GNU Radio and the USRP in Dynamic Spectrum Access

A Survey

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Ettus Research

Outline

1. Introduction and History
2. Dynamic Spectrum
3. DARPA Spectrum Challenge
4. Summary and Future Directions

Ettus Research

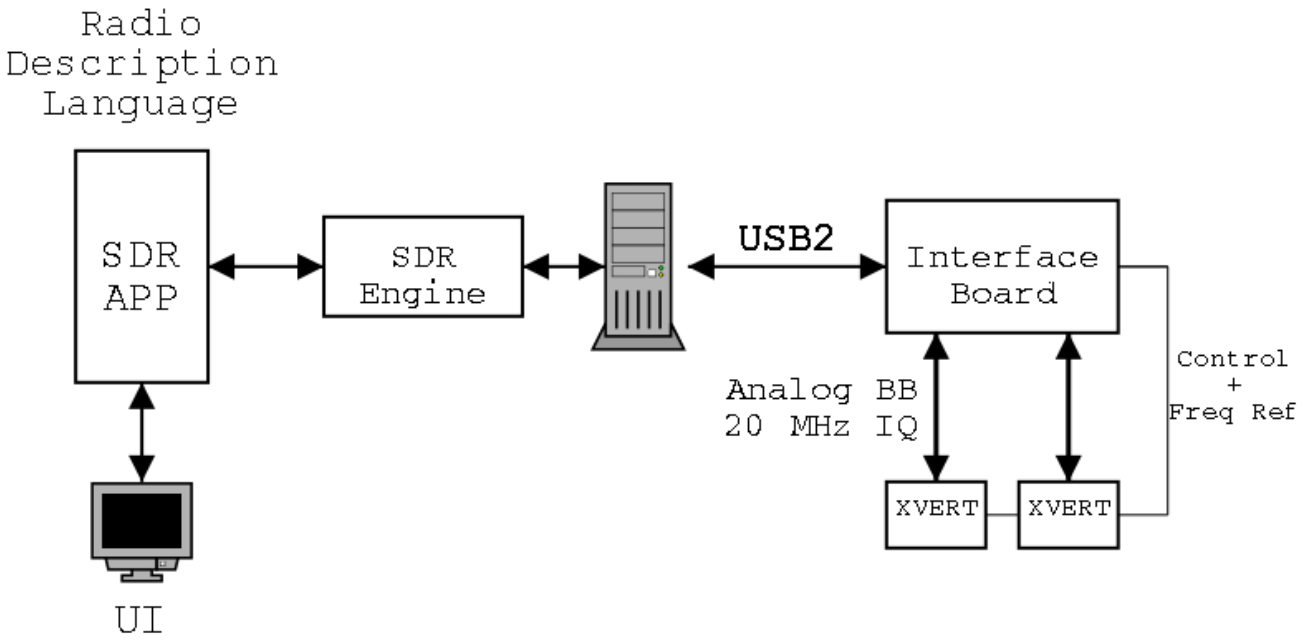
Introduction

- Who am I?
  - Core GNU Radio contributor since 2001
  - Designer of the USRP^{TM}product family (started in 2003)
  - Founder of Ettus Research (2004)
- Why am I here?
  - An interest in Open Spectrum since 1996
  - Built the USRP to investigate Cognitive Radio and Dynamic Spectrum Access (DSA)

The GNU Radio Story

- Founded by Eric Blossom in 2001
- GNU Radio is
  - A FREE framework for Software Radio
  - A Platform for experimenting with Digital Communications
  - A Platform for signal processing on commodity hardware
  - A platform for high-speed system simulation
- Little hardware support early on
  - sound cards
  - data acquisition card with TV tuner evaluation board
- GNU Radio Companion graphical design tool first released in 2006

The USRP story



USRP Concept, ca. 2002

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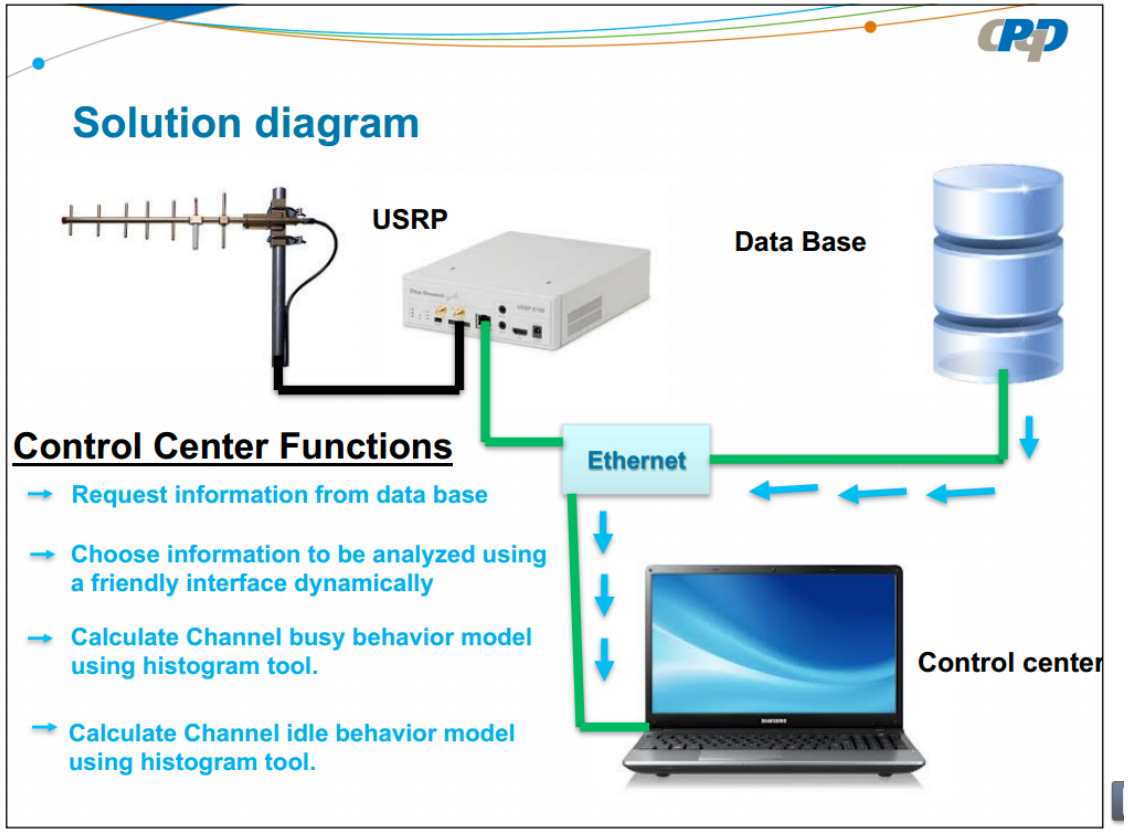
Classes of Dynamic Spectrum work

- Spectral occupancy studies
- PHY-layer
- MAC-layer
- Sensing, coexistence, and whitespaces
- Economic and game-theoretic
- Testbeds

Spectrum Occupancy

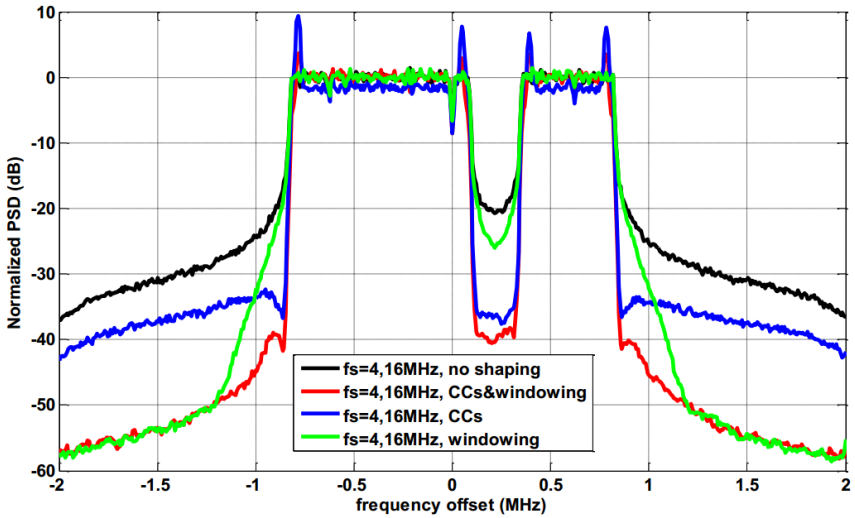
"If you can't measure something, you can't understand it" – H. James Harrington

- Measurement, data analysis, and modeling are critical to both the technology and policy of Dynamic Spectrum Access



PHY-Layer

- Signal design for easy detection at very low SNR
- Signal design for avoiding occupied spectrum



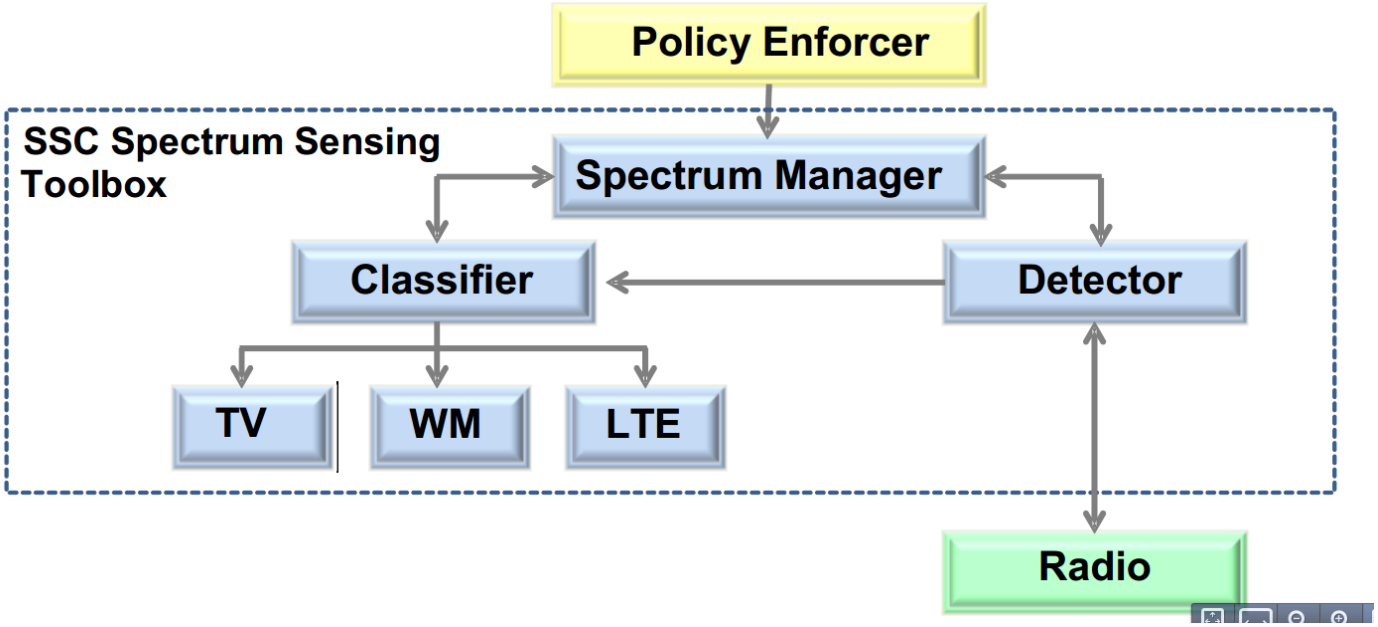
- System design for avoiding interfering with primary users
- System design for resilience to interference from primary users

MAC-Layer

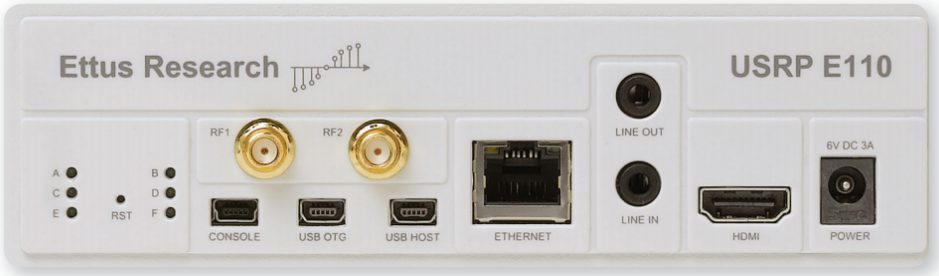
- Protocol design for detecting other users
  - Sensing
  - Packet loss or channel condition
- Protocol design for avoiding those users
  - in time
  - in frequency
- Rendezvous in uncertain channel conditions
  - Each side might sense different primary usage

Spectrum Sensing

- Spectrum Sensing Toolbox from Shared Spectrum Company



- Built around the USRP E110



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Whitespaces

- COGEU
  - http://www.ict-cogeu.eu/pdf/COGEU_D5.4%20(ICT_248560).pdf
- Original Microsoft whitespace demonstration radio used USRP

Economic and Game-theoretic

- University of Houston Wireless Amigo Lab
  - USRP2-based testbed for cooperative cognitive radios
  - Investigating coalition-forming games
- http://www.cis.temple.edu/~wu/research/publications/Publication_files/crowncom2.pdf

Testbeds

- Large testbeds are critical to demonstrating real-world CR and DSA success
- Open access lowers the barrier to entry
- Emulab at University of Utah
  - https://www.emulab.net/
- ORBIT/Winlab at Rutgers University
  - http://www.orbit-lab.org/
- CORNET at Virginia Tech
  - http://cornet.wireless.vt.edu/

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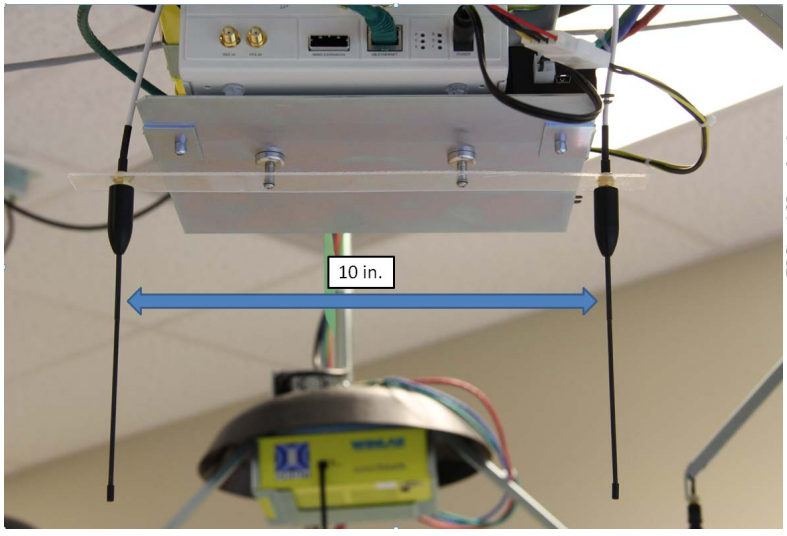
DARPA Spectrum Challenge

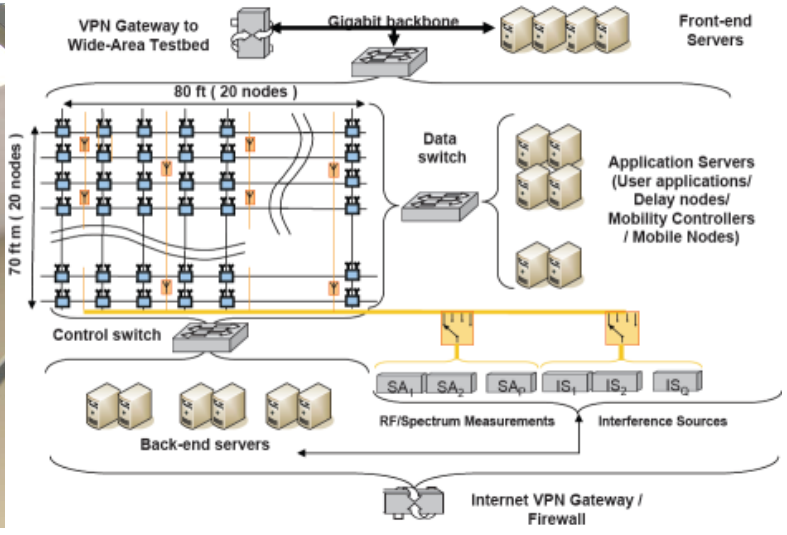
"The DARPA Spectrum Challenge is a competition to demonstrate a radio protocol that can best use a given communication channel in the presence of other dynamic users and interfering signals."

- In the tradition of other successful DARPA challenges
- Year-long competition started in 2013
- $150k in prize money
- 90 teams registered, 46 teams qualified, 18 to compete in finals
- Both competitive and cooperative challenges

Spectrum Challenge

- Hosted at Rutgers Open-Access Research Testbed for Next-Generation Wireless Networks (ORBIT)





- 200 Total nodes, ~50 USRPs

Spectrum Challenge

- Each team allocated 2 USRP nodes
- Other USRP nodes used to generate interference or to monitor the competition in real time
- Two teams compete head to head to see who can transfer files the quickest
- In cooperative mode, teams score higher when their partners do well
- Finals March 19th and 20th in Arlington, VA
  - Open to the public but you have to register
- http://darpa.mil/spectrumchallenge

Third Generation of USRP

- Easy integration of multiple processing paradigms, especially large FPGA fabric
- Very large bandwidth (56 to 160 MHz), very wide frequency coverage
- Massive MIMO scalability
- Three family members to start
  - High integration and ease of use, extremely low cost – B200/B210
  - Low power, handheld MIMO – E300
  - High capability and extreme performance and expandability – X300/X310
- RF Network on Chip Architecture
  - Common FPGA design allows for portable IP development
  - Enable easy FPGA programming without hand written Verilog

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What have we accomplished?

- USRP-based Cellphone Base Stations, both GSM and LTE
- GNU Radio is the dominant platform for research in SDR, Cognitive Radio and DSA
- Open Source leads to reproducible research
- Huge library of code available
  - Open Source means you don't have to reinvent the wheel
- Numerous testbeds
- Heavy presence in specialized radios, prototyping, research, etc.