CWN

# The Progress of National 973 Project "Cognitive Wireless Networks"

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**Beijing University of Posts and Telecommunications**

# CONTENTS

- Introduction of 973 Project
- CWN Research Background
- The key issues in Cognitive Wireless Networks
- Applications scenarios
- What we have done

# Project Information

National Basic Research Program of China
(973 Program):
Title: Research on Basic Theory and Key Technologies of Cognitive Wireless Network (2009CB320400)
Executive Time: 2009-2013
Chief Scientist: Ping Zhang
Funding: about 30million Yuan
Number of Partners: Eight

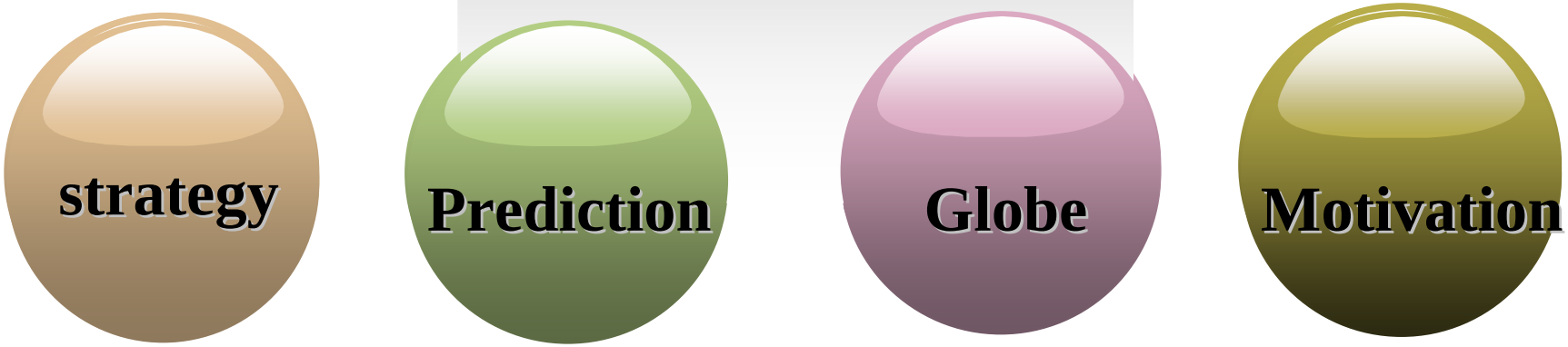
# 973 Project Introduction

The National Basic Research Program---"973" Project, which has features like strategy, prediction, globe and motivation, is created on the basis of existing research activities and deployments to organize and implement basic research to meet the national major strategic needs as well as to further reinforce basic research and scientific technology work.

**development and progress of scientific technology**

National Key Basic Research and Development Plans

（973 Project）



# Objectives for 973 project


Strengthening the original innovations and to address the important scientific issues concerning the national economy and social development

Improving China's capabilities of independent innovations and to providing scientific support for the future development of the country

# Tasks for 973 project

- Conducting multidisciplinary comprehensive research and providing theoretic and scientific foundations for important scientific issues
- Deploying relevant, important and explorative forefront basic researches
- Training outstanding person with high scientific qualification and creative capability
- Building a group of high-level scientific and technological research centers

**973 Project Main Tasks**

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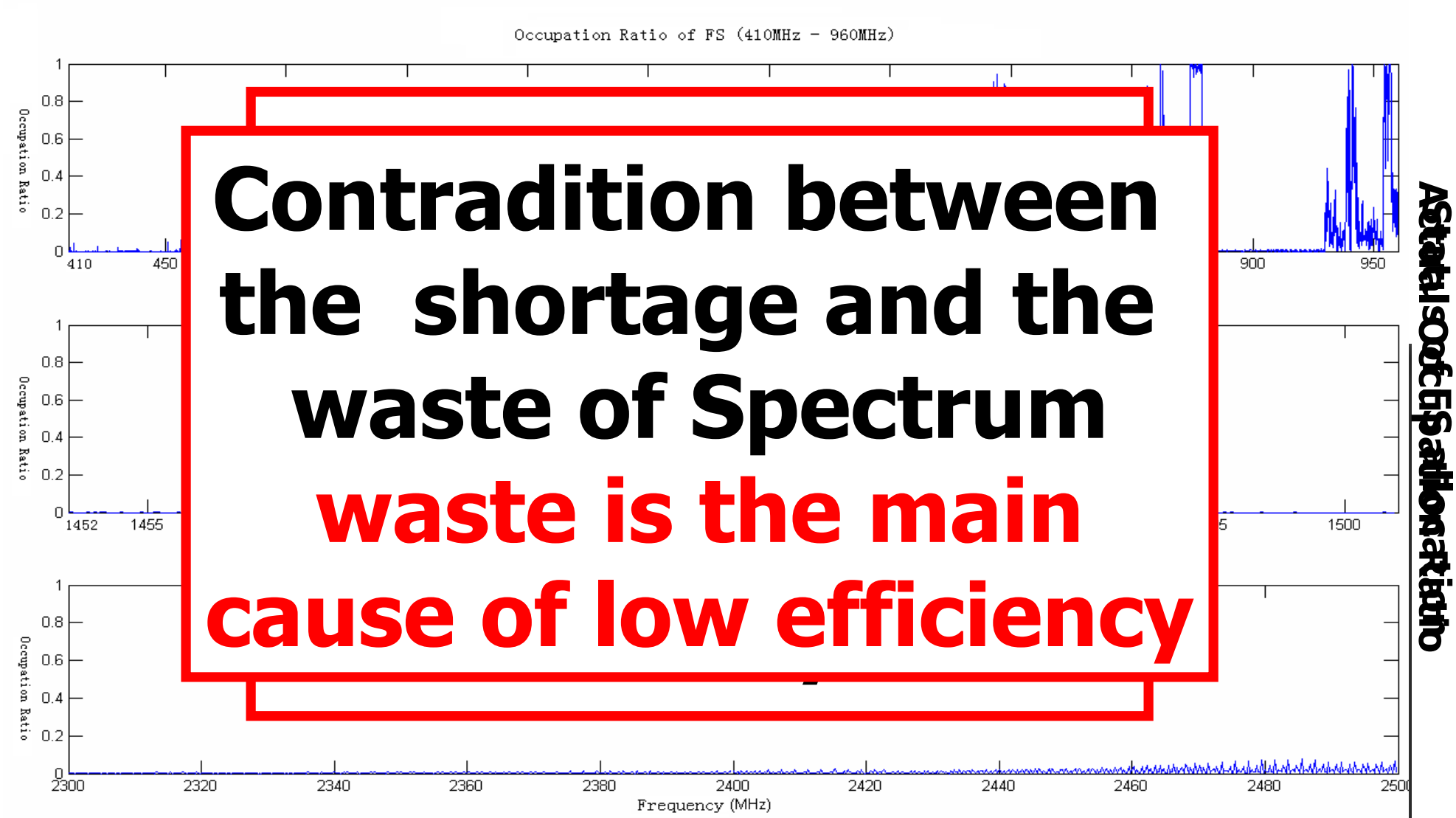
# Motivation 1: Requirement of Spectrum

Field test of Spectrum Occupation (Time: from 8 p.m., Mar 16, 2008 to 8 p.m., Mar. 17, 2008. Scenario: typical urban area, Location: BUPT Campus)




**Contradition between the shortage and the waste of Spectrum**

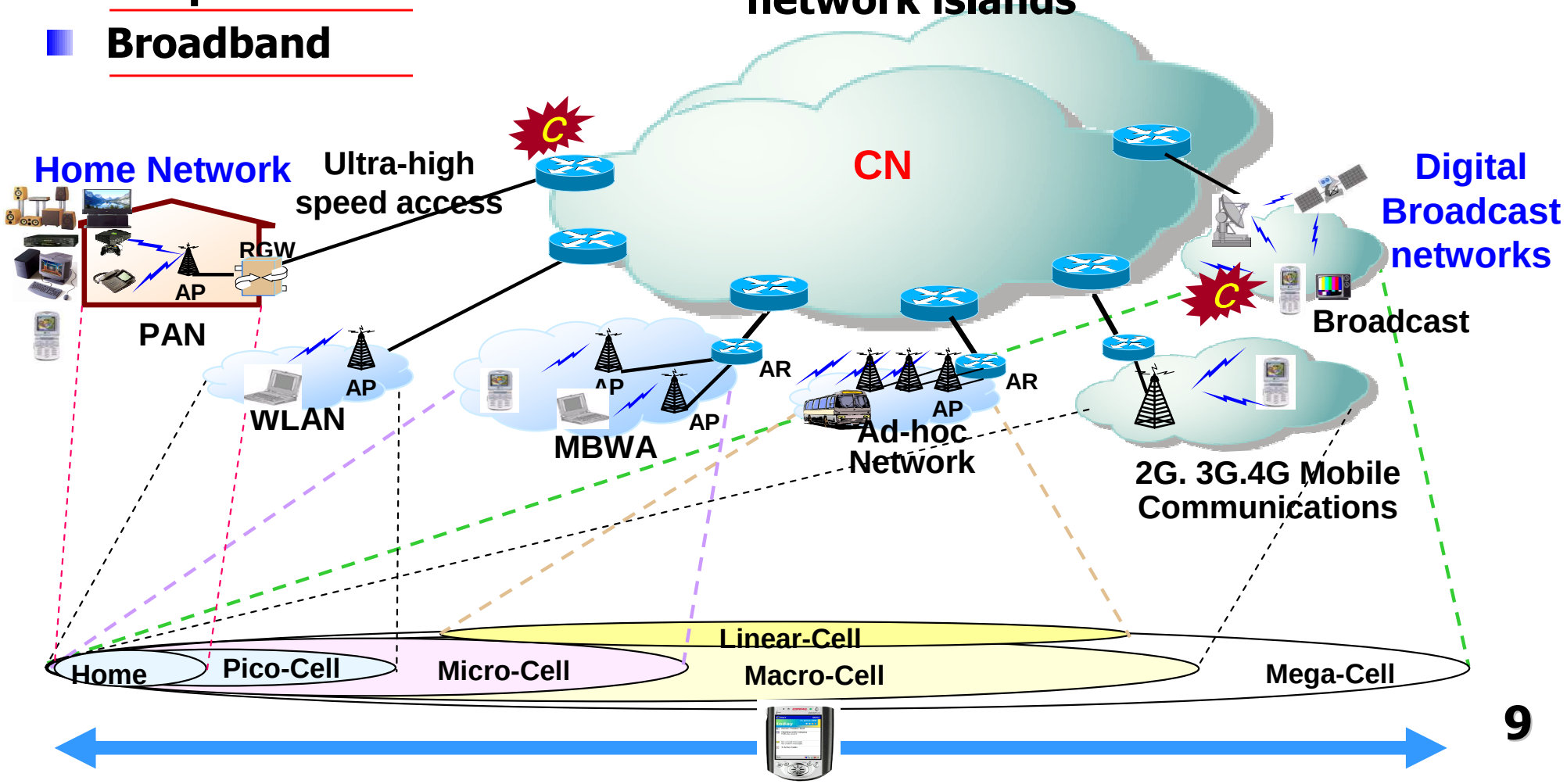
**waste is the main cause of low efficiency**

# Motivation 2: Heterogeneity

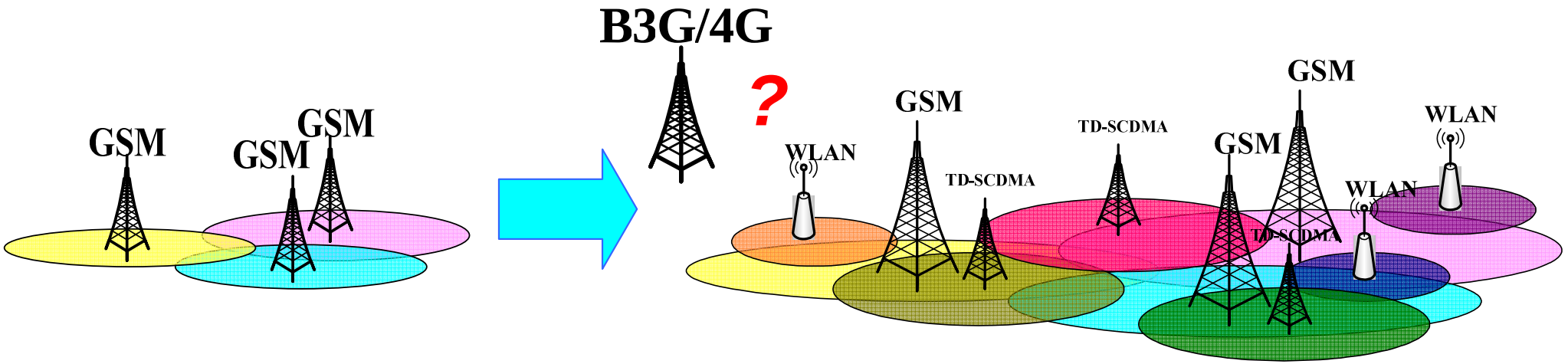
**Radio Networks Developing Trend:**

- **Heterogeneous**
- **Ubiquitous**
- **Broadband**

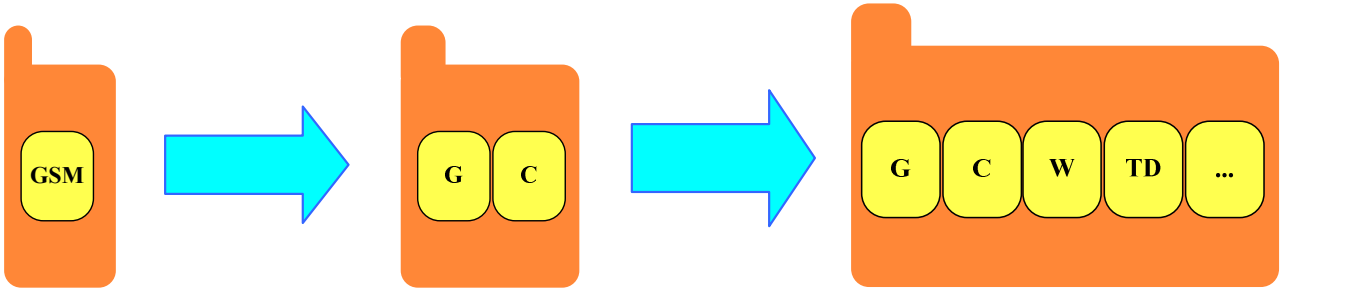
**Heterogeneity: distinct architectures, models and schemes of different networks, in accordance with different goal and requirement, lead to various "network islands"**



# Problems caused by Heterogenerous Wireless Networks




**Too many antennas, BSs, causing resource waste and compatibility difficulties**




Single-Mode Dual-Mode Multi-mode ?

# Current Status of Wireless NW

- Coexistence of various RATs and the scarcity of Spectrum resource is holding back wireless mobile communications from evolving towards wide-band and ubiquity. Hence, there's an urgent demand for innovation of wireless networks technologies, aiming at dynamic and efficient use of FS, and solve the issues on heterogeneous wireless networks.
- Recently, many countries are devoting their intellectual and financial resources to working on the two aspects.

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# Analysis of the Essential Problem

**Problems**

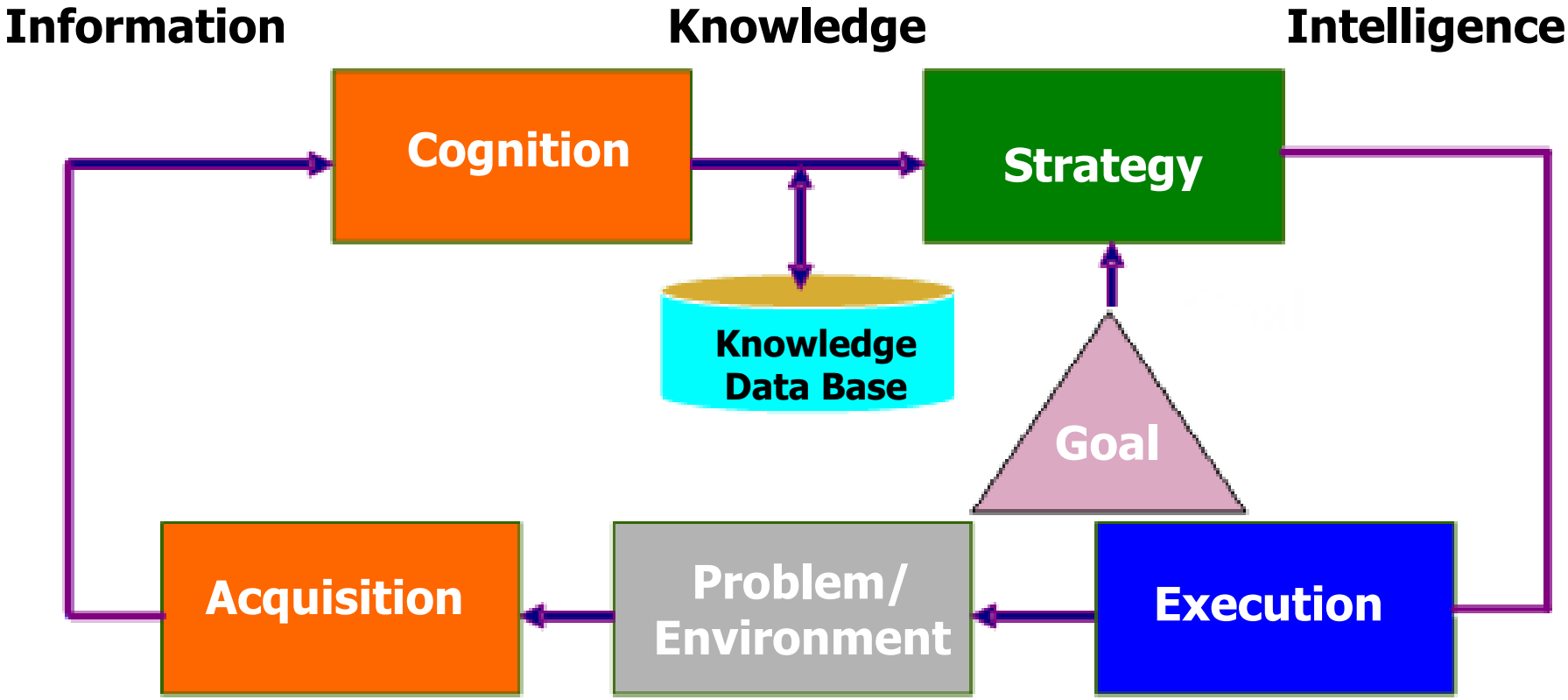
Scarcity and Waste of Spectrum

Failure of Wireless NWs to [illegible]nverge

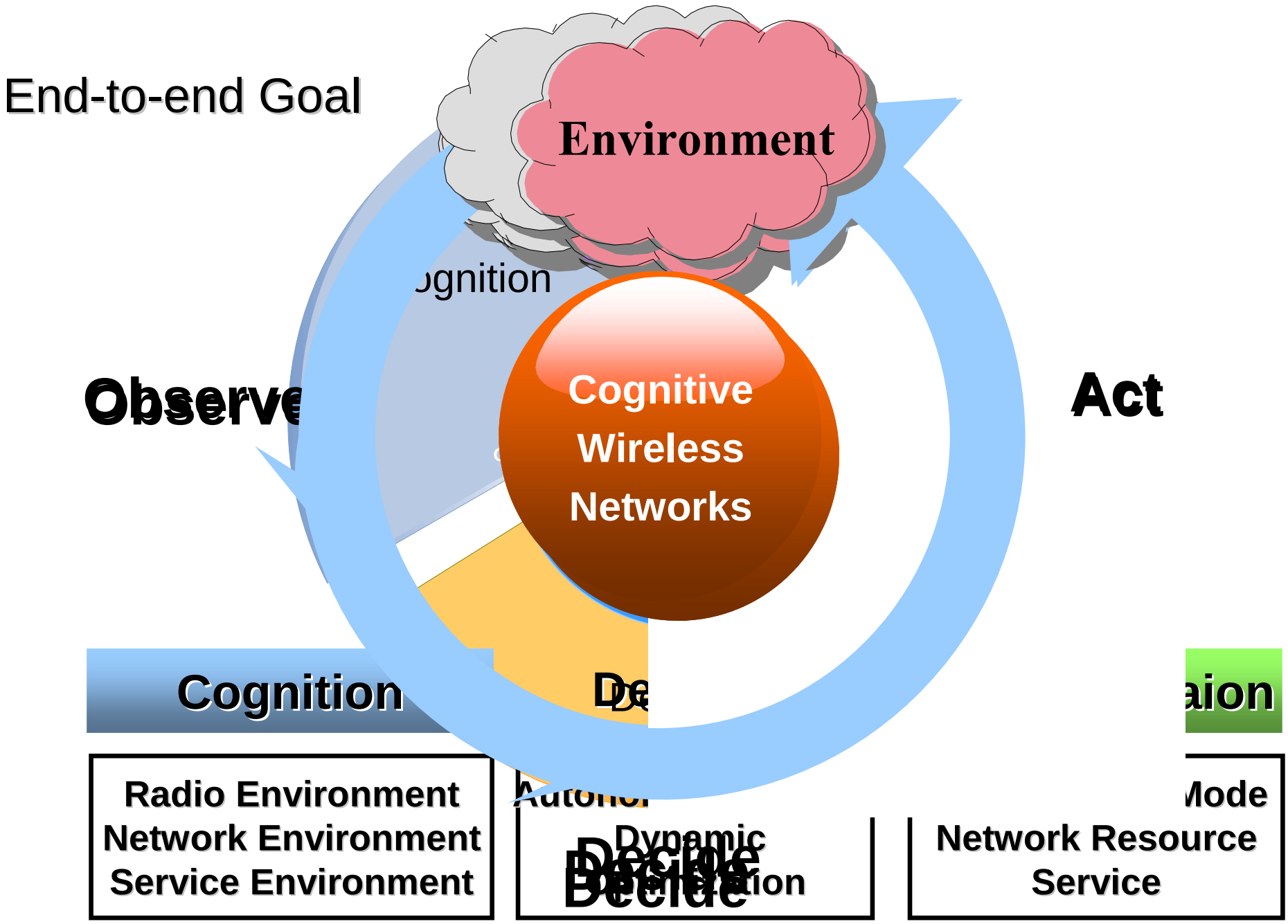

**How can wireless NW Adapt to complex dynamic environment**

# Introduction of Cognition Theory

- Cognition theory offer a decent manner to solve these problems, as well as a theoretical support.

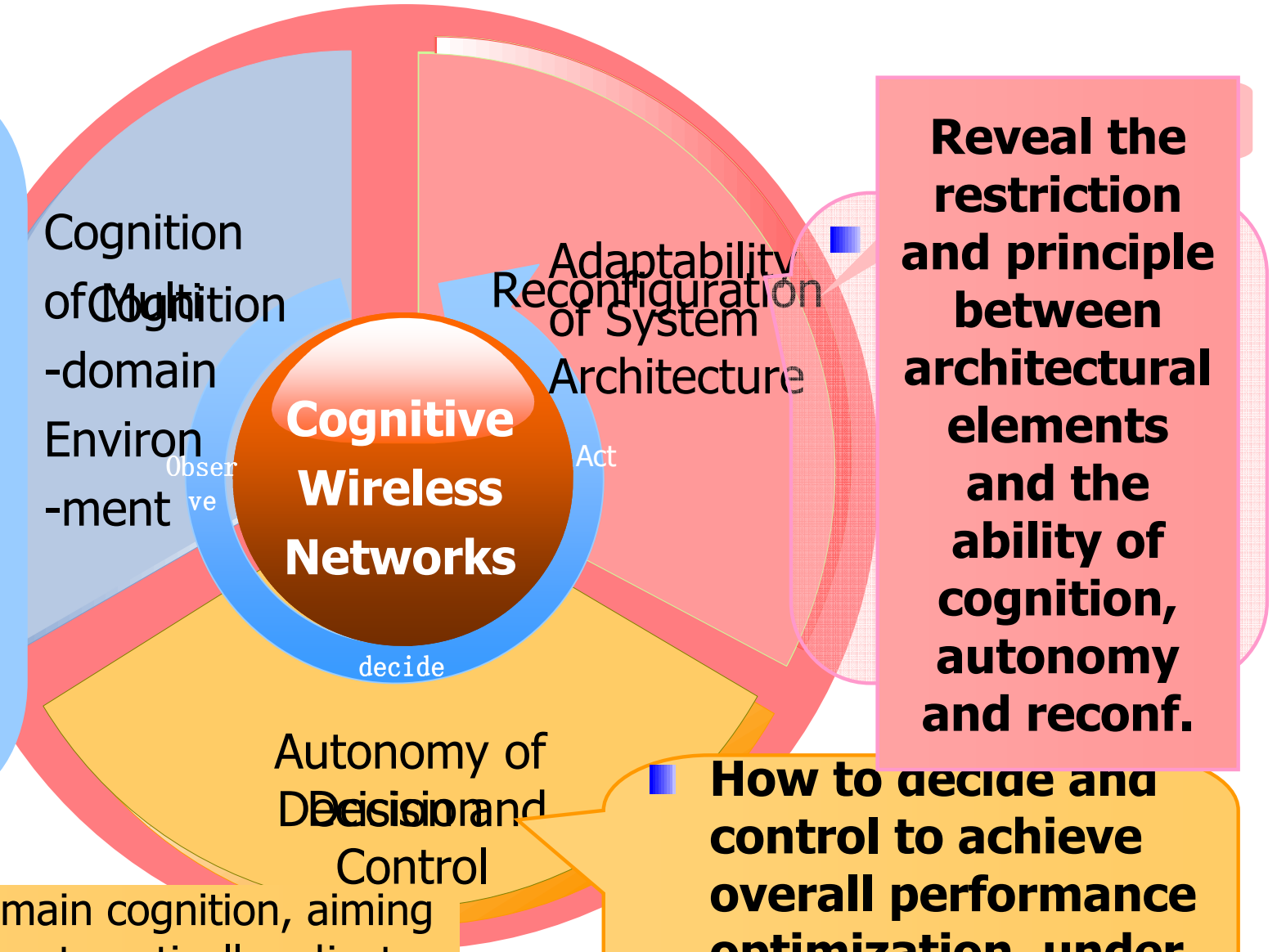


# What is Cognitive Wireless Networks (CWN)



# Scientific Issues in CWN

- How to acquire, express, communicate and utilize the cognitive info. among multi-domain including radio, networks and users environments?




- **Reveal the restriction and principle between architectural elements and the ability of cognition, autonomy and reconf.**

- **How to decide and control to achieve overall performance optimization, under complex dynamic environment?**

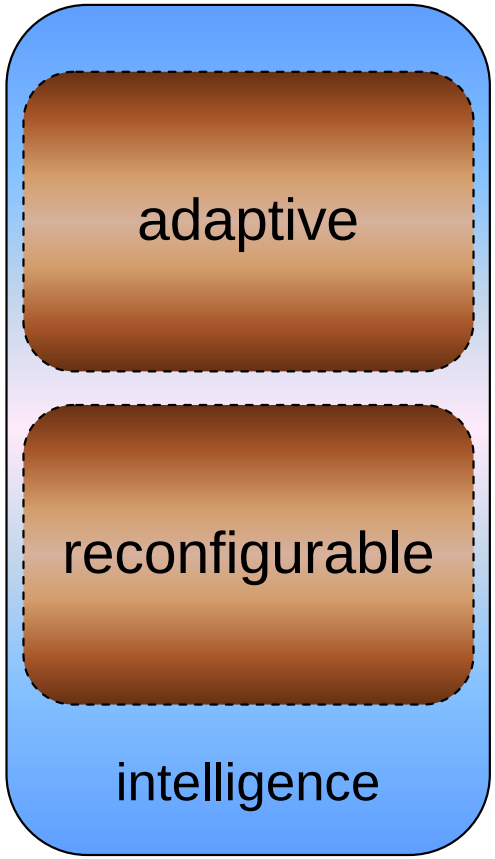
According to multi-domain cognition, aiming at end-to-end goal, automatically adjust elements in NW in order to adapt to complex dynamic environment

# Two Definitions

- Joseph Mitola proposed the concept of "cognitive radio" for the first time in 1999: Radios that change the parameters of transmitters based on its interaction with environments。
- Our definitions for Cognitive Wireless Networks: wireless networks that change network features based on its interaction with multi-domain environments。

  Our definitions suggest wireless networks with cognitive functions (intelligence)； Optimizing aims at global optimization of end-to-end purpose； Cognizing is active and in multi-domain； Network components can be reconfigurable。To solve problems of spectrum utilization efficiency and convergence of heterogeneous networks

# Cognitive Wireless Networks




Cognitive (adaptive, reconfigurable) networks

- Cognitive networks are capable of continuously adapting to changing environmental conditions and/or user needs.
- Adaptation is mainly realized by means of self-management, or in other words in accordance with autonomic computing principles, and typically involves machine learning.
- Reconfiguration of the systems' own infrastructure may affect more than just the traditional networking layers of the protocol stack, i.e., the middleware, presentation and application layers in addition to the physical (PHY), MAC (Medium Access Control), LLC (Logical Link Control), network, and transport layers.


# Cognitive Wireless Networks

- Cognitive wireless networks do not presume the fixed deployment of technologies in terminals and network segments; rather, they have embedded intelligence that enables them to learn, from previous interactions with the environment, and, based on those interactions, adapt their functionality according to different external stimuli.

- Cognitive wireless networks have been proposed for the realization of the B3G vision, with reduced CAPEX. This is achieved through their inherent ability to adapt to varying requirements (e.g., change RATs and spectrum at the PHY/MAC layers).
- Change RATs——Have **cooperative** networks to operate different RATs
- Change spectrum——spectrum **sensing** and **allocating**


# The key issues in Cognitive Wireless Networks

- Cognition
  - **Spectrum Sensing**
  - **Cognition of wireless environment, network environment and service environment (Multi-domain)**
  - **How to process and use acquired information**
  - **Cognitive enablers**
- Intelligent adaptation
  - **Dynamic spectrum management, Spectrum sharing, Spectrum Mobility**
  - **Joint Radio Resource Management**
  - **Power Control**
  - **Self-x (Self-configuration, Self-healing, Self-optimization, Self-protection) of wireless network**
- Reconfiguration
  - **The capabilities of reconfigurable Networks**
  - **Reconfigurable Protocols**
  - **Software Download**
  - **Reconfiguration of transmission mode**
- Others
  - **System architecture of Cognitive Wireless networks**
  - **Protocol**
  - **Cross-layer Design**

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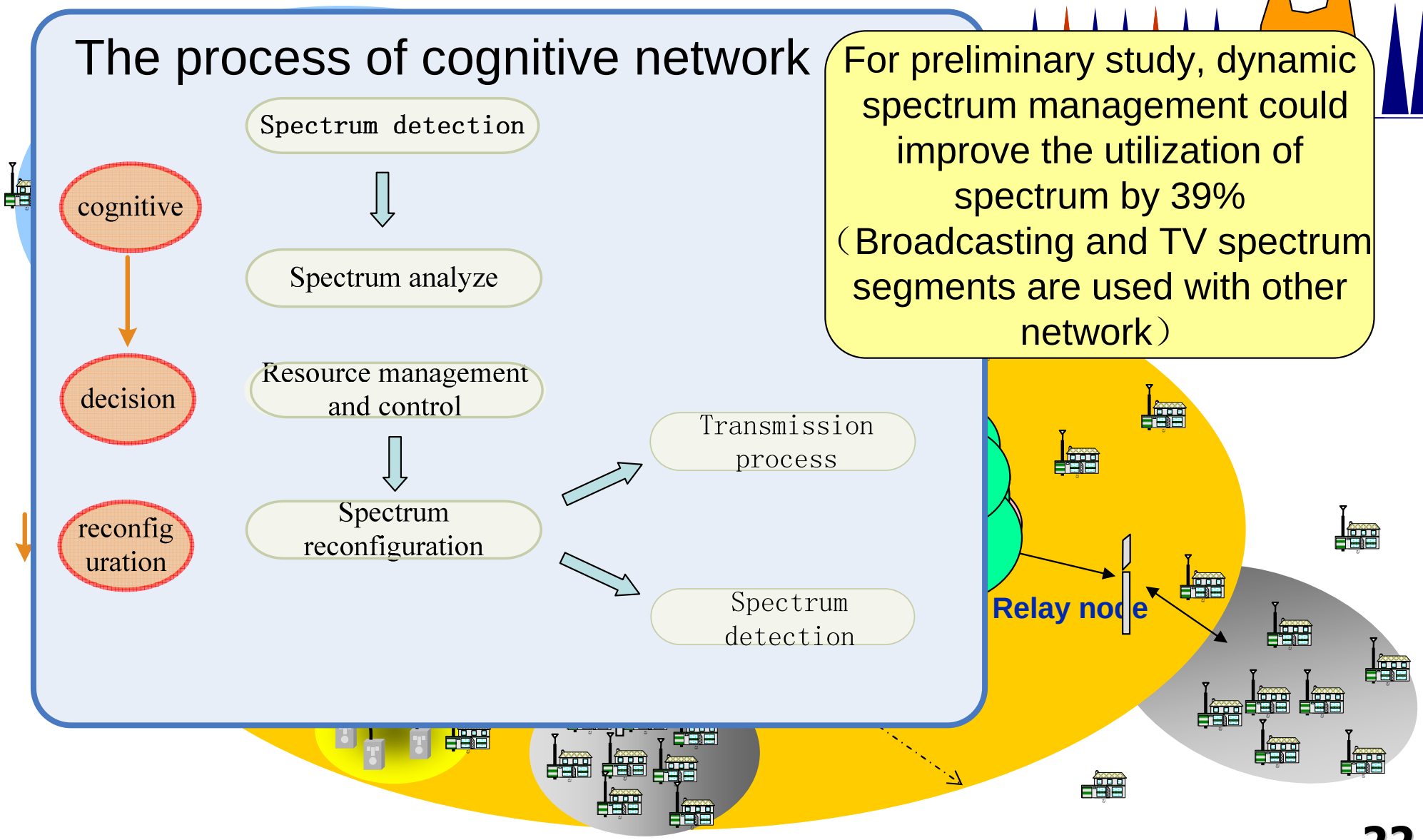
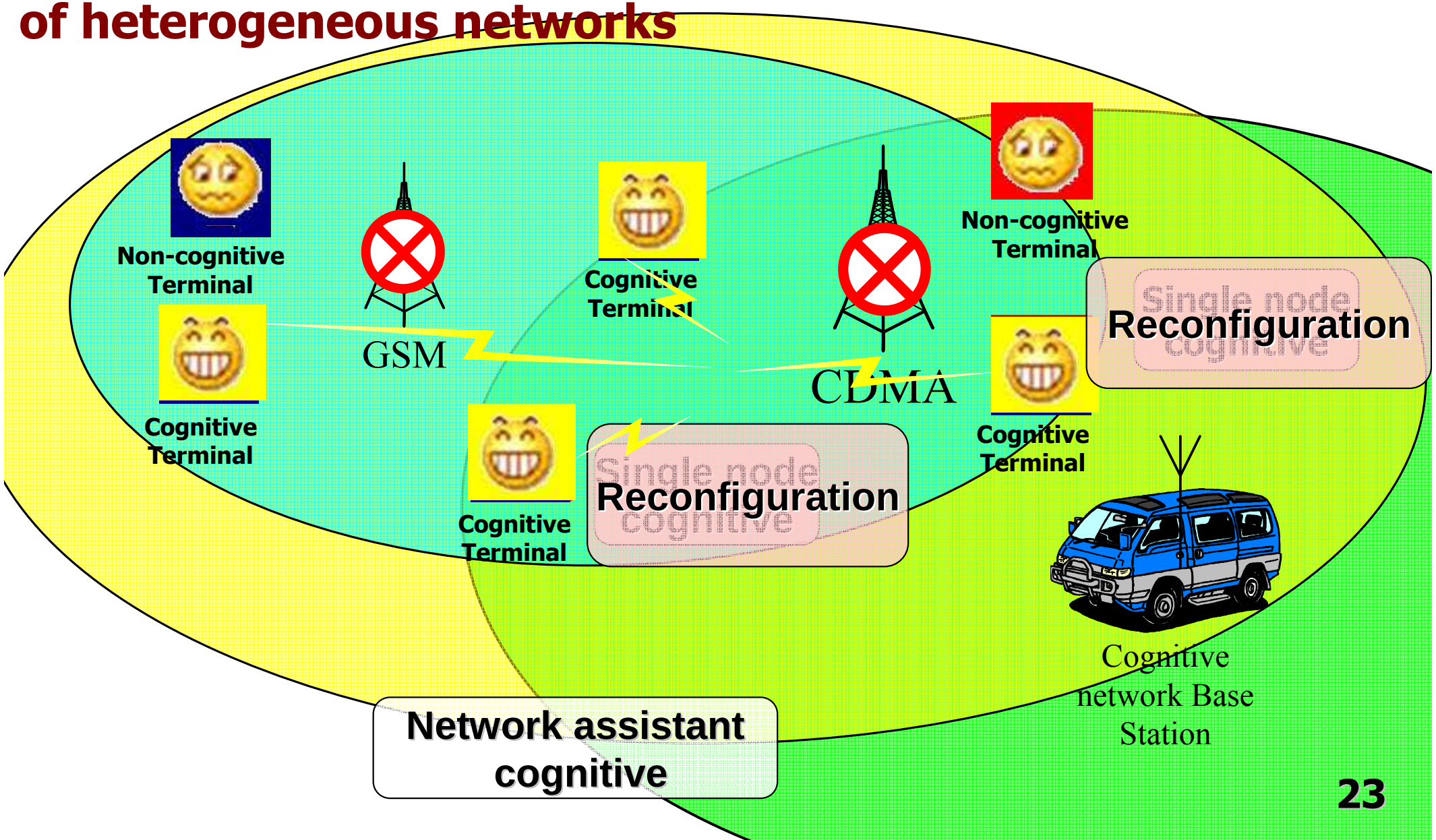
# Application Scenarios（1）

## Application Scene1——The effective using of spectrum



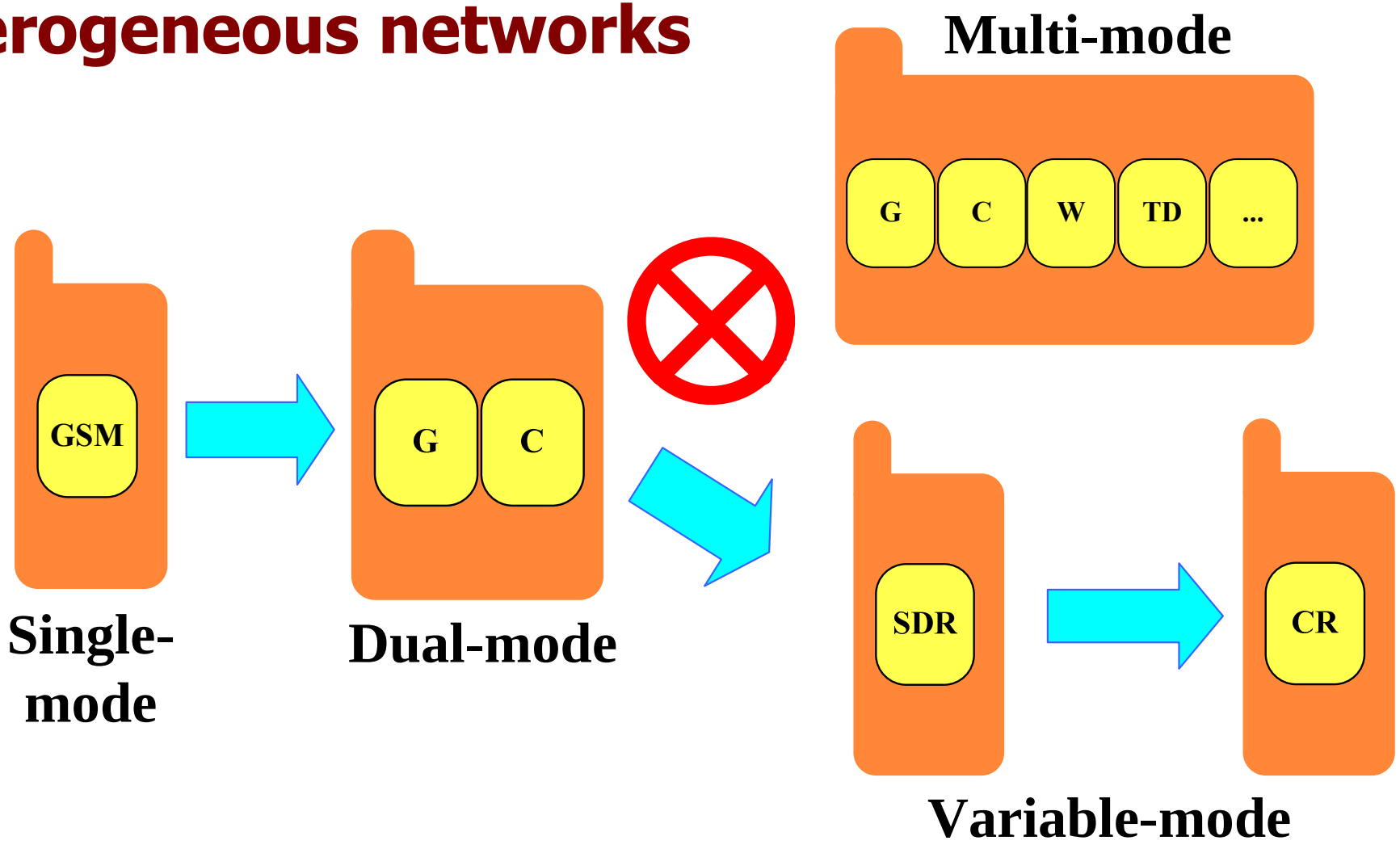
# Application Scenarios（2）

## Emergency Communication-Resolving the issue of island of heterogeneous networks



# Application Scenarios（3）

## The integration terminals in the heterogeneous networks



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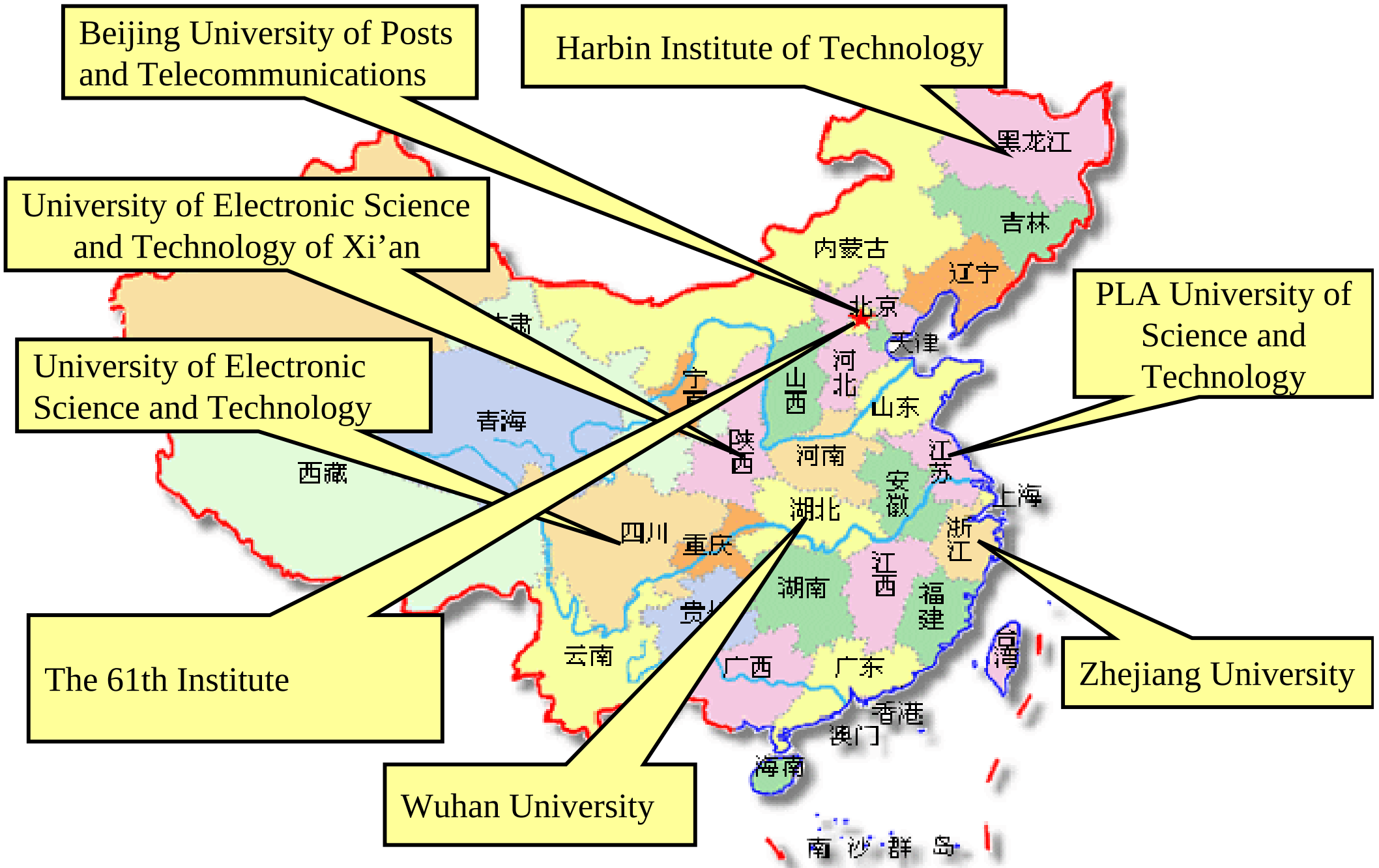
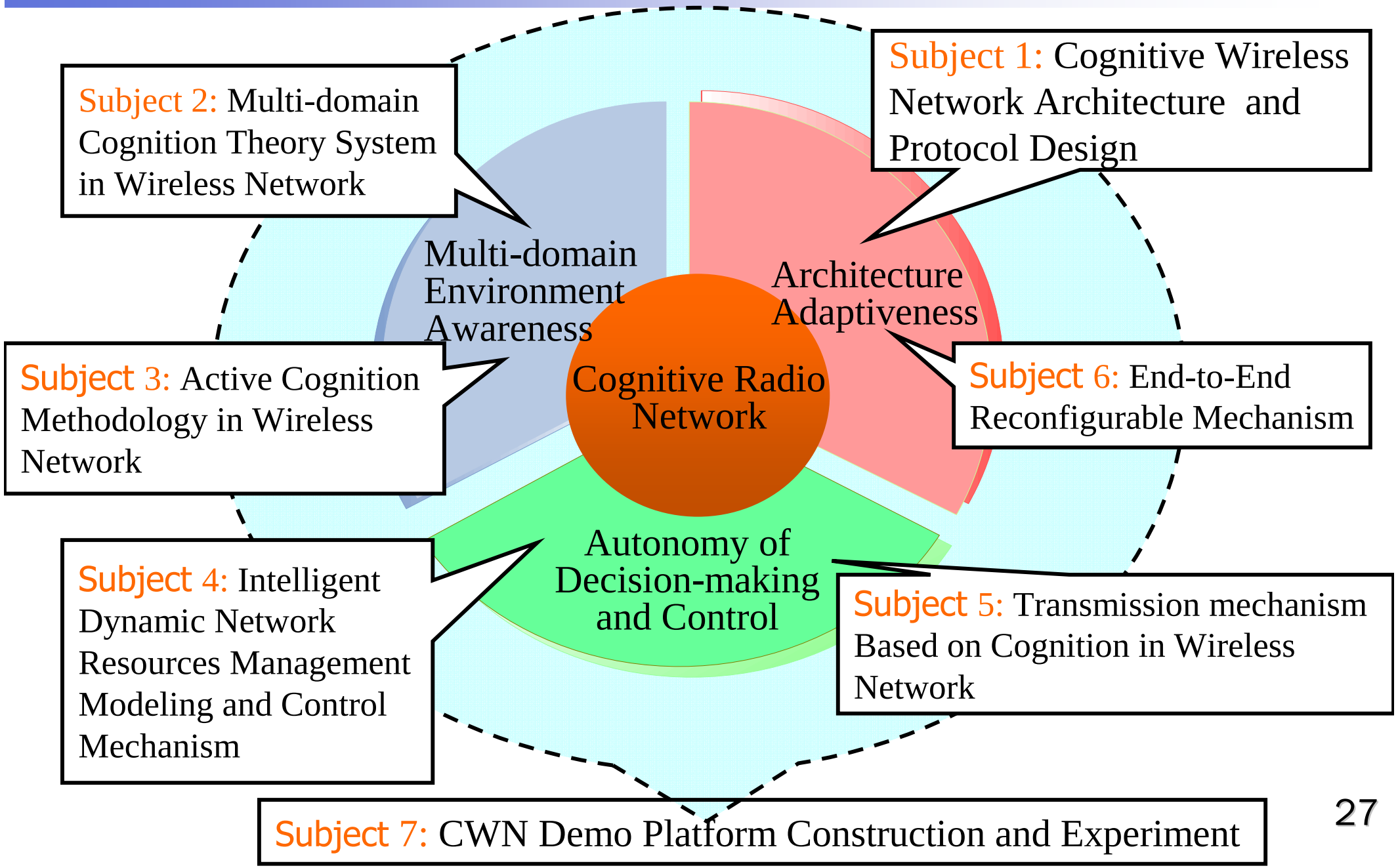
# The Project Partners



# Research Contents



# Subject 1 of 973 Project

**Task Name**

Cognitive Wireless Network Architecture and Protocol Design

**Research Topics**

- Multi-plane CWN Architecture Design
- Design of Prototyping Protocols with Cognition, Adaption and Reconfigurability
- CWN Performance Optimization
- Cognitive Service System Satisfing End-to-end Efficiency

**Members**

Subject Leader: Professor Jiaru Lin

- Beijing University of Posts and Telecommunications
- Wuhan University

# Subject 2 of 973 Project

**Task Name**

Multi-domain Cognition Theory System in Wireless Network

**Research Topics**

- Multi-domain Cognition Architecture and Models
- Spectrum Cognition Theories and Methods
- Multi-domain Local Cognition Theories and Methods
- Multi-domain Cooperative Cognition Theories and Methods

**Members**

Subject Leader: Professor Desheng Zhu

- PLA University of Science and Technology
- Harbin Institute of Technology

# Subject 3 of 973 Project

**Task Name**

Active Cognition Methodology in Wireless Network

**Research Topics**

- Multi-domain Active Cognition Models in CWN
- Active Learning and Deducting Theories and Methods
- Knowledge Sharing and Reusage in CWN
- Cognitive Strategies Studies in Dynamic Environments

**Members**

- Subject Leader: Dr. Quan Yu
- The 61th Institure of the Headquarters of the General Staff of PLA
- PLA Institute of Technology

# Subject 4 of 973 Project

**Task Name**

Intelligent Dynamic Network Resources Management Modeling and Control Mechanism

**Research Topics**

- Theories and Methods of Vector Resources Allocation
- Resource Mobility Controlling Theories and Methods
- Adaptive Deciding Models and Schemes of Dynamic Resource Management
- Joint Management of Inter-network Resources

**Members**

Subject Leader: Professor Jiandong Li

- University of Electronic Science and Technology of Xi'an
- The 61th Institure of the Headquarters of the General Staff of PLA

# Subject 5 of 973 Project

**Task Name**

Transmission Mechanism Based on Cognition in Wireless Network

**Research Topics**

- Transmission Capacity Analysis in CWN
- CWN Transmission Mechanisms Approximating Capacity
- Auto-management and Adaptive Schemes in CWN Transmission

**Members**

Subject Leader: Professor Wei Guo

- University of Electronic Science and Technology of China
- Zhejiang University

# Subject 6 of 973 Project

**Task Name**

End-to-End Reconfiguration Mechanisms

**Research Topics**

- Modeling and Construction of End-to-end Reconfiguration Administrating Framework
- Fine-grained Decomposition and Function Re-composition of Network Behaviors
- Feasibility and Approaches of Network and Protocols Reconfiguration
- Evaluation of Efficiency and Security of Reconfiguration

**Members**

Subject Leader: Professor Zhiyong Feng

- Beijing University of Posts and Telecommunications

# Subject 7 of 973 Project

**Task Name**

Cognitive Wireless Network Prototyping Platform Construction and Tests

**Research Topics**

- Construction of Multi-plane Adaptive CWN Architecture
- Evaluation of the Principles and Schemes of the Multi-domain Cognition
- Evaluation and Demonstration of Key Technologies within CWN
- Evaluation of the End-to-end Efficiency of CWN

**Members**

Subject Leader: Professor Ping Zhang

- Beijing University of Posts and Telecommunications

# What we have done -other topics

**Cognitive Pilot Channel**

- Design of an in-band/out-band CPC scheme
- Design of a CPC based network selection scheme

**Self-configuration of Wireless Networks**

- Plug-and-play technology used in base station equipments
- Research of working state and channel selection scheme of multi-mode access point

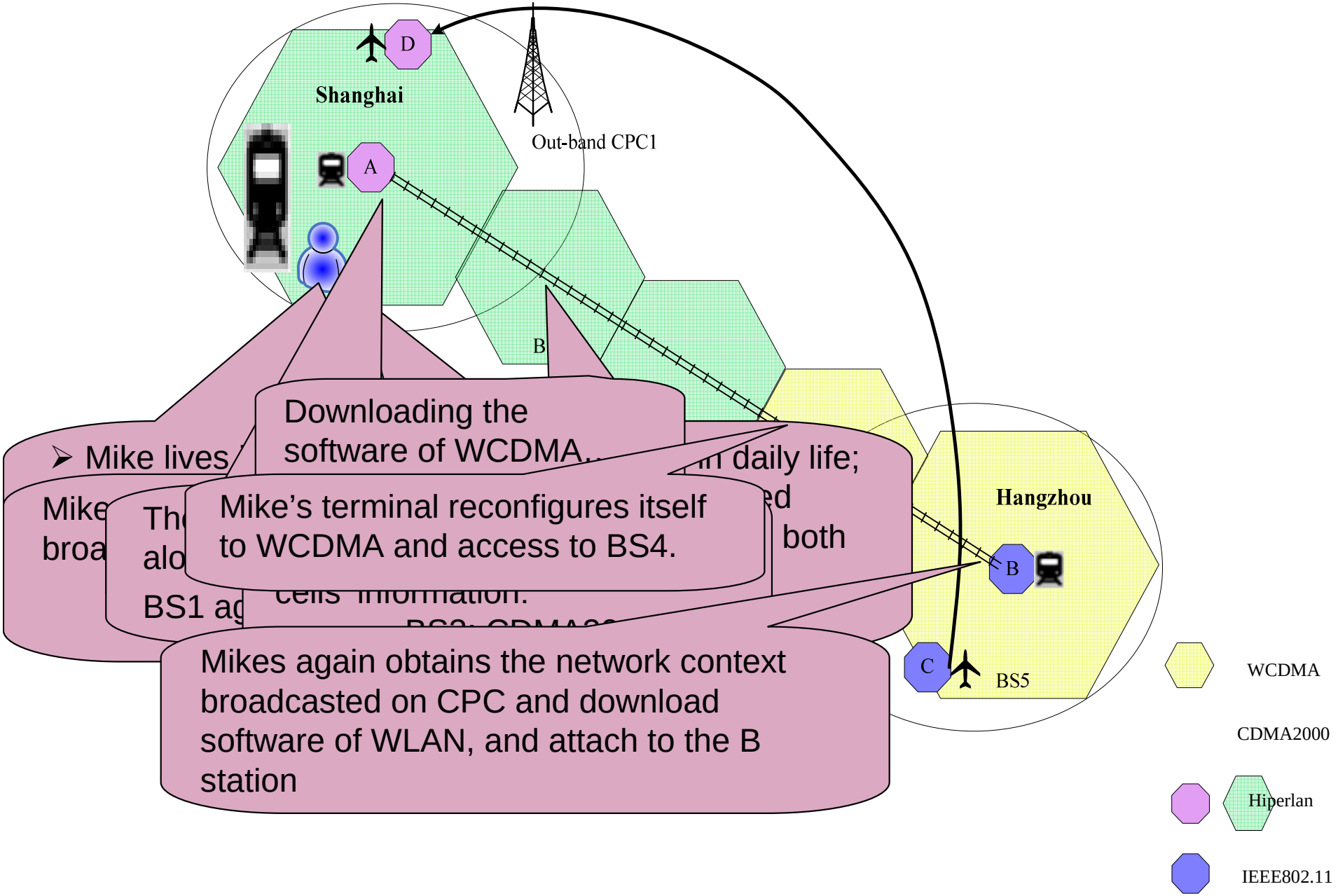
**Reconfigurable Protocols**

- Component-based Protocol Stack Management for Reconfigurable System
- Evaluation mechanism for Protocol Components for Reconfigurable System

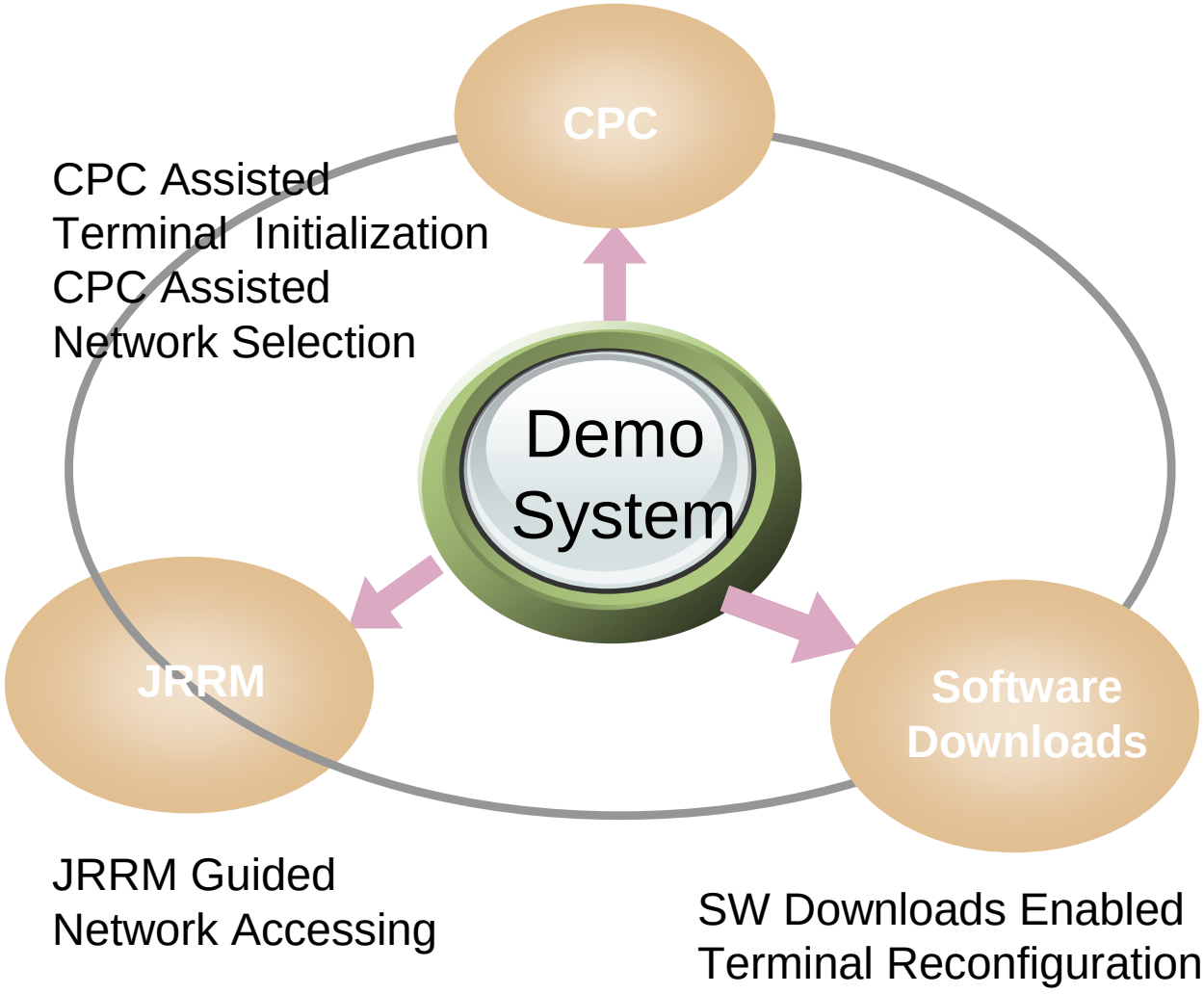
# CPC Structure Approach

- The goal of CPC:
  - To support an efficient discovery of the available radio accesses and reconfiguration management in a heterogeneous wireless environment between network and user terminals
- CPC is anticipated to be a combination of two components:
  - Out-band CPC and the In-band CPC
    - Out-band is a Physical channel outside the component radio access technologies
    - In-band refers to logical channel within the component radio access technologies
- As radio enabler, CPC is also anticipated to have both downlink and uplink components

# Background of CPC



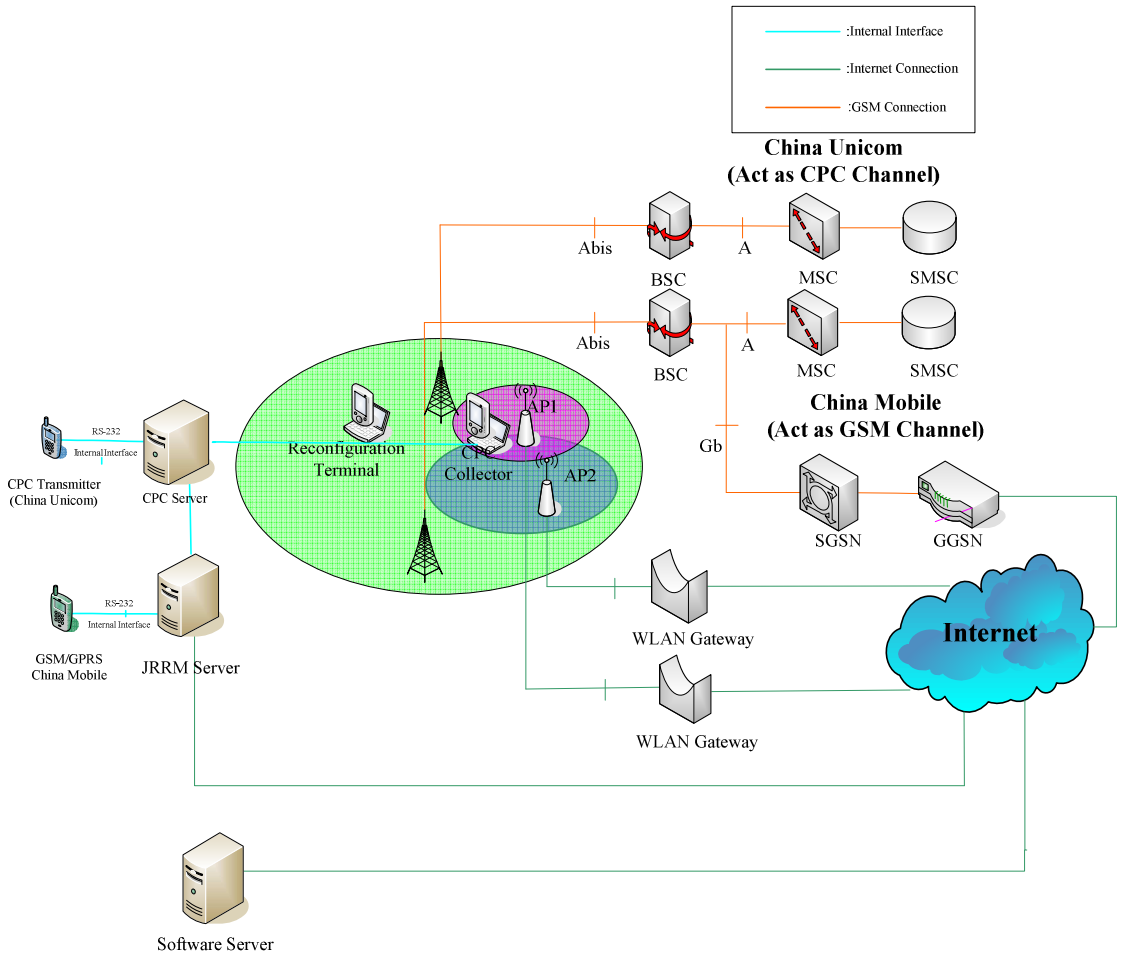
# Demo System from BUPT




**Goal**

- **Demonstrating the complete end to end reconfiguration process in future communication system**
- **Evaluating the CPC performance**

# Overview of Demo System




## Key Conception

- CPC Server
- JRRM Server
- Software Server
- Reconfiguration Terminal

## Traffic Channel

- GSM
- 802.11 b
- 802.11 g
- CDMA

## CPC Channel

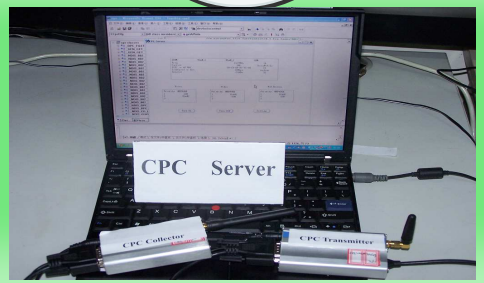
- Out-band CPC

# System Components

1

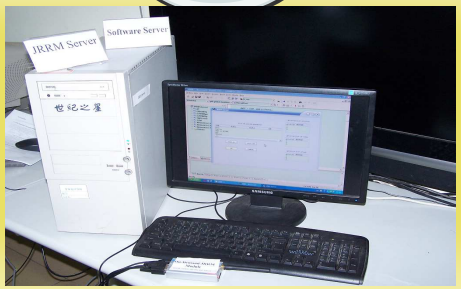
Overview

2



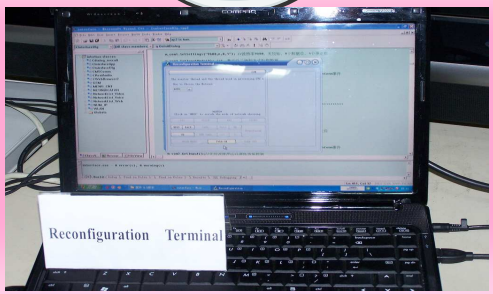

CPC Server

3



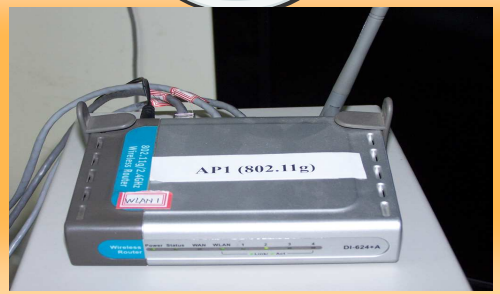

JRRM & Software Server

4




Reconfigurable Terminal

5



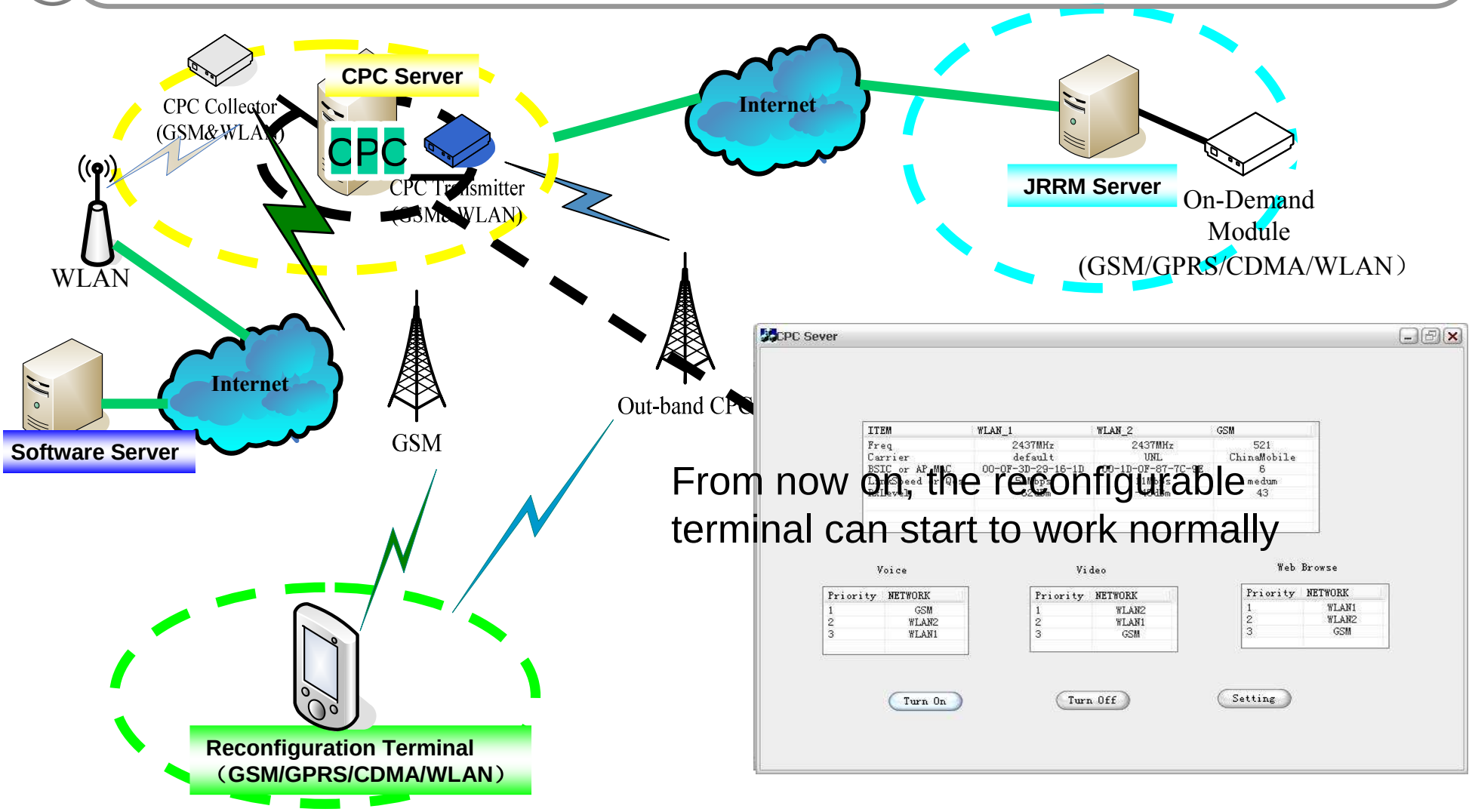

AP1(802.11 g)

6


AP2(802.11 b)

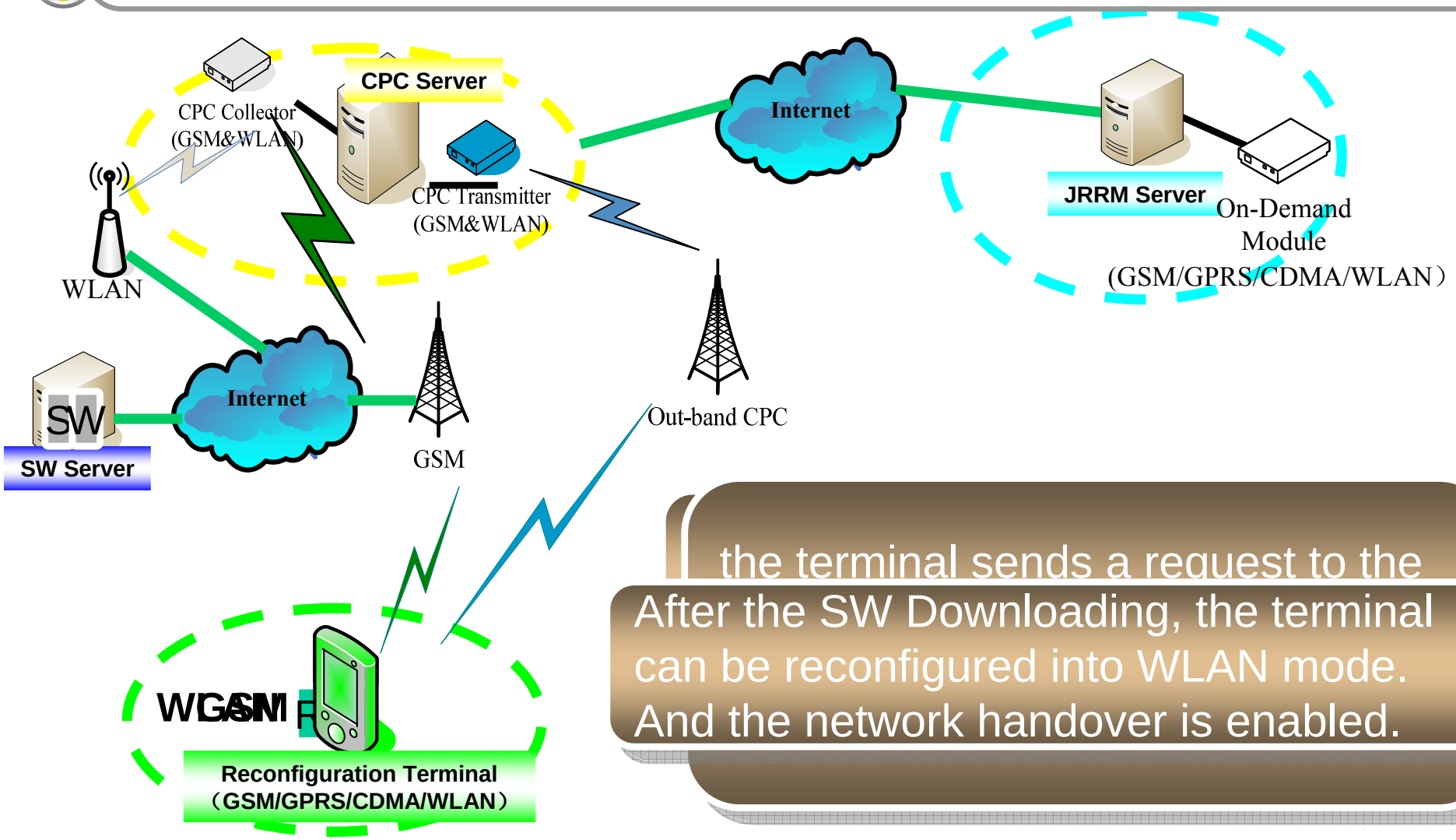
# Demo on CPC

- [illegible] periodically



# Demo on Software Downloads

## Mechanism of Software Downloads to Enable Network Handover

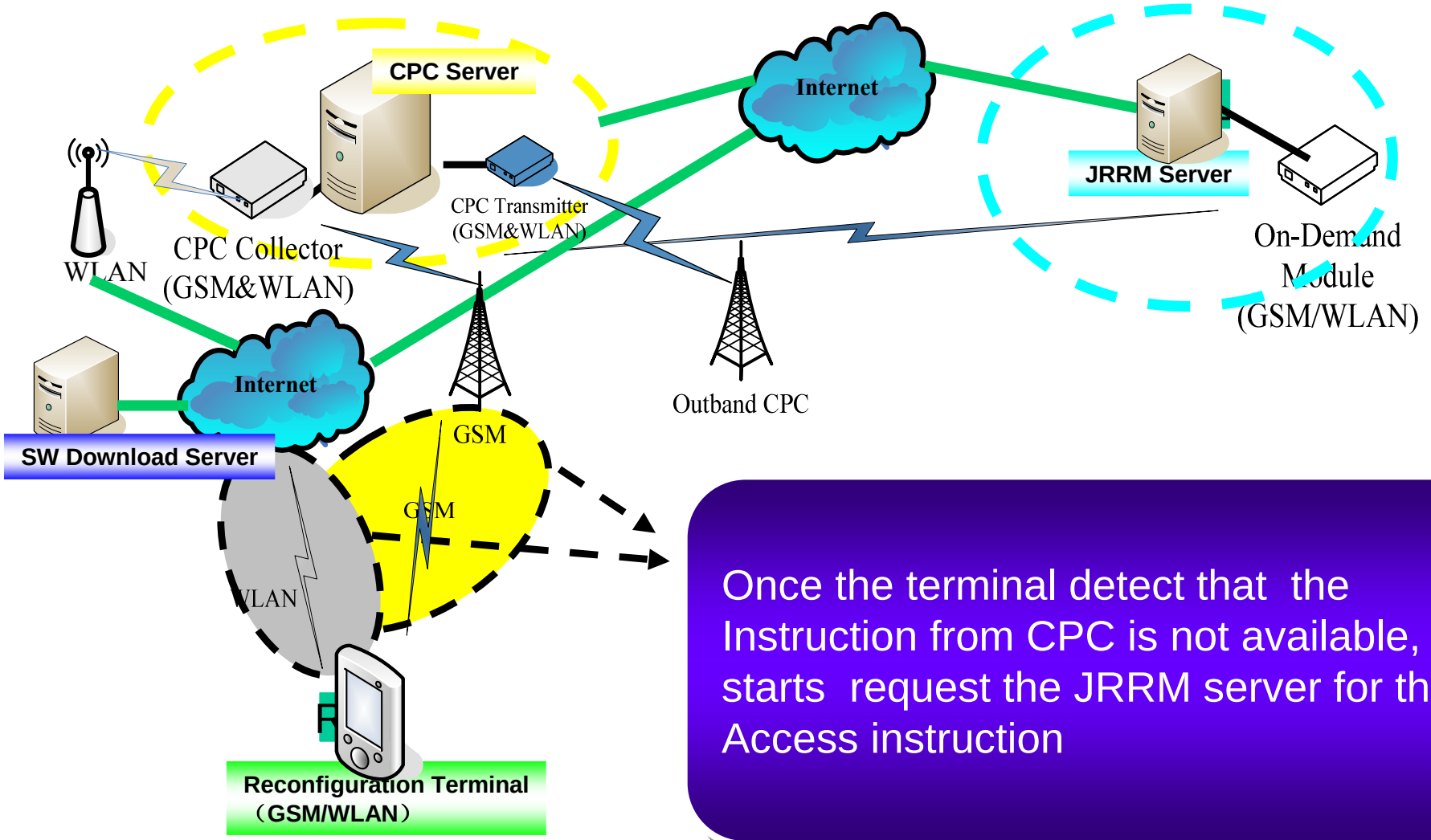



the terminal sends a request to the

After the SW Downloading, the terminal can be reconfigured into WLAN mode. And the network handover is enabled.

# Demo on JRRM

## Scenario on JRRM

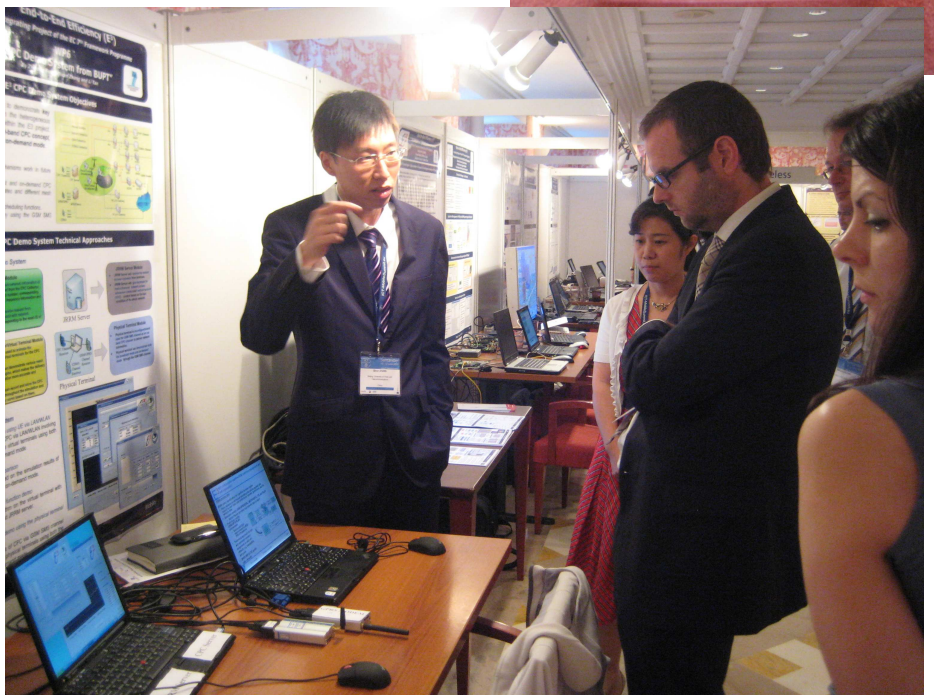



Once the terminal detect that the Instruction from CPC is not available, it starts request the JRRM server for the Access instruction

# CPC Demo System in EU

- In ICT-Mobile Summit2009, in June 10~12, EU FP7 E3 obtain the “Best Demonstration Stand”





# Future Work

- **Demo system**
  - Evaluating the CPC performance
    - Out-band CPC (On-demand mode)
    - In-band CPC
    - CPC Extension with CDMA Channel
    - Delivery Delay
    - Delivery Approach
    - Required Bandwidth
  - Evaluating the JRRM function
    - Joint Admission Control
    - Joint Load Balancing
    - Joint Scheduling

# Future Work

- **Standardization of CPC**
  - Recently, several proposals have been proposed to different standardization organizations.
  - Proposals on CPC architecture and CPC management will be proposed to worldwide standardization organizations.
    - IEEE 1900.4
    - ITU-R
    - ETSI
    - WWRF
  - Performance evaluation for the implementation of CPC will be carried out.

# Reference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# Projects on Cognitive Wireless Networks

## Domestic Projects:

- 2009-2013: National Basic Research Program of China (973 Program): Basic Research on Cognitive Wireless Networks(2009CB320400)
- 2007-2010: NSFC (Natural Science Foundation of China ) Project: Research on Architecture and Key Technologies of Autonomous End-to-end Reconfigurable Radio Networks(60632030)
- 2009-2012: NSFC (Natural Science Foundation of China ) Project: Research on Resource Management Based on Cognitive Technology
- 2007-2008: National 863 Program of China: Research on key technologies of Reconfigurable Radio Networks (2006AA01Z276)

## EU Co-operation Projects:

- 2008-2009: EU ICT FP7 Integrated Project: E3(End-to-end Efficiency)(FP7-ICT-2007-216248)
- 2006-2007: EU IST FP6 Integrated Project IST-E2R(End-to-end Reconfiguration) II (IST-2005-027714)


# Thank You for Your Attention!

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