Chapter 1

When Radio Meets Software
Outline

- Motivation
- Software-Defined Radio
- Cognitive Radio
- Key Applications
- Chapter 1 Summary
Outline

- Motivation
- Software-Defined Radio
- Cognitive Radio
- Key Applications
- Chapter 1 Summary
The Information Age

- Data communications an integral part of modern society
  - Financial transactions
  - Social interactions
  - Education
  - National security
  - Commerce
Recent Growth

- Growing number of data applications and users
  - Diverse services
    - Voice telephony
    - Web browsing
    - Text messages
  - Different performance requirements
    - Bandwidth/data rate
    - Latency
    - Power consumption
Increasing Demand

- Rapid growth in the wireless communications sector, requiring more spectral bandwidth
  - Increasing number of users
  - Increasing number of new wireless services being offered
  - Some applications are bandwidth-intensive
Maybe Too Much Growth?

- Spectrum **scarcity** due to command-and-control structure of frequency allocation
  - Fixed amount of spectrum **versus** growing number of wireless applications/users
  - License holders maintain exclusive rights to their allocated spectrum
    - Purchased during a spectrum auction, e.g., 3G auctions
    - Allocated via government decree, e.g., military, television

“Cognitive Radio Communications and Networks: Principles and Practice”
Spectrum Scarcity

- Unlicensed devices not permitted to transmit in licensed bands
- Allocated unlicensed bands (with transmit constraints)
  - Industrial, Scientific, Medical (ISM) bands
    - 900 MHz, 1.8 GHz, 2.4 GHz, 5.8 GHz
  - Unlicensed National Information Infrastructure (UNII) band
    - 5.15 GHz – 5.825 GHz
Conventional Wireless Devices

- Today’s wireless devices are constrained in operation
  - Fixed applications (e.g., cellular, WLAN)
  - Fixed frequency bands of operation
  - Fixed modes of operation (e.g., data rates, power levels)
Interoperability

- Plethora of different wireless standards for a wide range of applications
  - Tower of Babel syndrome
  - Interoperability issues
- Public safety sector especially affected by these issues
  - Need for reliable communications across platforms employing different communication standards

“Cognitive Radio Communications and Networks: Principles and Practice”
Moore’s Law to the Rescue!

- Microelectronics evolution leading to increasingly sophisticated wireless system designs
  - Versatility
  - Computationally powerful
  - Portability
- Over the past decade wireless devices have been employing programmable attributes
Outline

- Motivation
- Software-Defined Radio
- Cognitive Radio
- Key Applications
- Chapter 1 Summary
SDR: An Enabling Technology

- Rapidly programmable radio functions
- Device can assume any configuration available in memory
- Capable of performing on-the-fly transceiver optimization to enhance performance
Underneath the Hood

- Motherboard
  - FPGA
  - DAC / ADC
- Daughterboards
  - RF front-end
  - Interchangeable
- Affordable = Accessible

“Cognitive Radio Communications and Networks: Principles and Practice”
Software Defined Radio

Software or Programmable Logic

"Cognitive Radio Communications and Networks: Principles and Practice"
Software Defined Radio

“Cognitive Radio Communications and Networks: Principles and Practice”
Outline

- Motivation
- Software-Defined Radio
- Cognitive Radio
- Key Applications
- Chapter 1 Summary
What is a Cognitive Radio?

- An intelligent wireless communications system
- Based on SDR technology
  - Reconfigurable
  - Agile Functionality
- Aware of its environment
  - RF spectrum occupancy
  - Network traffic
  - Transmission quality
- Learns from its environment and adapts to new scenarios based on previous experiences

"Cognitive Radio Communications and Networks: Principles and Practice"
Cognitive Radio: Definition

“Cognitive radio is an intelligent wireless communication system that is aware of its surrounding environment (i.e., outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters (e.g., transmit-power, carrier-frequency, and modulation strategy) in real-time, with two primary objectives in mind:

• highly reliable communications whenever and wherever needed;
• efficient utilization of the radio spectrum.”

Cognitive Radio, Knobs, & Dials

“Cognitive Radio Communications and Networks: Principles and Practice”
Outline

- Motivation
- Software-Defined Radio
- Cognitive Radio
- Key Applications
- Chapter 1 Summary
Tower of Babel

- Plethora of communication standards
  - Jurisdictional differences (federal, state, provincial, municipal)
  - Organizational differences
- Legacy equipment

Notice how different public safety teams operate on different frequency and each use a different communication standard.
Interoperability
Apparent Scarcity

- Measurement studies have shown that in both the time and frequency domains that spectrum is underutilized.

Spectrum measurement across the 900 kHz –1 GHz band (Lawrence, KS, USA)

"Cognitive Radio Communications and Networks: Principles and Practice"
Dynamic Spectrum Access

Spectrum measurement across the 900 kHz –1 GHz band (Lawrence, KS, USA)

“Cognitive Radio Communications and Networks: Principles and Practice”
RF Spectrum Occupancy

Spectrum measurement across the 928 – 948 MHz band (Worcester, MA, USA)

“Cognitive Radio Communications and Networks: Principles and Practice”  
Outline

- Motivation
- Software-Defined Radio
- Cognitive Radio
- Key Applications
- Chapter 1 Summary
Chapter 1 Summary

- Employ latest advances in microprocessor technology to enable highly flexible wireless devices
  - Platforms possess ability for decision-making
  - Agility allows for wide range of communications and networking operations
  - Critical rethinking/reinvention of data transmission