EEEN3008J: Advance wireless communications

Cognitive Radio

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Dictionary

cognition

cognition

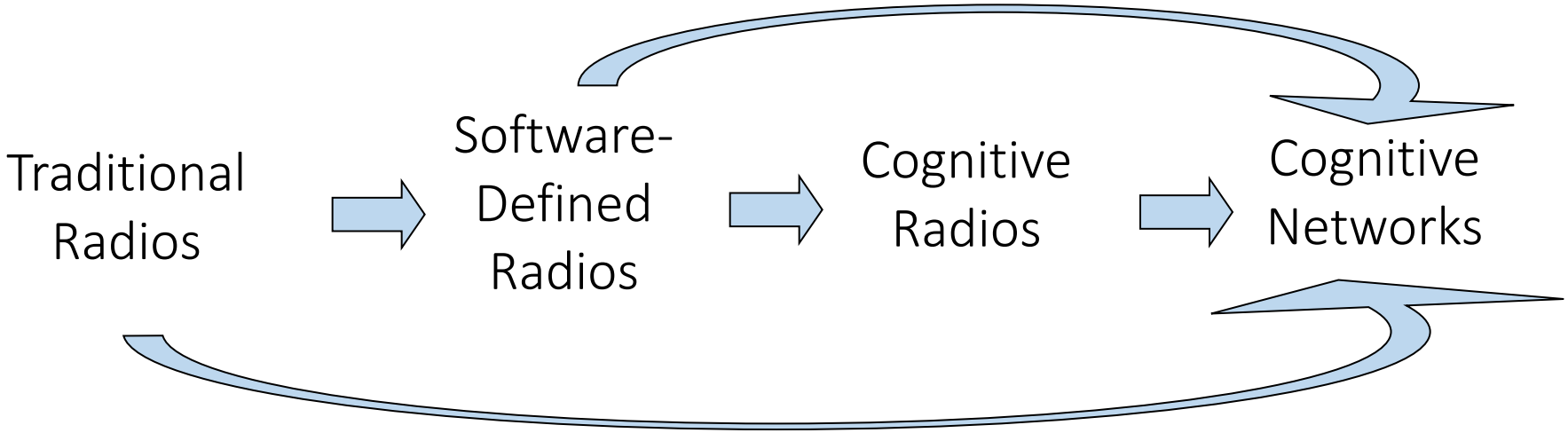
/kɒgˈnɪʃ(ə)n/

noun
noun: **cognition**

the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses.
synonyms: perception, discernment, awareness, apprehension, learning, understanding, comprehension, enlightenment, insight, intelligence, reason, reasoning, thinking, (conscious) thought
"a theory of human cognition"

- a perception, sensation, idea, or intuition resulting from the process of cognition.
  plural noun: **cognitions**
  synonyms: perception, discernment, awareness, apprehension, learning, understanding, comprehension, enlightenment, insight, intelligence, reason, reasoning, thinking, (conscious) thought
  "a theory of human cognition"

Evolution


Traditional Radios
Software-Defined Radios
Cognitive Radios
Cognitive Networks

SDR and cognitive radio

- Software-defined radio (SDR) - a collection of hardware and software technologies that enable reconfigurable system architectures for wireless networks and user terminals (SDR Forum)

- Cognitive radio (CR) – a radio that is aware of and can sense its environment, and can make decisions about its operating behavior based on that information and pre-defined objectives (IEEE 1900.1)

Definition

- A transceiver that is aware, adaptive, and capable of learning from experience

… of the RF environment (communication waveform features, propagation channel characteristics)
… of its own capabilities (power consumption, DSP clock rate, device operational status, …)
… of policies it needs to follow
… of local (link) and global (network) objectives
… of network conditions
… of other users' priorities and authorizations

Definition

- A transceiver that is aware, adaptive, and capable of learning from experience

… transmit power control
… dynamic waveform selection
… dynamic spectrum access
… block edge masks
… routing
… negotiation of waveforms and protocols

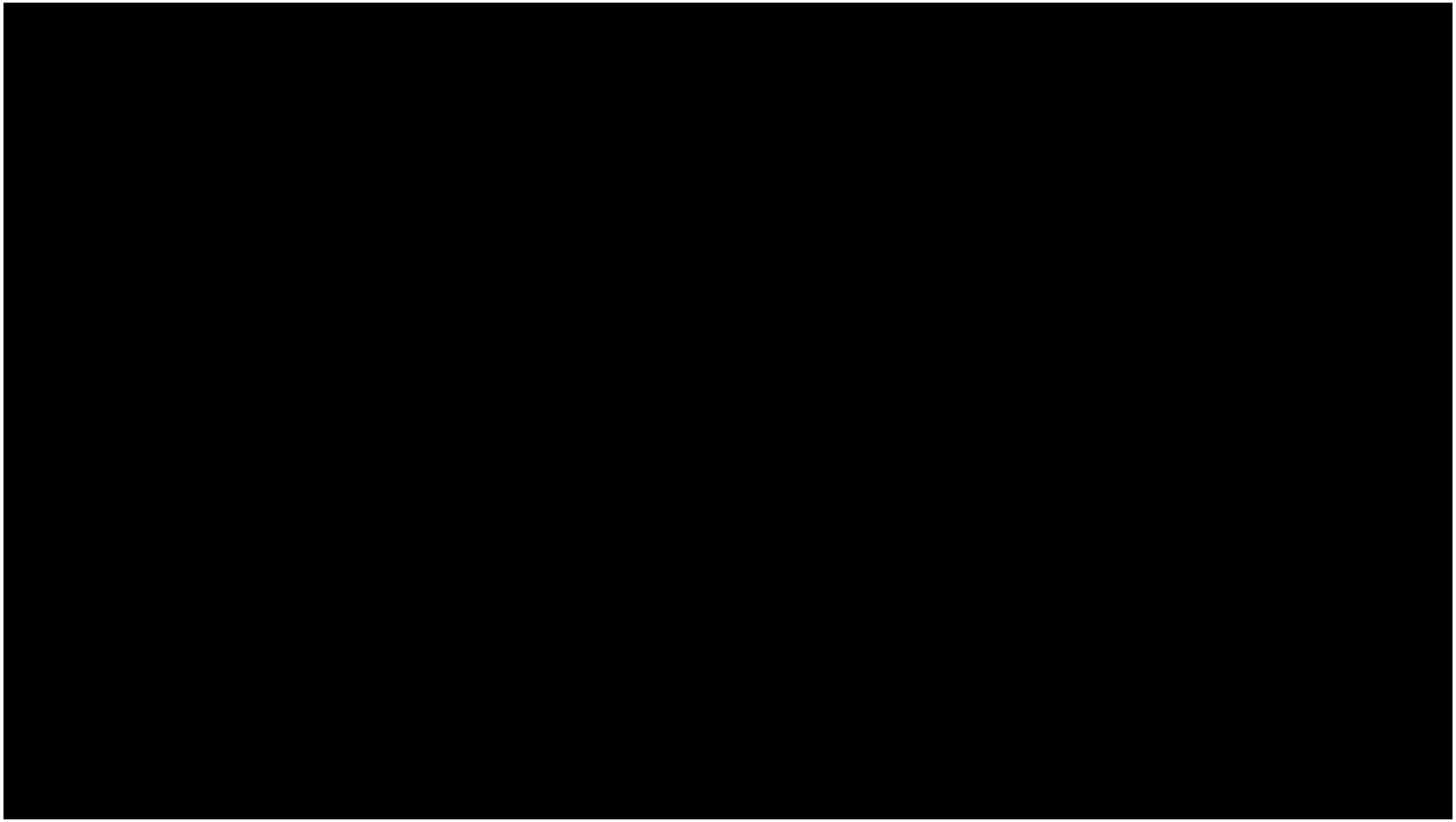
Definition

- A transceiver that is aware, adaptive, and capable of learning from experience

… experience-weighted table lookup

… machine learning algorithms

Cognitive Radio Video



Evolution, revisited

Conventional Radio

- Traditional RF Design
- Traditional Baseband Design

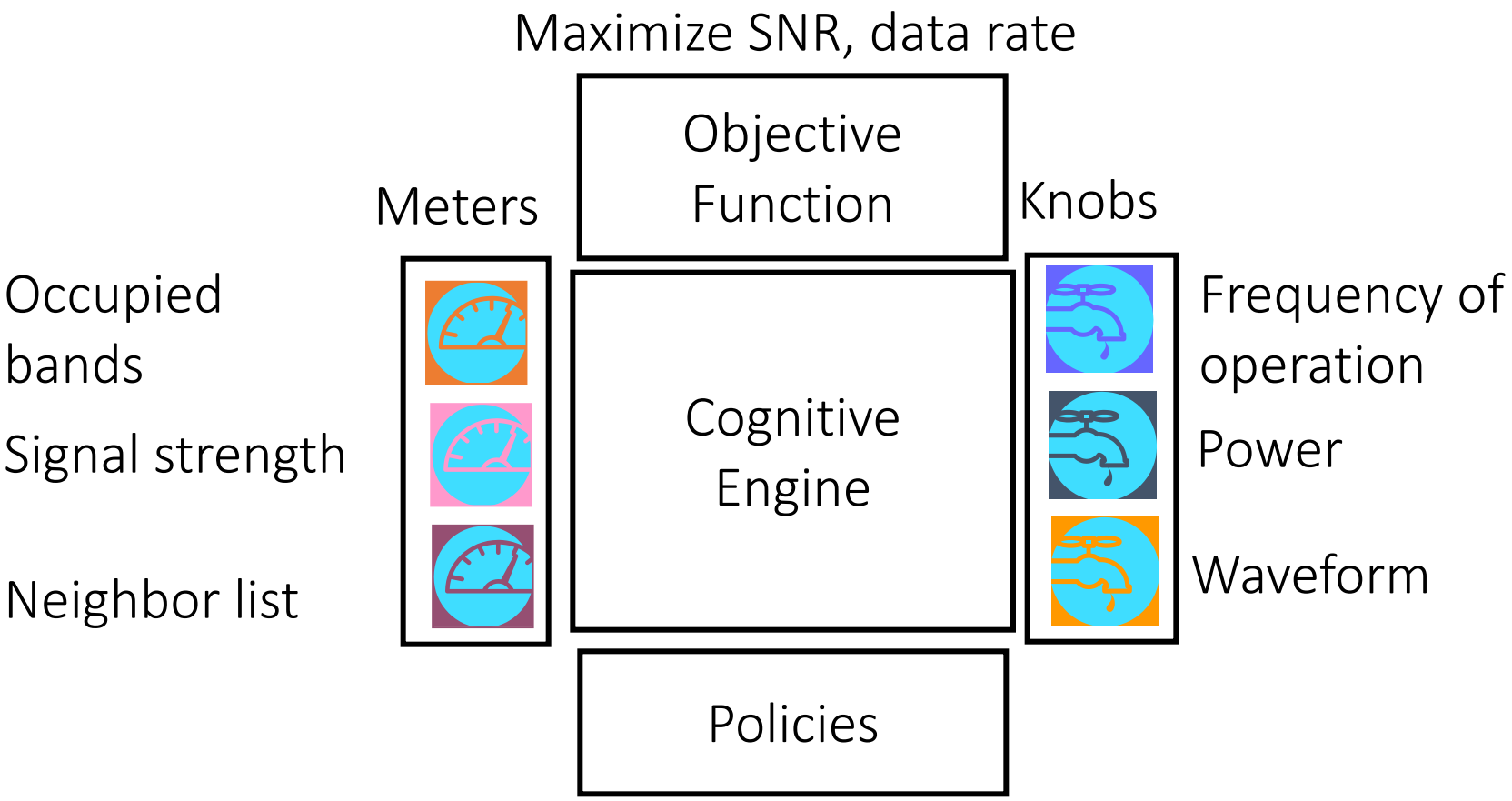
Software Radio

- Conventional Radio +
- Software Architecture
- Reconfigurability
- Provisions for easy upgrades

Cognitive Radio

- SDR +
- Intelligence
- Awareness
- Learning
- Observations

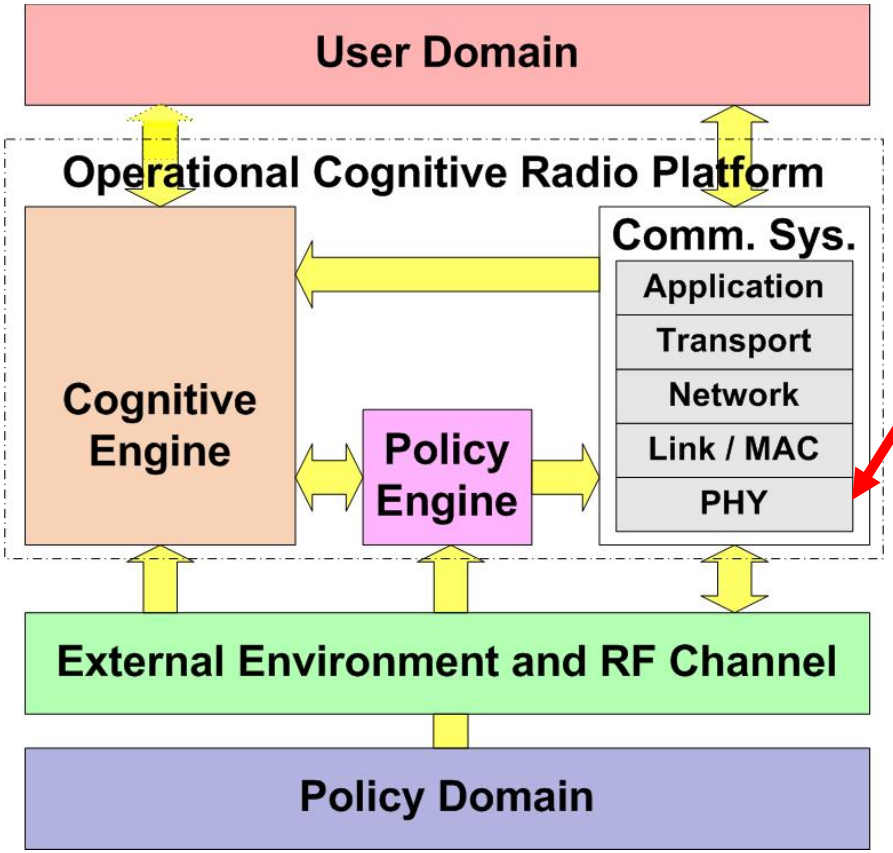
Cognitive Radio



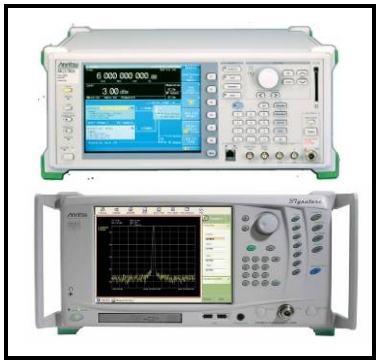
Desirable features

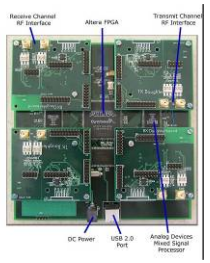
- Wideband
  - "DC to daylight"
- Any waveform
- Flexible architecture
- High performance and low power consumption
- Affordable and accessible
- Relatively straightforward to use and innovate with
- Robust
- Access to suitable frequency spectrum segments for innovation and testing

Hardware and software



Any SDR can go here



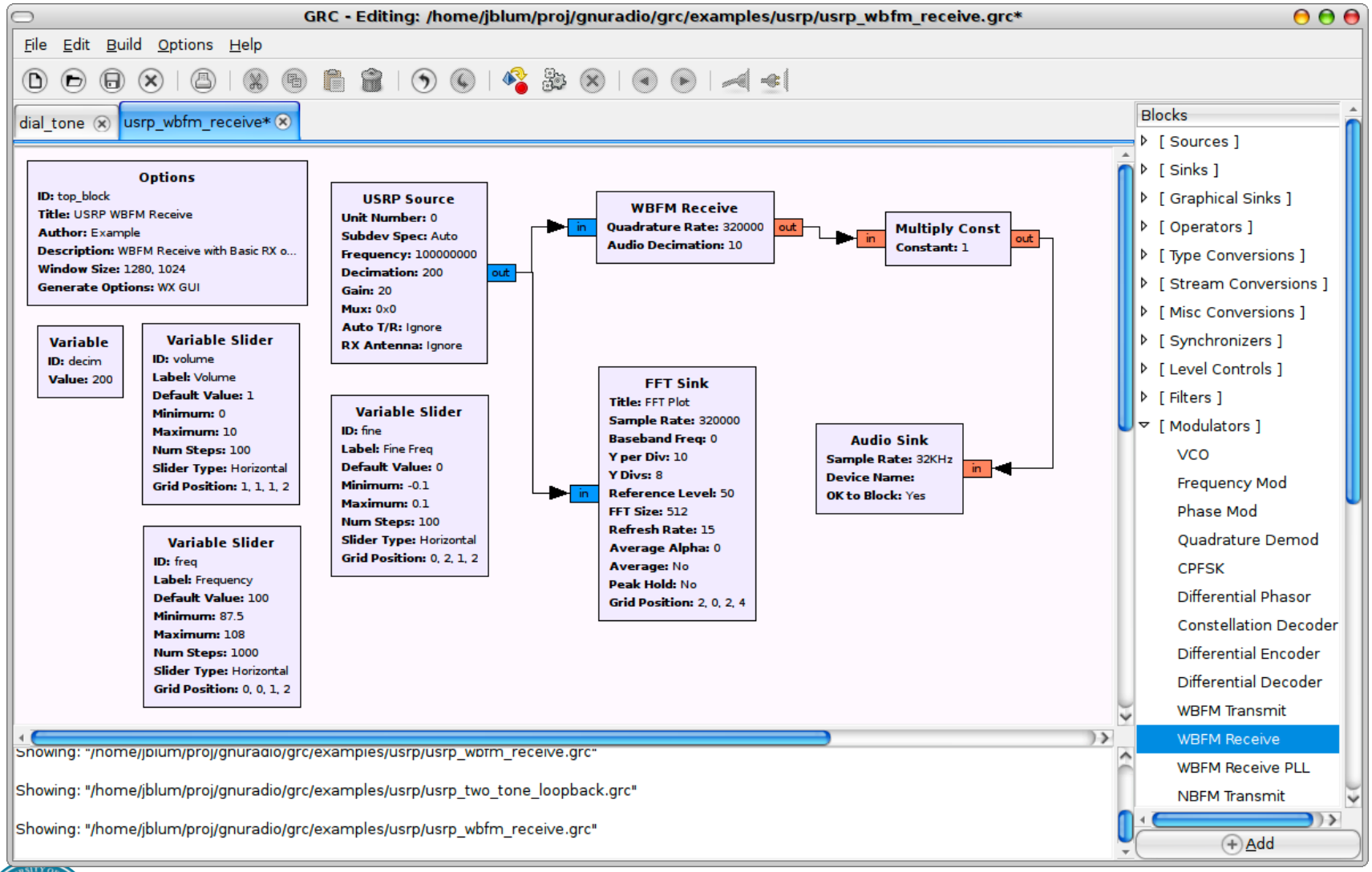


Source: Bostian, 2007

GNU radio

- http://gnuradio.org/
- Free and open source
- Communication system flow graphs are built out of discrete components
  - One responsibility per component
- Components cover:
  - Sources and sinks (sound, file, vector)
  - Filters (FIR and IIR)
  - Math (add, subtract, multiply, etc.)
  - Probes (GUI windows, power)
  - Signal processing (synchronization, mod/demod, etc.)
- Combined Python/C++

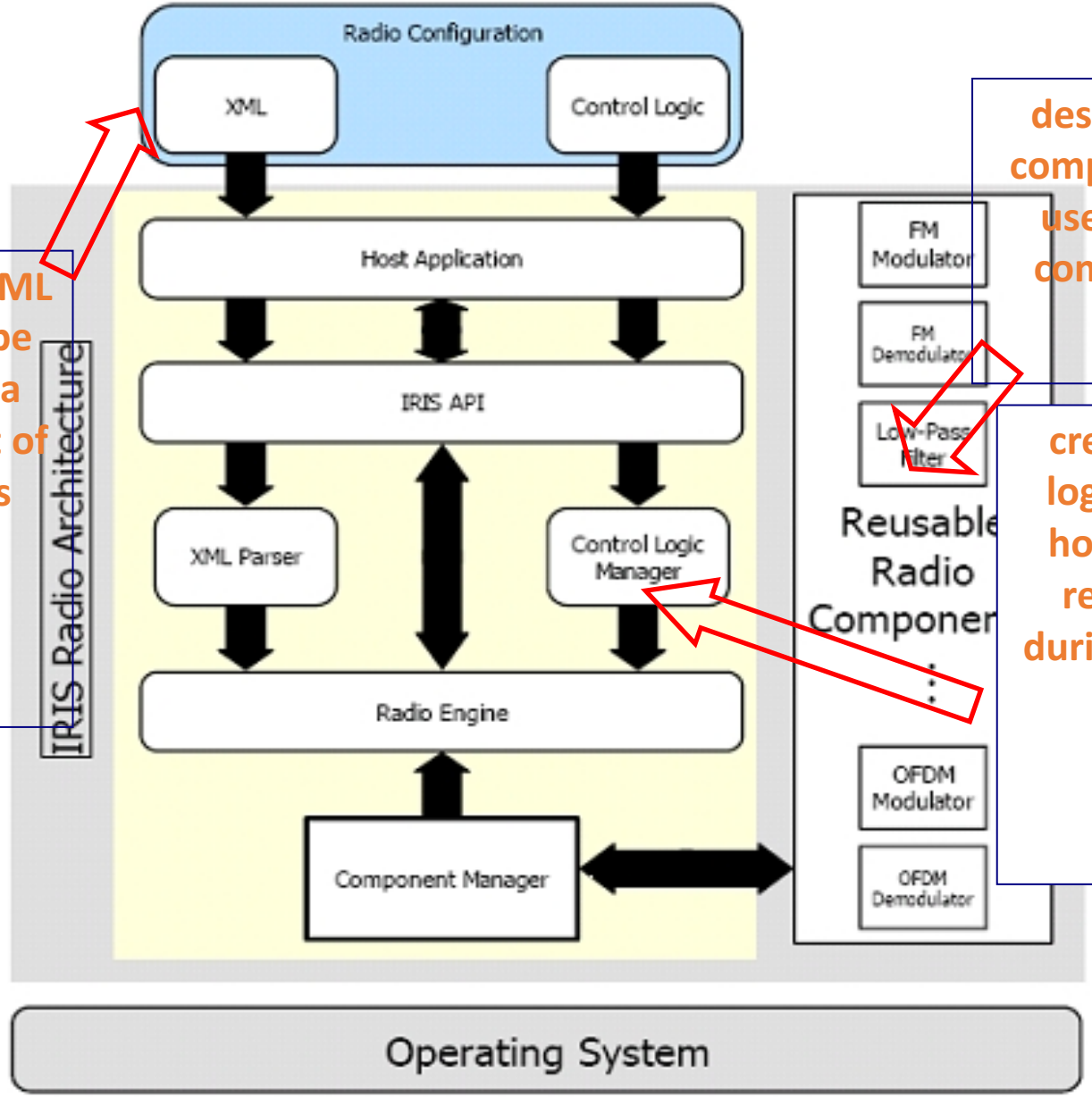
GNU radio: Example



IRIS

- http://www.softwareradiosystems.com/
- Developed at CTVR, Trinity College Dublin
- Reconfigurable radio testbed on a general-purpose processor platform
- Designed to facilitate dynamic reconfiguration
- Platform independent
- Large inventory of signal-processing components
- Source and sinks, math, signal-processing, communications systems

IRIS operation



users create XML file to describe the radio as a connected set of components

design radio components or use existing components

create control logic to define how the radio reconfigures during operation

Not Secure | crew-project.eu/iris.html

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CREW project

Cognitive Radio Experimentation World

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CREW offers Open Access

CREW is in continuous Open Access phase to support your experiments free of charge!

Final public event & Globecom tutorial

CREW will present its final results at the Wireless Community event (Leuven, Belgium, 29 October 2015, more info) and organises a hands-on tutorial at Globecom (San Diego, USA, 10 December 2015, more info)

CREW PORTAL: access the CREW facilities

Interested in using the CREW facilities?
[Start here] - [Browse by name] - [Overview images] - [Advanced info] - [WTA GitHub].

Testbeds

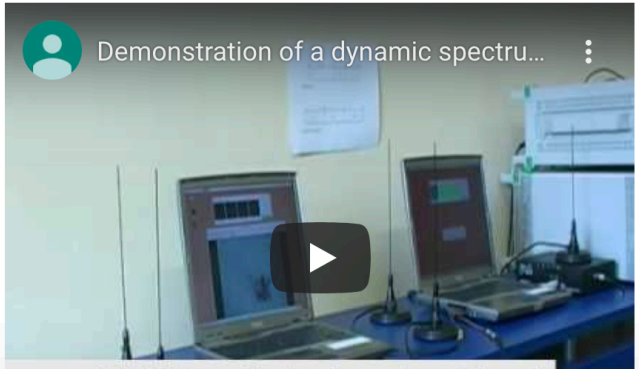
- w-iLab.t (iMinds)
- IRIS (CTVR, Trinity College Dublin)
- TWIST (TUB)
- LTE/ LTE advanced testbed (TUD, Vodafone)
- Outdoor heterogeneous ISM/TVWS VSN testbed

Home » Testbeds

IRIS (CTVR, Trinity College Dublin)

Important note: *For a more detailed and up to date description of Iris and the Iris testbed, please consult the CREW portal. A high-level overview of Iris and the testbed is given below.*

The reconfigurable radio consists of a general-purpose processor software radio engine, known as IRIS (Implementing Radio in Software) and a minimal hardware frontend. IRIS can be used to create software radios that are reconfigurable in real-time.



Upcoming events

Fire week Poznan / Servicewave 2011 / Joint Demonstration Evening / FIRE workshop
ITEA/Artemis Co-summit
Future internet week
ICT 2010

[full list of upcoming events]

CREW newsletter

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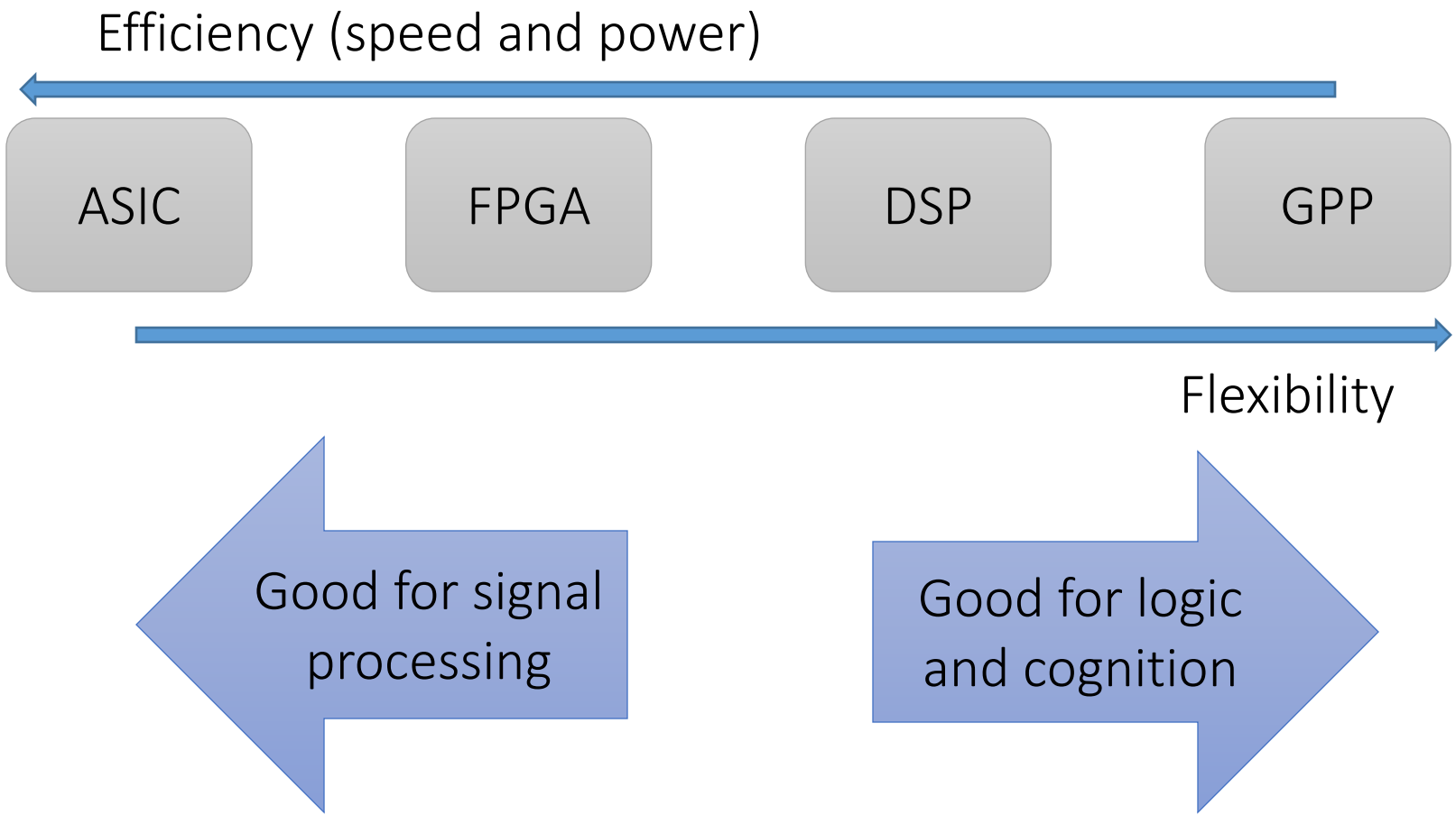
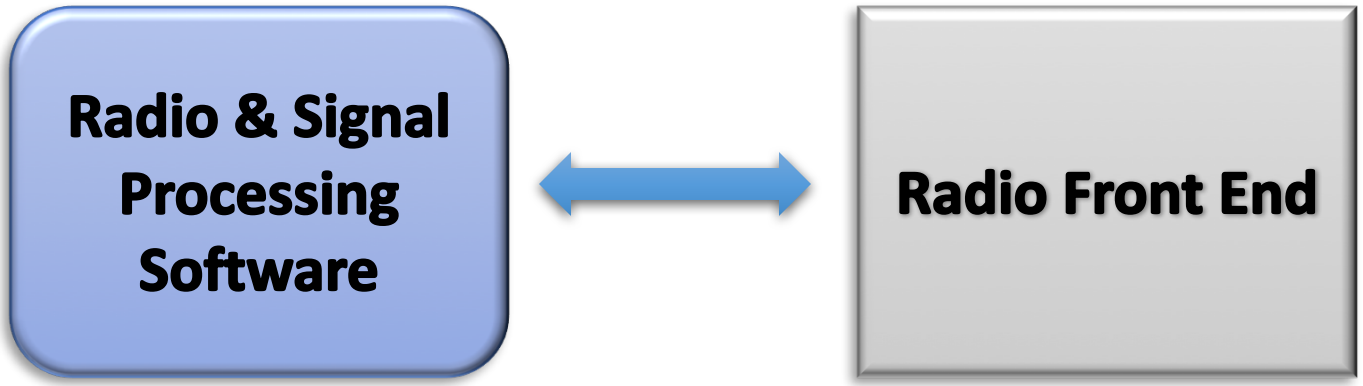
Processing elements trade offs

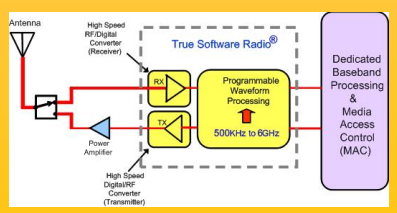


SW/RF front-end separation

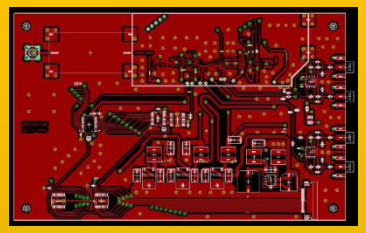


Front end deals with frequency, filtering, and power
Software handles waveforms and protocols

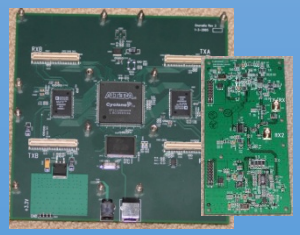
Some SDR RF systems



Softronics

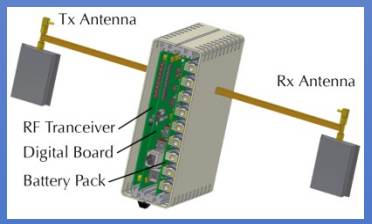


Maynooth's RF



USRP

Lyrtech

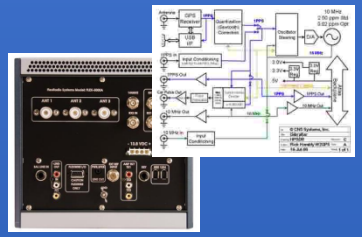


KUAR

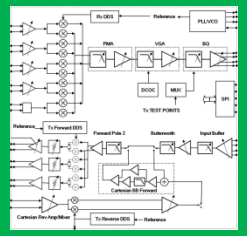
VANU Inc.

WNaN

WARP



FlexRadio, HPSDR



Motorola

BitWave

RF Front End

Integrated RF & digital processing

Full radio systems

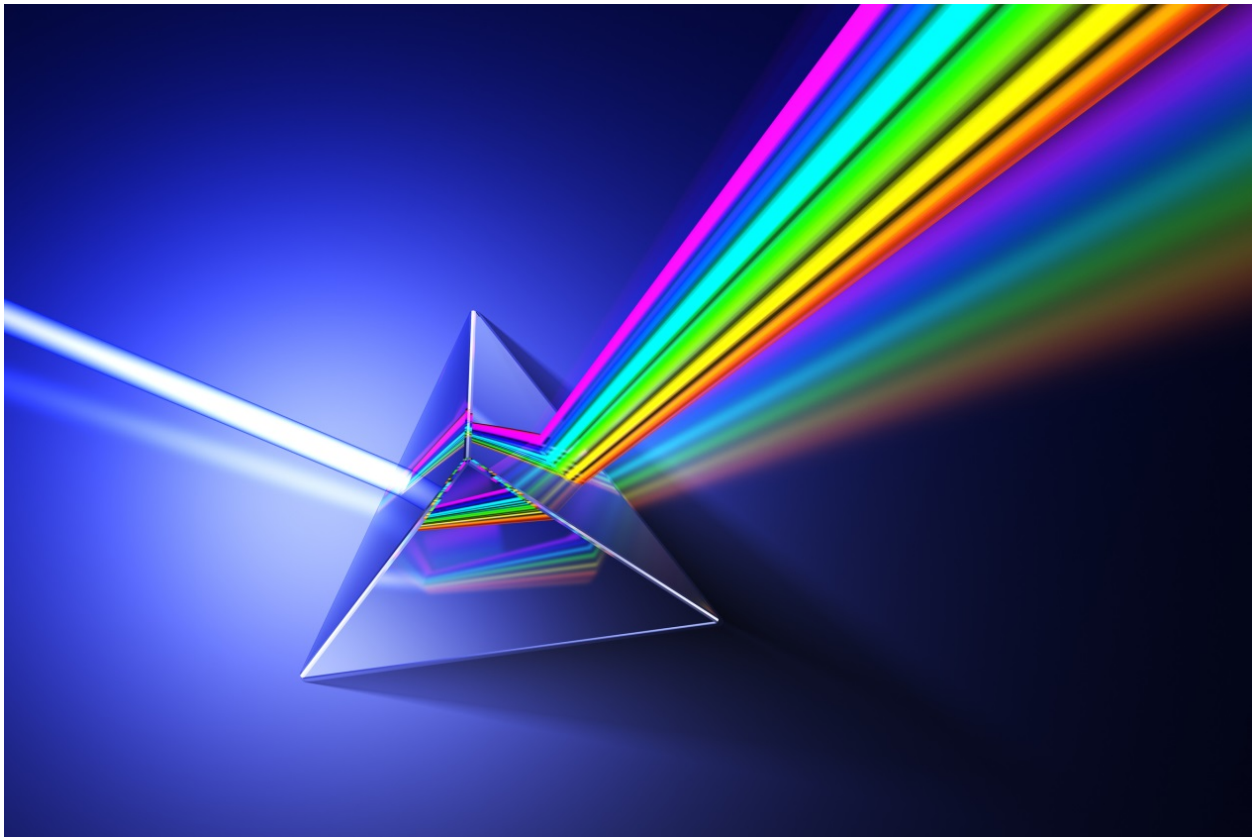
RFICs

Cognitive radio applications

- Dynamic spectrum access
- Cooperative medium access and cooperative communications
- Opportunistic switching among available wireless networks (cellular, WLAN, mesh, etc.)
- Adaptive selection of available radio resources (e.g., cognitive MIMO, selection among different waveforms)
- Increased interoperability (e.g., law enforcement and public safety applications)

Dynamic Spectrum Access

- The Radio Spectrum



Dynamic Spectrum Access

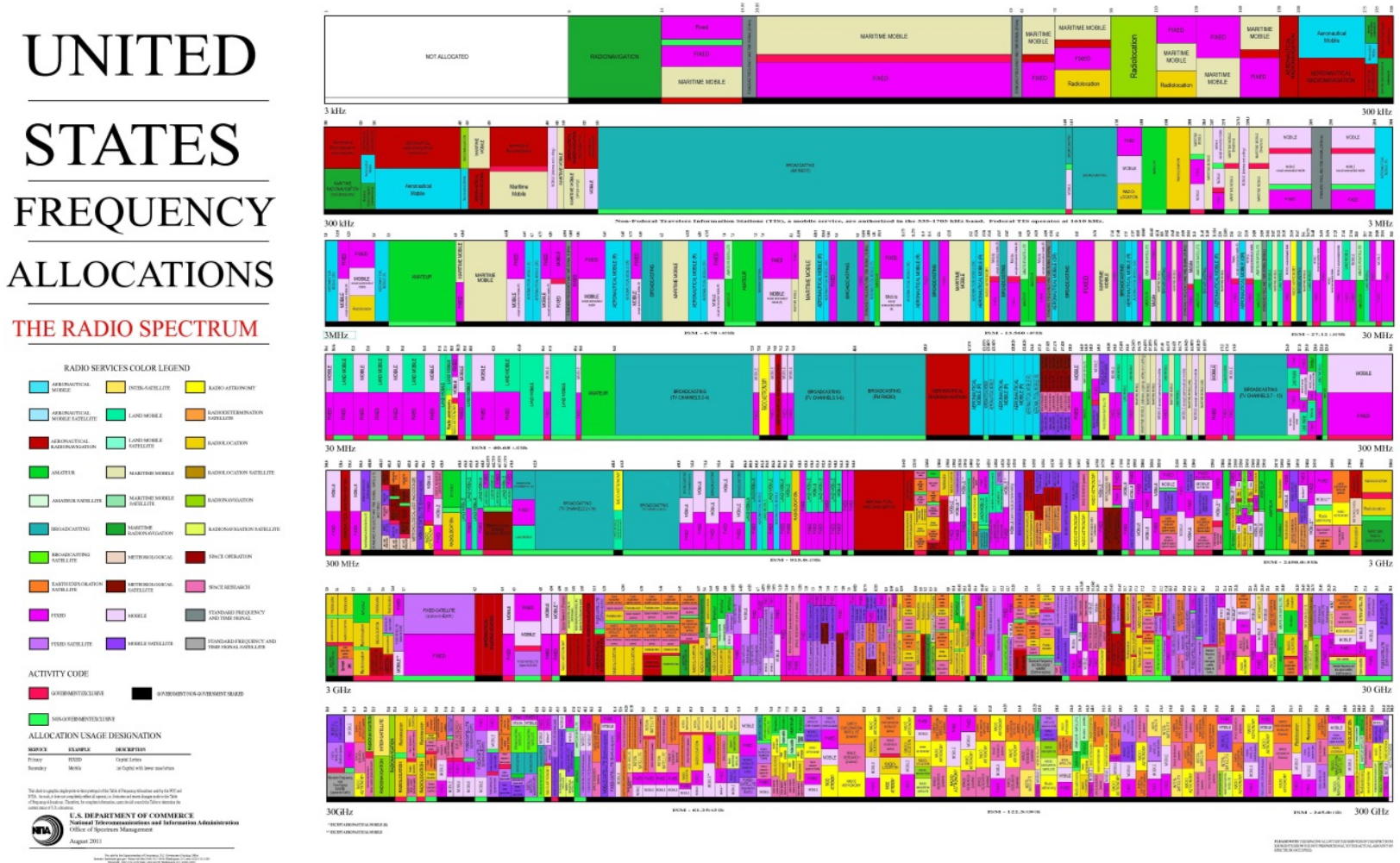
- Different spectrum bands for different services





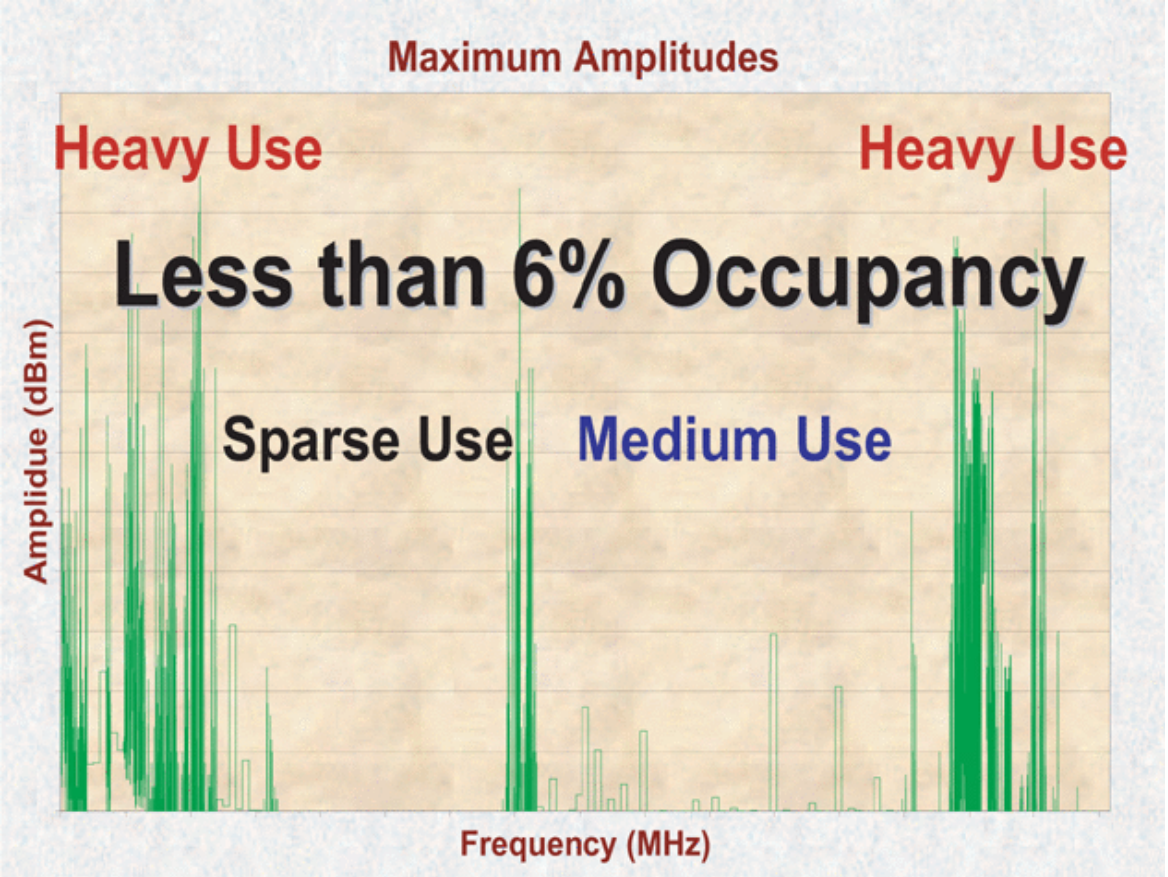

Dynamic Spectrum Access

- The Radio Spectrum is crowded



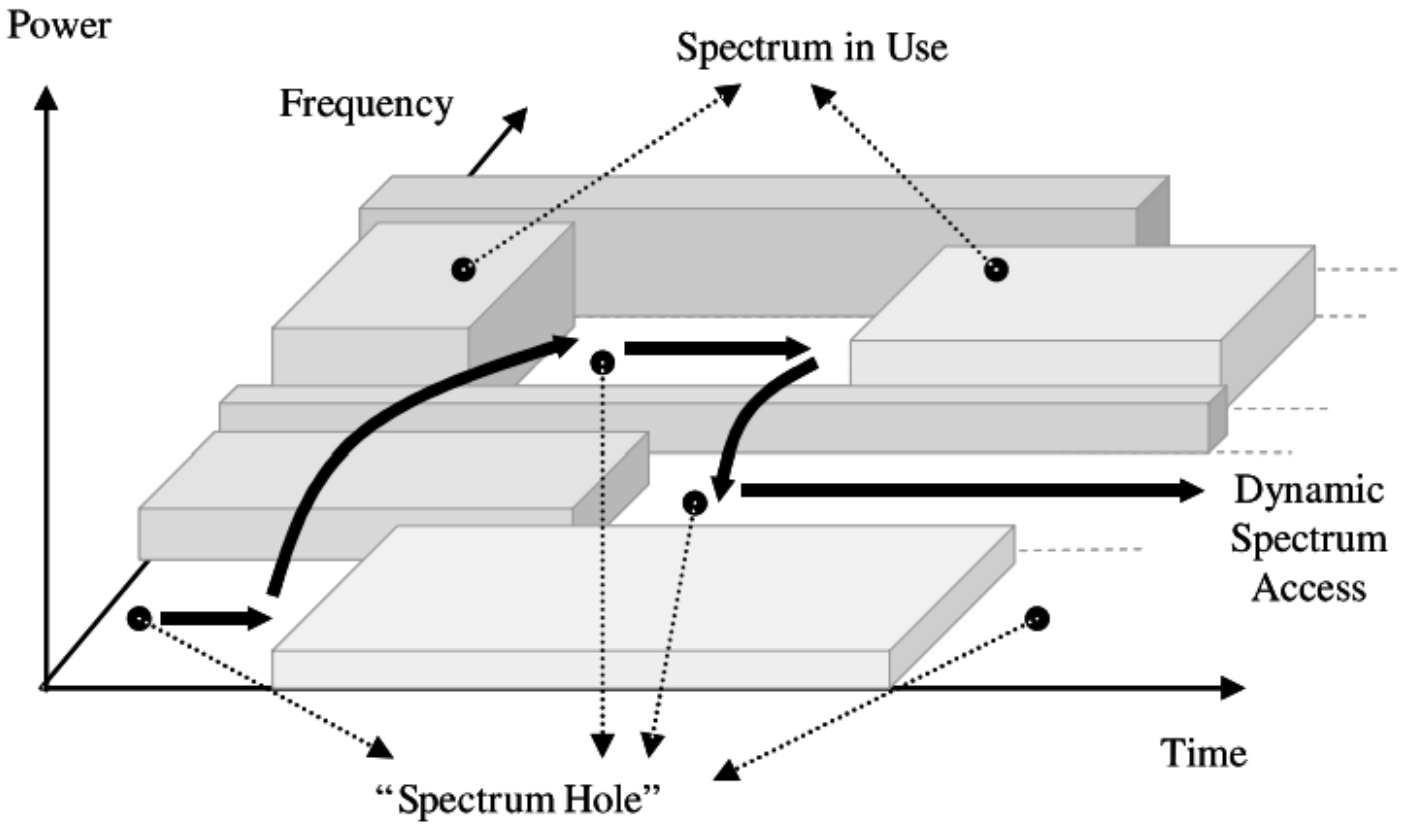
Dynamic Spectrum Access

- The spectrum is underutilised



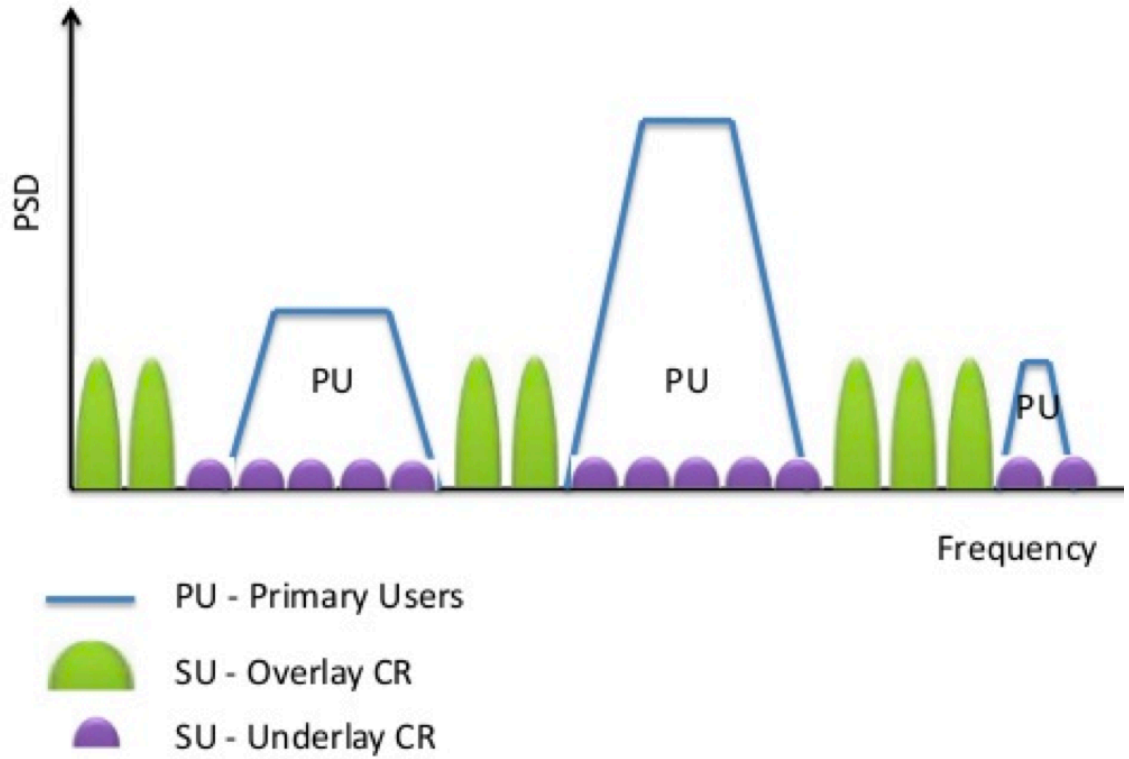
Dynamic Spectrum Access

- The concept of “White Space”

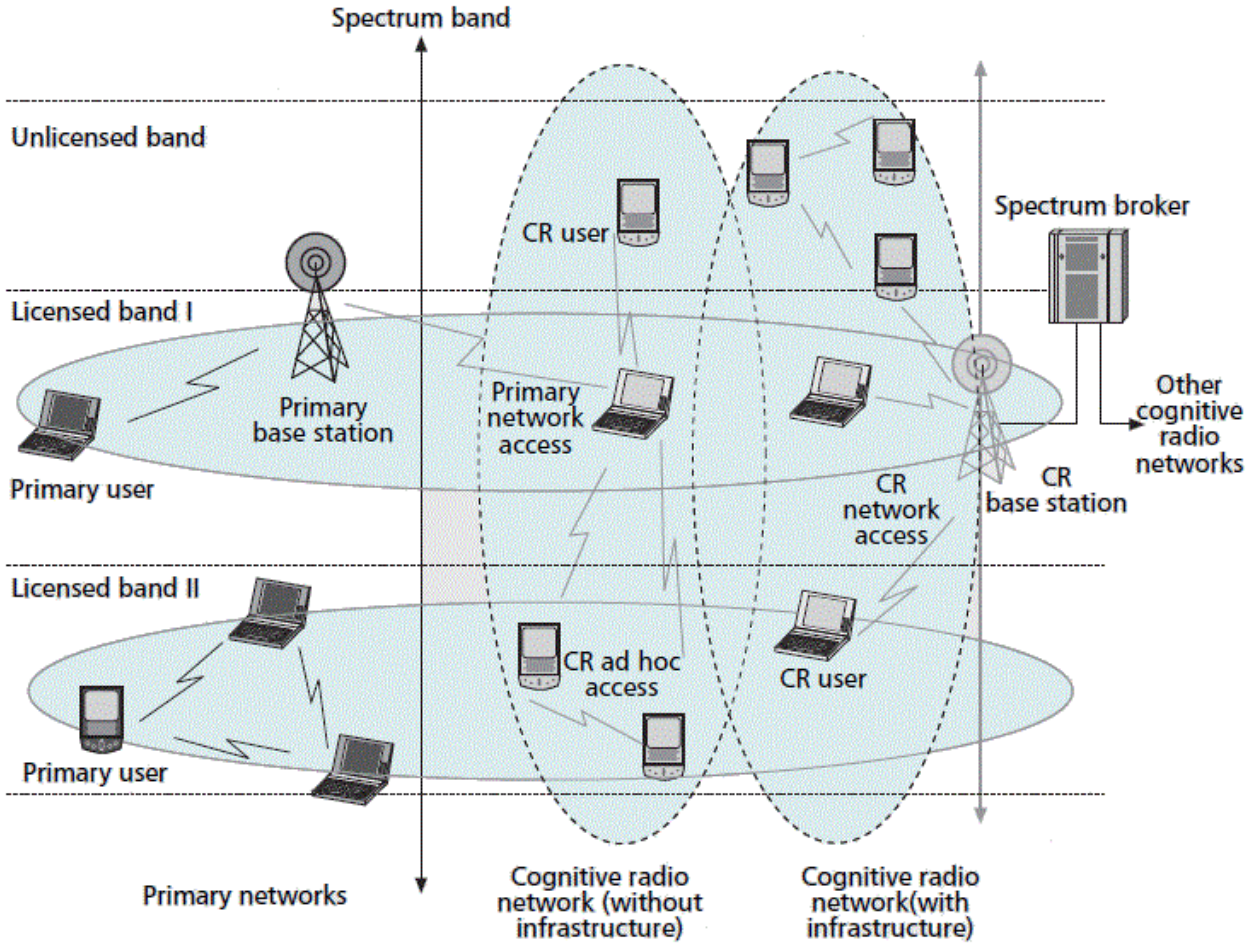


Spectrum sharing

–Overlay – Opportunistic use of fallow spectrum
–Underlay – Non-interfering easement use



Primary and Secondary Users



DSA major players

- IEEE and other standards organizations
- Federal Communications Commission (US), OFCOM - Federal Office of Communication (UK), ComReg (Ireland) and regulators around the world
- US Department of Defense (DoD)
- Industry
  - E.g., interest in shared use of spectrum vacated by shift to digital TV
- Law enforcement and public safety agencies

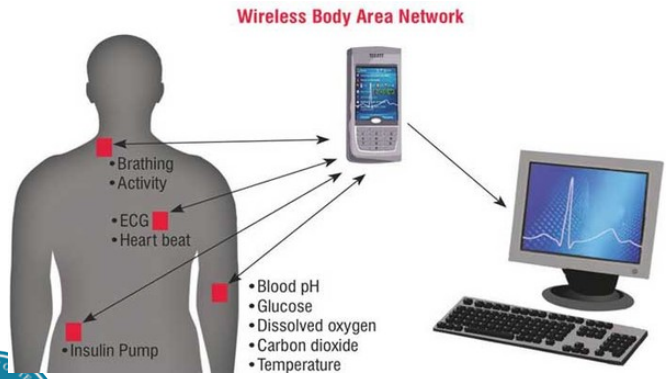
Regulators

- FCC addresses cognitive radios in several Notices of Public Rule Making
  - And spectrum sharing is a feature of the 700 MHz spectrum auction
- US President's Spectrum Policy Initiative
  - Calls for 20 MHz of bw (around 400 MHz) for a spectrum sharing and innovation testbed
  - Authorized Feb 2008
- Canada, Japan, South Korea and EU regulators show interest in more flexible allocation of spectrum

Industry

- White Spaces Coalition and Wireless Innovation Alliance
  - Delivery of broadband Internet using white spaces in TV spectrum
  - Microsoft, Google, Dell, HP, Intel, Philips, Earthlink, Samsung
- ETRI (South Korea) development of IEEE 802.22
- NICT (Japan) development of “software defined cognitive wireless networks”
- Numerous EU-supported partnerships between industry and academia

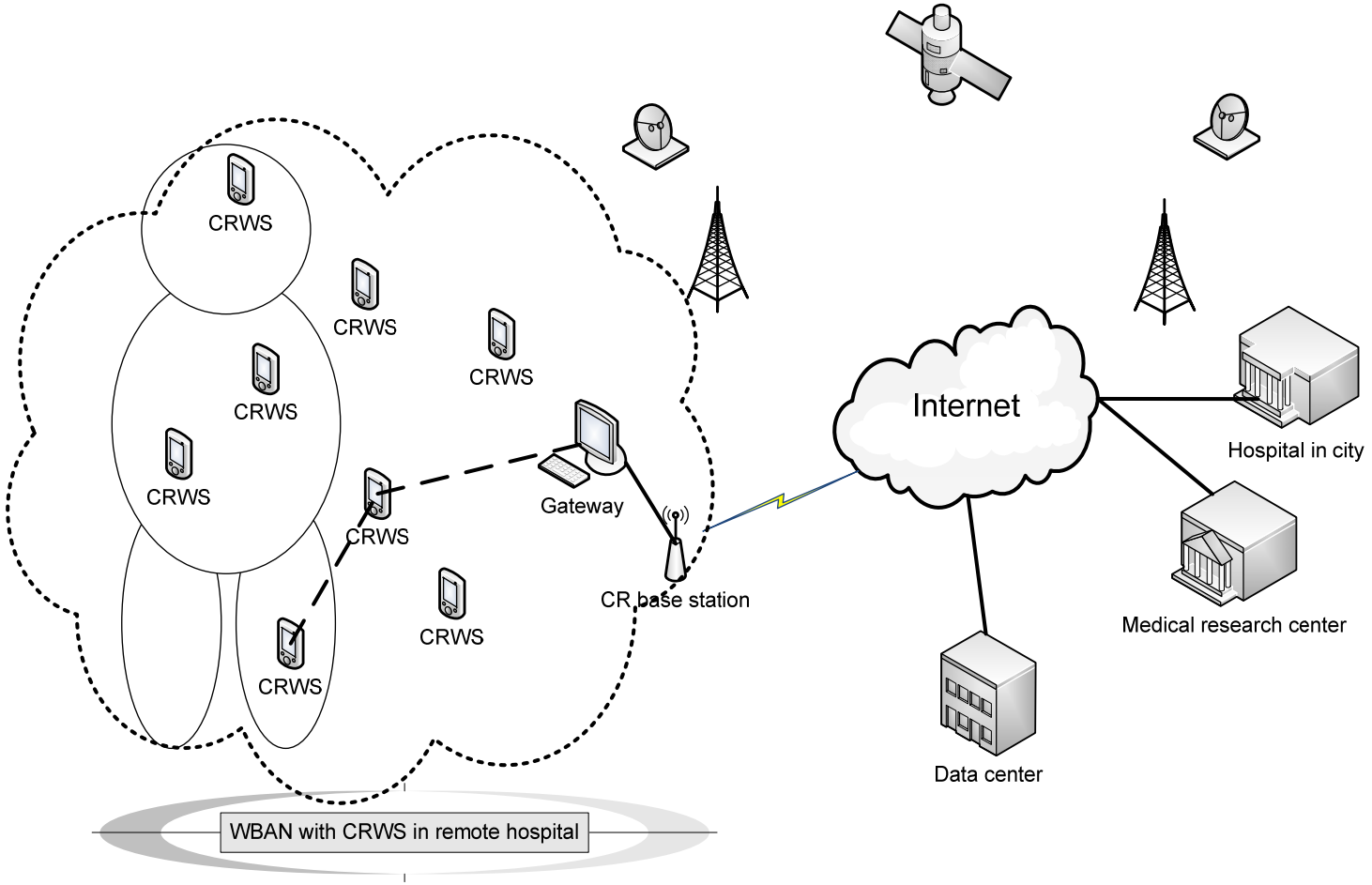
Applications of Cognitive Radio



Applications of Cognitive Radio

- Wireless Cellular Networks
- Public Safety Networks
- Smart Grid
- Wireless Medical Networks
- …

CR Applications: Healthcare



Ref: Joshi et al., "Cognitive Radio Wireless Sensor Networks: Applications, Challenges and Research Trends,"Sensors 2013, 13, 11196-11228; doi:10.3390/s130911196 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3821336/

Broadband cellular

- More bandwidth at (roughly) same price point
  - Approaches to date have included increased efficiency (MIMO, more efficient modulation), piecemeal addition of spectrum (700 MHz)
- Cognitive radio and spectrum brokers
  - Capital intensive to build networks that guarantee coverage and performance
  - LTE deployment is planned in 11+ bands worldwide
  - Capacity on demand implies DSA

Femtocells

- Small cellular base stations for residential / business installation, sharing 2G/3G/4G spectrum
- Starting to hit the market: Verizon, Sprint, AT&T (US), Softbank (Japan), Starhub (Singapore), TDC (Denmark)
  - Ubiquisys, picoChip
- Mass market device, so ease of deployment and low price point are major issues
  - Radio planning must be automated: cognitive radios

Self-organizing networks

- Can automatically extend, change, configure and optimize their topology, coverage, channel allocation and other operating parameters
- Excellent scalability, robustness
- In a sense, prevalent in wired networks at various levels of abstraction
  - The Internet, the web
  - P2P
- Cognitive radios/networks may make it possible in wireless networks