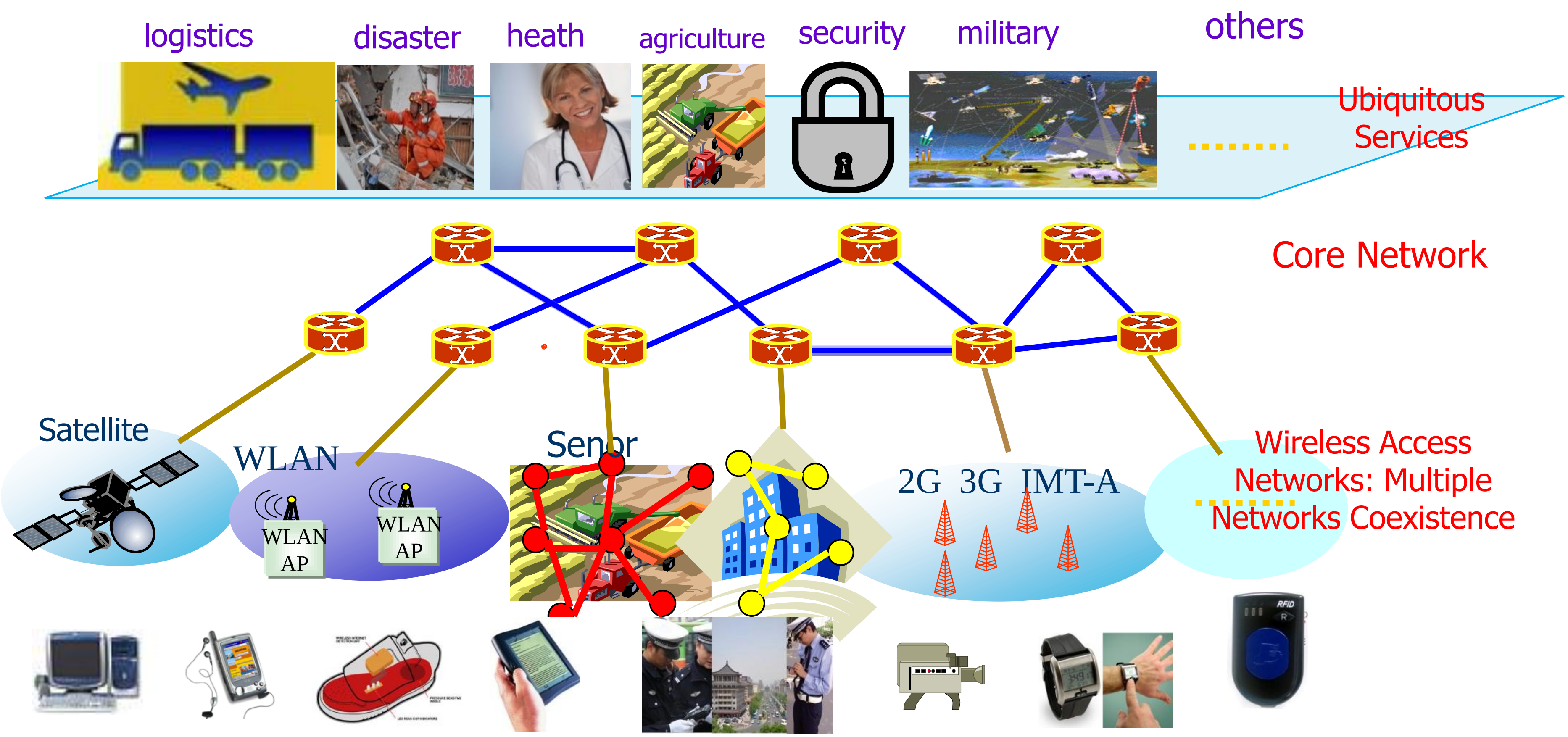
- 2010s, 3G/4G
- Voice, SMS, MMS, email, Web, TV, VoD……

Mobile ?

- 2020s
- *wireless in everything*
- Ubiquitous service..

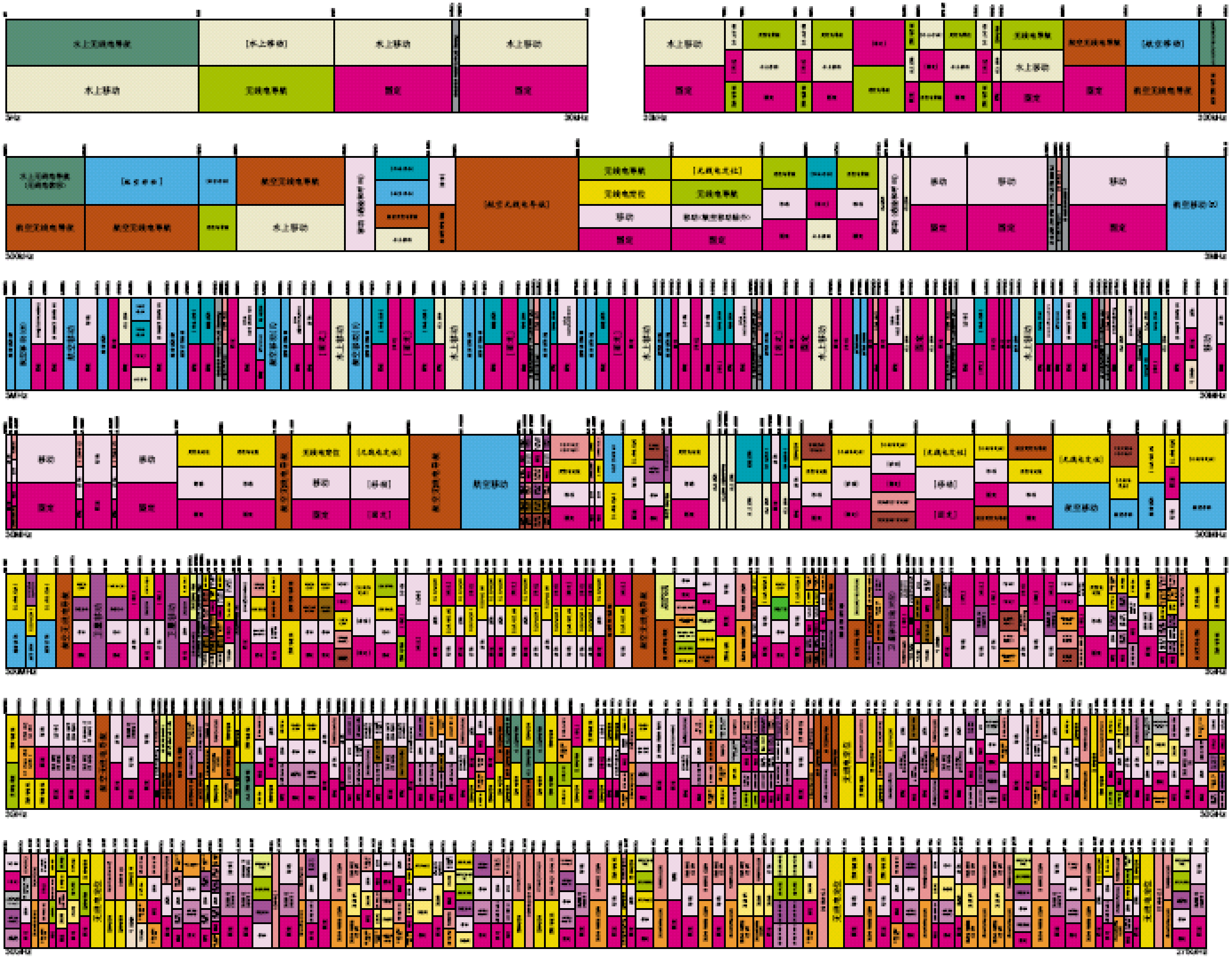
More and more wireless services arise in recent years.

Multiple Networks Coexistence: Opportunities and Challenges


logistics
disaster
heath
agriculture
security
military
others
……
Ubiquitous Services
Core Network
Satellite
WLAN
WLAN AP
WLAN AP
Senor
2G 3G IMT-A
……
Wireless Access Networks: Multiple Networks Coexistence

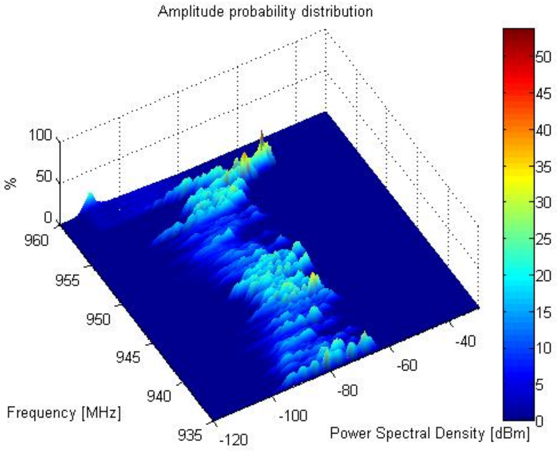
- **Problems: Multiple networks coexistence incurs resource scarcity.**
- **Opportunities: resource can be shared among networks to improve efficiency.**

Multiple Networks Coexistence: Opportunities and Challenges

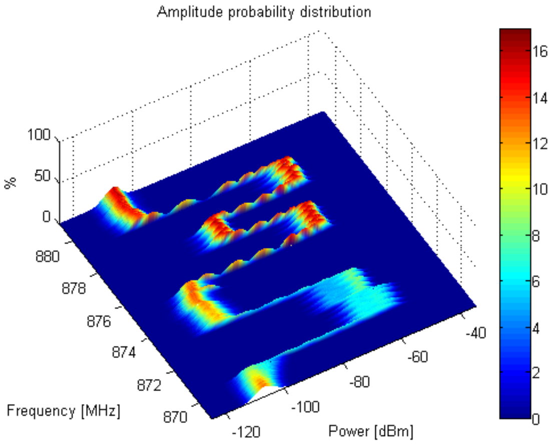


Multiple Networks Coexistence: Opportunities and Challenges (Cont.)

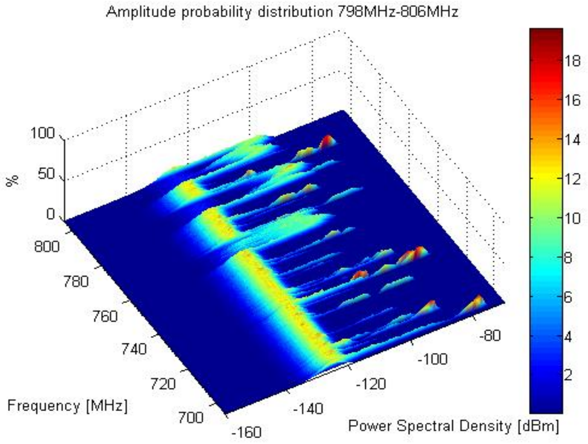
- Opportunities Analysis



GSM: 955MHz-960MHz (24hours)



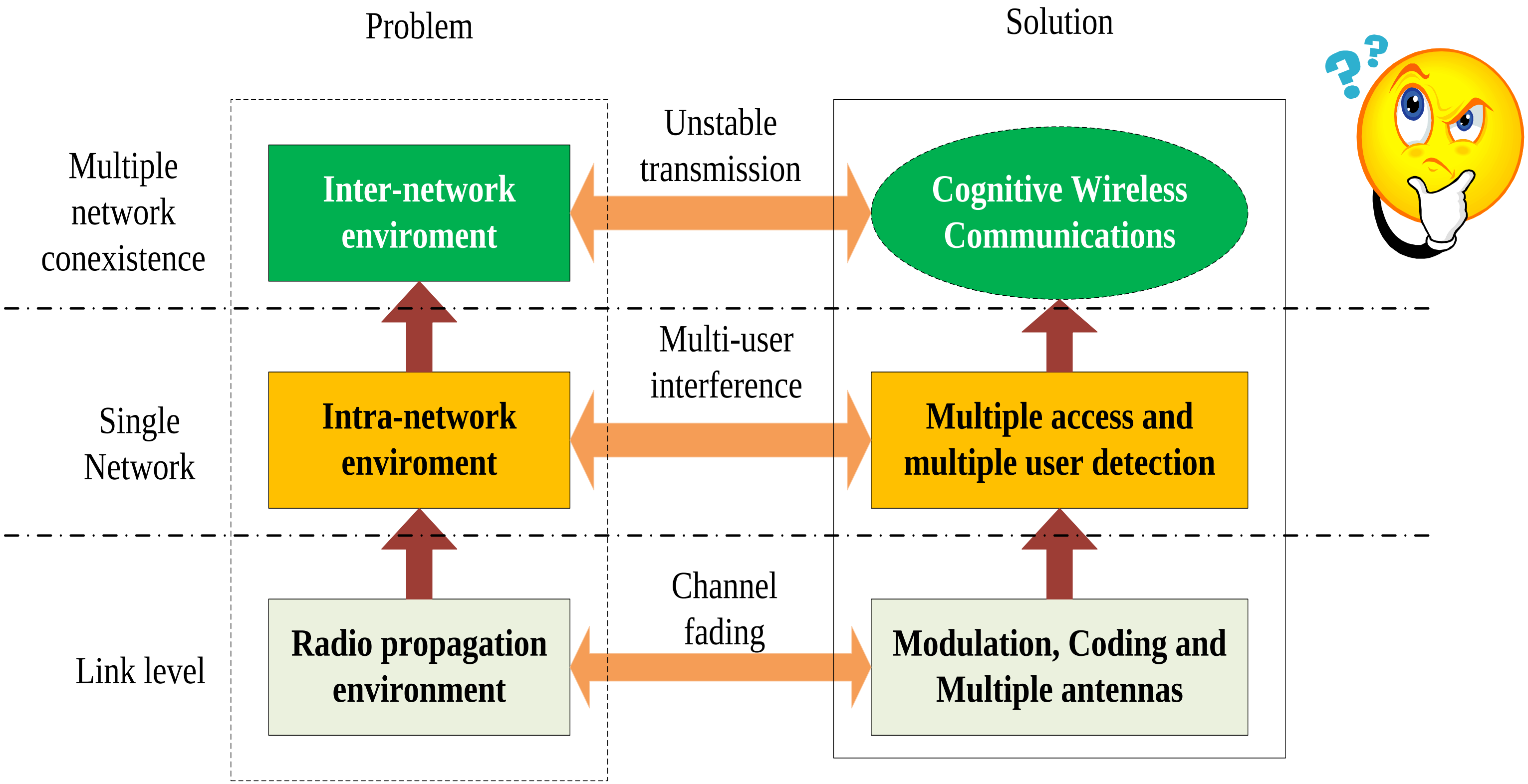
IS-95: 869MHz-881MHz (24hours)



- There exist great opportunities to share resource among networks.
- To utilize the potential opportunities, it is necessary to meet the requirements of primary networks.

Multiple Networks Coexistence: Opportunities and Challenges (Cont.)

- Cognitive Wireless Communications is an efficient solution for multiple networks coexistence scenarios.



Problem

Solution

Multiple network conexistence

Inter-network enviroment

Unstable transmission

Cognitive Wireless Communications

Single Network

Intra-network enviroment

Multi-user interference

Multiple access and multiple user detection

Link level

Radio propagation environment

Channel fading

Modulation, Coding and Multiple antennas

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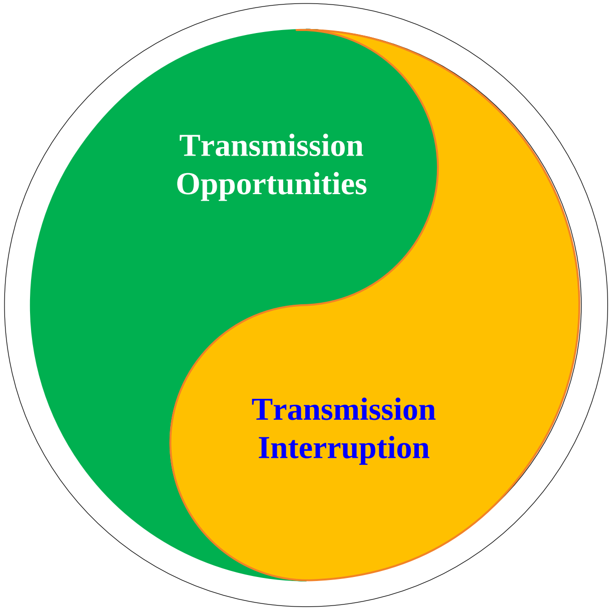
Multiple Networks Coexistence: Opportunities and Challenges (Cont.)

- There exists paradox of “transmission opportunities ” and “transmission interruption” for resource sharing under multiple networks coexistence scenarios.

- Transmission Opportunities: A new network can provide wireless services by dynamically sharing resource with the existing networks to improve the utilization efficiency of resource.



- Transmission Interruption: A network can be interrupted by the existing networks due to their reclaiming resource.

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Outlines

- Multiple Networks Coexistence: Opportunities and Challenges

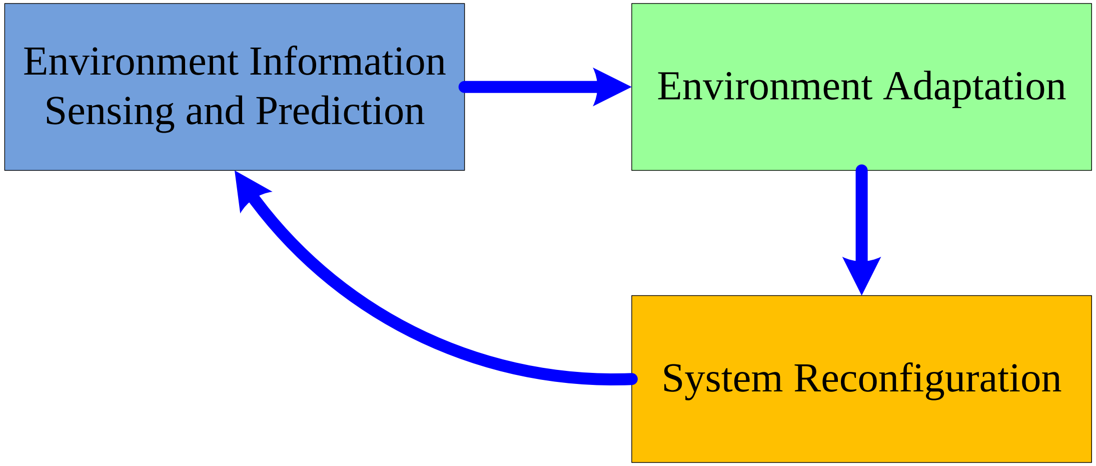
☞ ***Cognitive Wireless Communications***

  - ***Components***
  - ***Key Technologies***

- Dynamic Spectrum Sharing Network (DySNet): A developing prototype

Cognitive Wireless Communications

- The Cognitive Wireless Communication System intelligently find and utilize existing available resources to provide services.
- Fundamental Characteristics
  - Environment Sensing and Prediction
  - Environment Adaptation
  - System Reconfiguration

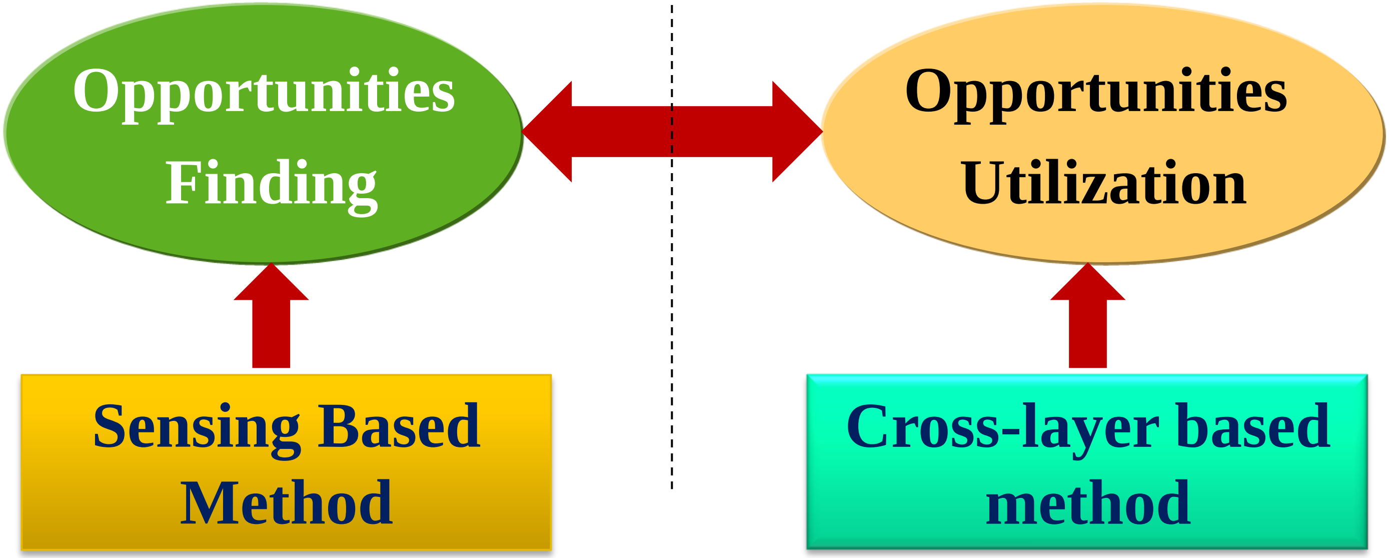

Environment Information Sensing and Prediction

Environment Adaptation

System Reconfiguration

Cognitive Wireless Communications: Components

- System Components
  - **Opportunities Finding**: find the available resource independently or cooperatively
  - **Opportunities Utilization**: efficiently use the resource to provide wireless service



Opportunities Finding

Opportunities Utilization

Sensing Based Method

Cross-layer based method

Opportunities Finding: Sensing Based Method

Low SNR

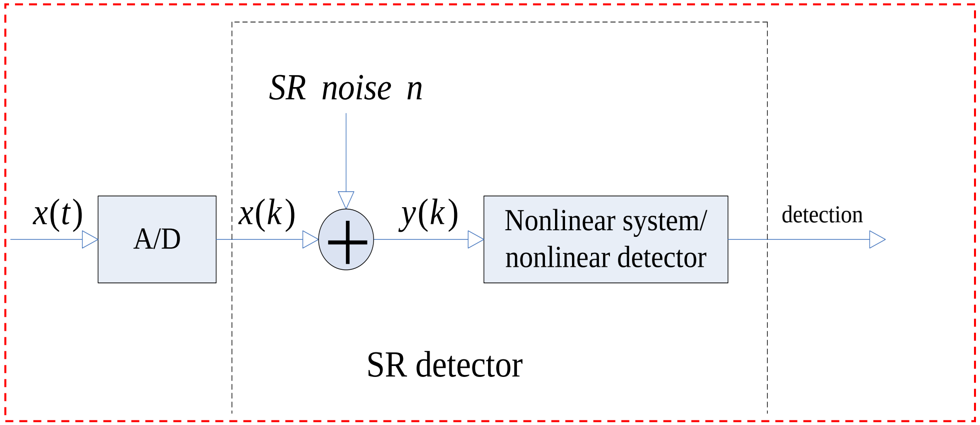
- Low received SNR at the cognitive receiver due to channel shadow and fading;
- IEEE 802.22 requires to achieve 90% detection at 10% false alarm rate when the SNR is as low as -20dB.

Speed

- Sense the environment as quickly as possible to;
- Monitor the primary network’s activity and vacate the spectrum as fast as possible when the primary network reactivates
- IEEE 802.22 requires the sensing period less than 200ms.

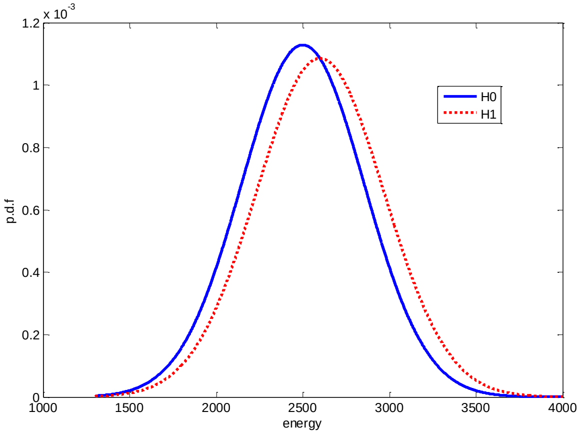
Sensing: Stochastic Resonance Based Sensing

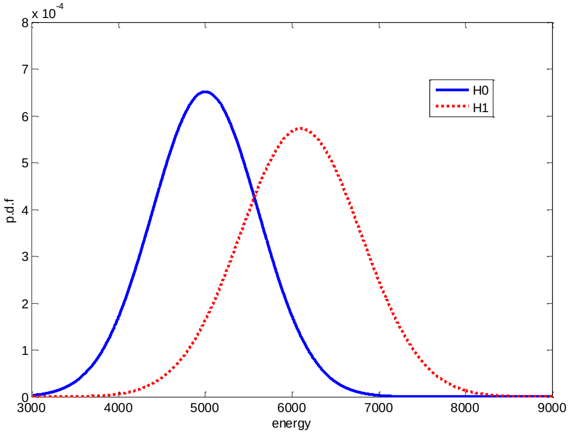
- Basic principle
  - The output SNR can be enhanced when proper noise is added into the *nonlinear* system;
  - In the field of signal detection, the SR effect has been studied to improve the signal detectability
- System model

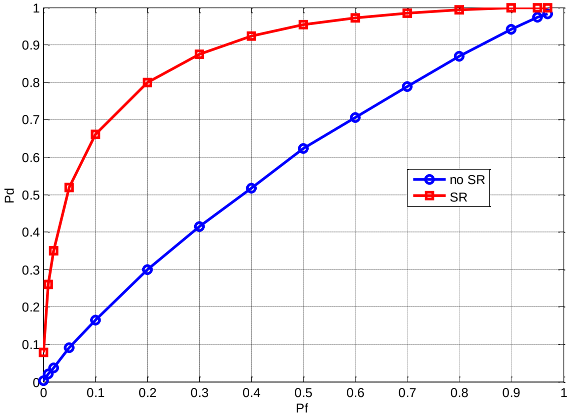

SR noise n
$x(t)$
A/D
$x(k)$
$y(k)$
Nonlinear system/ nonlinear detector
detection
SR detector

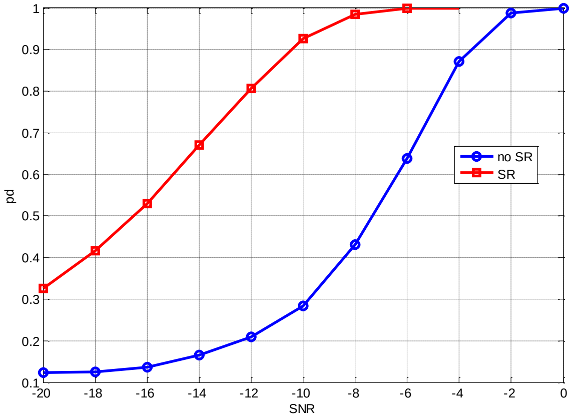
Stochastic Resonance Based Sensing: Local Sensing

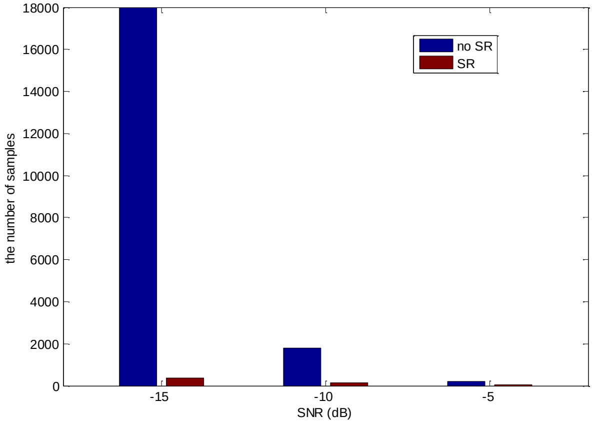
- Results











Sensing performance can be significantly improved!

Opportunities Utilization: A Cross layer based method

- **Challenges of Opportunities utilization**
  - It possible to sense several channels;
  - Transmission rate and collision determines the throughput;
  - The time-varying nature of the radio and network environment poses a complicated task for adaptive access and transmission techniques

The solution to above problems asks for cross-layer design between physical layer and upper layer.

Outlines

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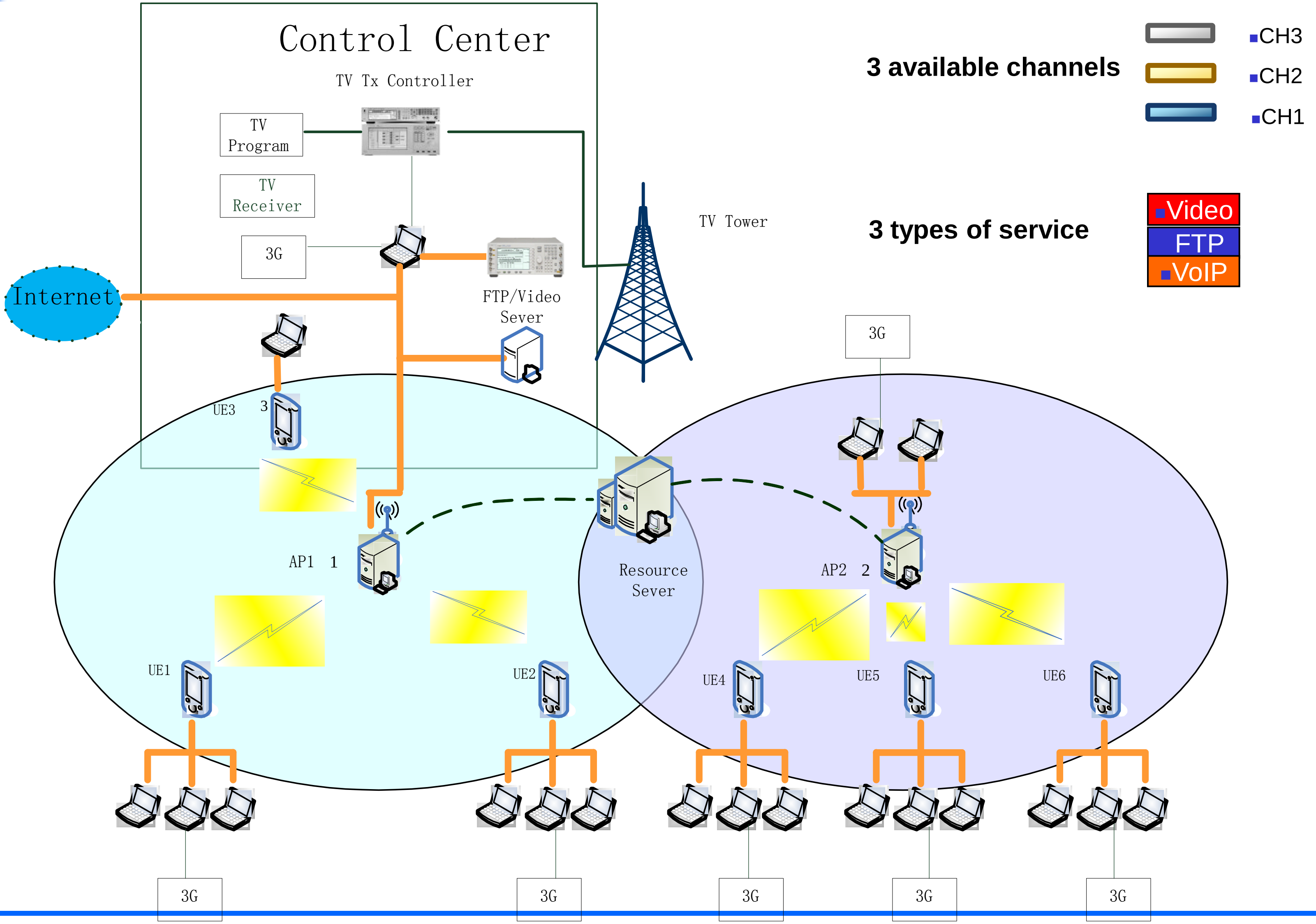
☞ ***Dynamic Spectrum Sharing Network (DySNet): A developing prototype***

DysNet: a developing prototype


Control Center
TV Tx Controller
TV Program
TV Receiver
3G
Internet
FTP/Video Sever
TV Tower
UE3
3
AP1
1
Resource Sever
AP2
2
3G
UE1
UE2
UE4
UE5
UE6
3G
3G
3G
3G
3G

3 available channels

- CH3
- CH2
- CH1

3 types of service

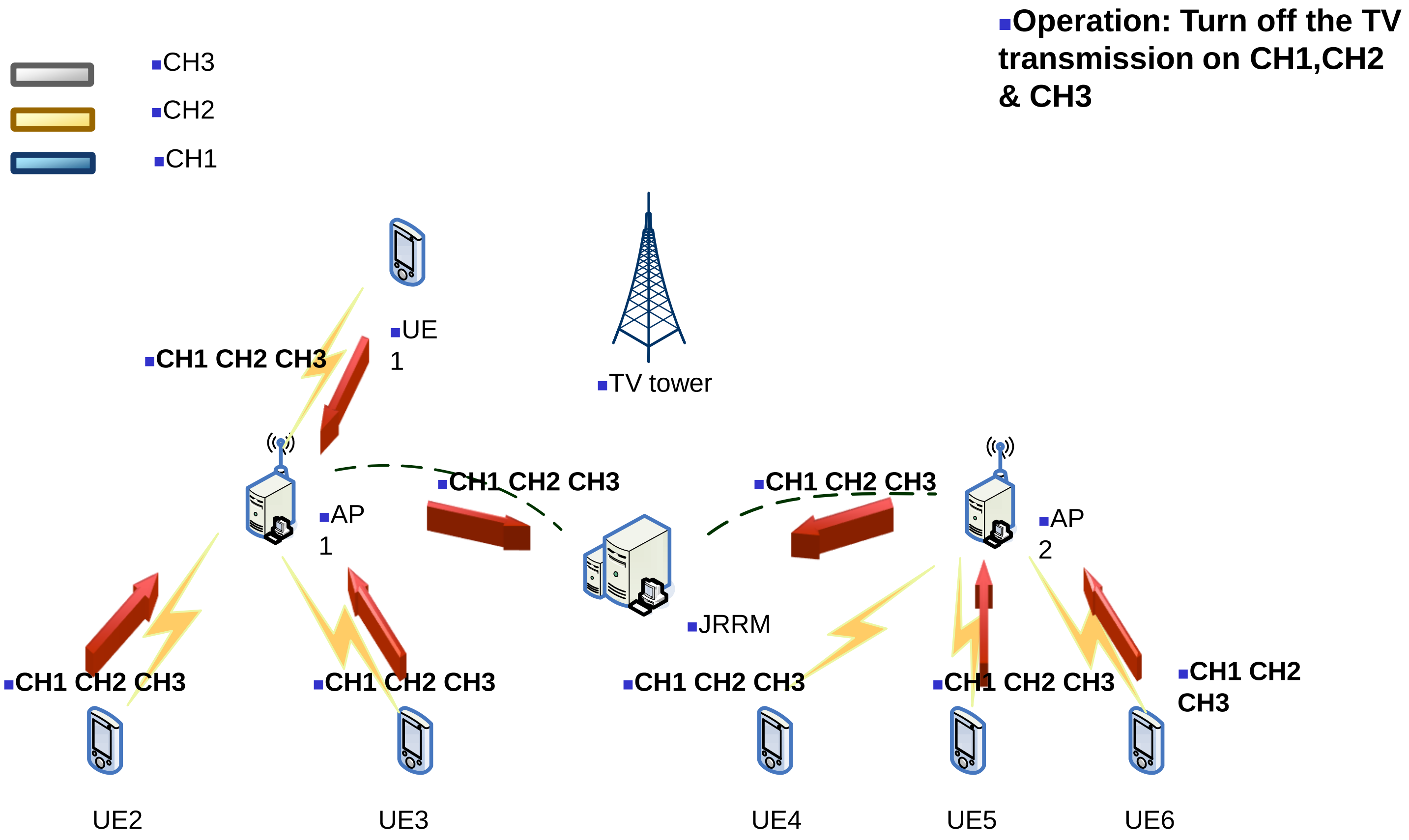
- Video
- FTP
- VoIP

DysNet: a developing prototype

VIRTEX-5
DSP
DSP
CompactPCI

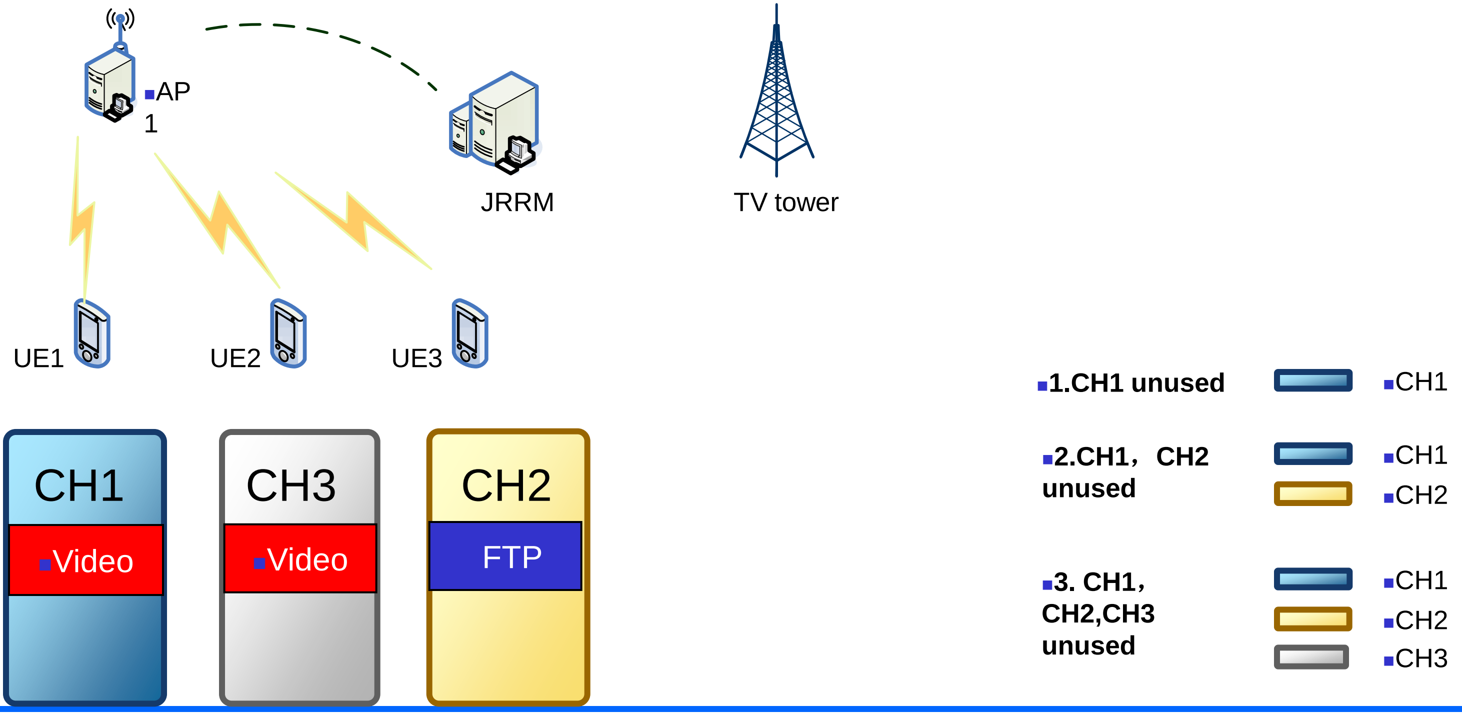
DysNet: Spectrum Sensing

- Turn off the TV transmission, and demo the single/cooperative sensing


Operation: Turn off the TV transmission on CH1,CH2 & CH3
CH3
CH2
CH1
UE 1
CH1 CH2 CH3
TV tower
AP 1
CH1 CH2 CH3
CH1 CH2 CH3
AP 2
JRRM
CH1 CH2 CH3
CH1 CH2 CH3
CH1 CH2 CH3
CH1 CH2 CH3
CH1 CH2 CH3
UE2
UE3
UE4
UE5
UE6

DysNet: Dynamic Access

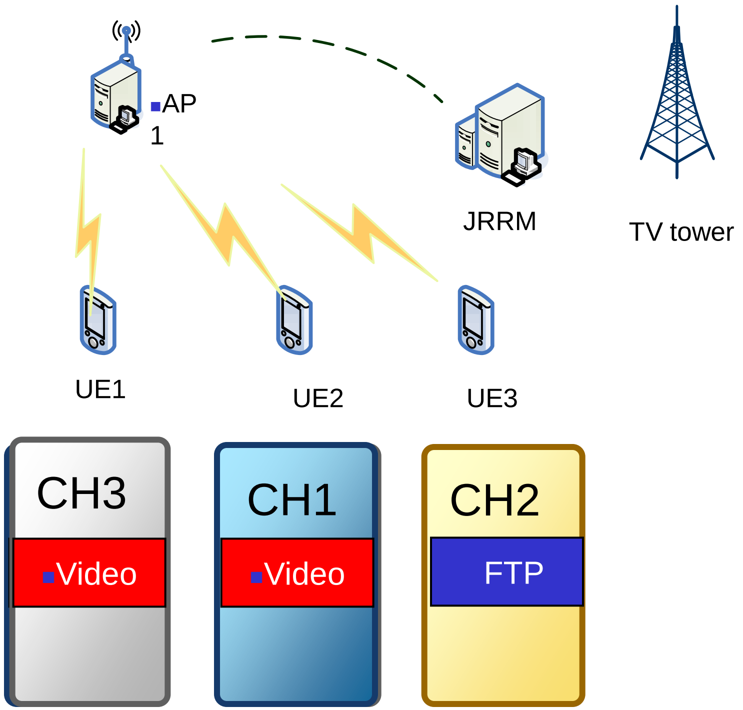
- Dynamically Provides services to CRUs as the TV transmission are turned off
  - Step 1: 1 unused TV channel;
  - Step 2: increase the no. of unused channel to be 2;
  - Step3: turn off TV transmission on all 3 channels
  - As the no. of CRUs increases, the peak data rate increases



AP 1
JRRM
TV tower
UE1
UE2
UE3
CH1
Video
CH3
Video
CH2
FTP
1.CH1 unused
CH1
2.CH1，CH2 unused
CH1
CH2
3. CH1，CH2,CH3 unused
CH1
CH2
CH3

DysNet: Resource Management

- Provide Prioritized service to CRUs
  - Turn off low priority users' transmission to provide service for high priority users
  - Resume service for low priority users when interference disappears


AP
1
JRRM
TV tower
UE1
UE2
UE3
CH3
Video
CH1
Video
CH2
FTP

- **Priority: UE2>UE3>UE1**
- **Channel: CH1，CH2，CH3**

- **Strong Interference at CH3** ▭ CH3
- **Interference disappear** ▭ CH3

Summary

- New services demand more & more spectrum resources;
- Spectrum is a scare resource;
- Technical Challenges to make the cognitive wireless network work:
  - Spectrum sensing—fast and reliably sense the radio environment;
  - Spectrum utilization—efficiently use the available resource

Thanks！