WIRELESS INSTITUTE

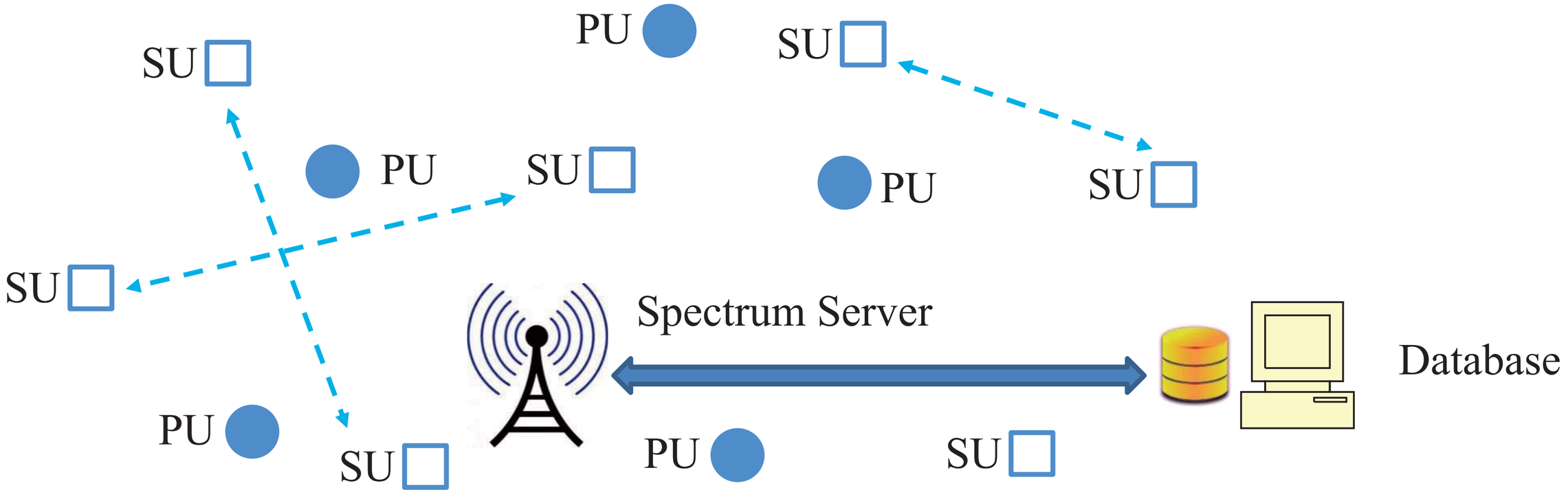
UNIVERSITY OF NOTRE DAME

An LTE-Based Wideband Distributed Spectrum Sharing Architecture

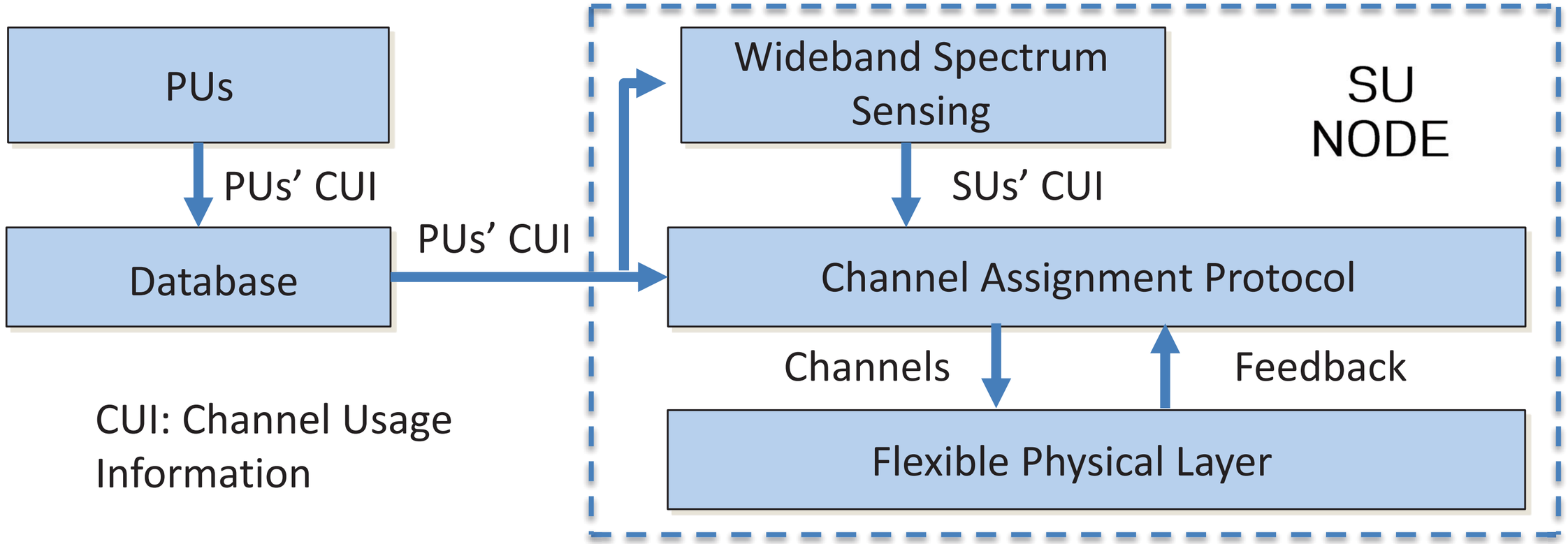
Mingming Cai & J. Nicholas Laneman
Department of Electrical Engineering

WInnComm 2016
Reston, VA

Scenario Considered



System Architecture

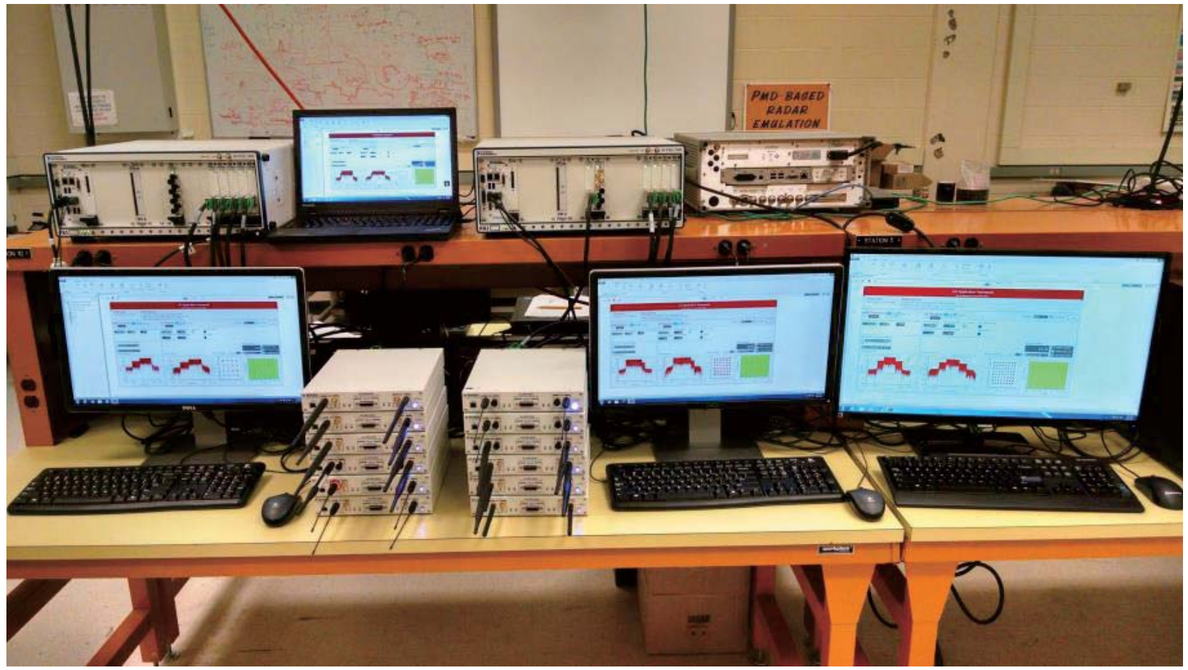


Roadmap

- Sensing-Based Distributed OFDMA
  - DARPA Spectrum Challenge Finalists
  - GNU Radio + Ettus N210 Prototype
  - M. Cai, MS Thesis, University of Notre Dame, August 2014
- System Architecture / SU Channel Assignment Protocols
  - Four levels of database interactions
  - Multi-channel random access with hold (MRAH)
  - Allerton 2015 paper
- Prototypes & Experimental Validation
  - Flexible Wideband Physical Layer (Asilomar 2015)
  - **Simple MAC & System-Level Evaluation (WInnComm 2016)**

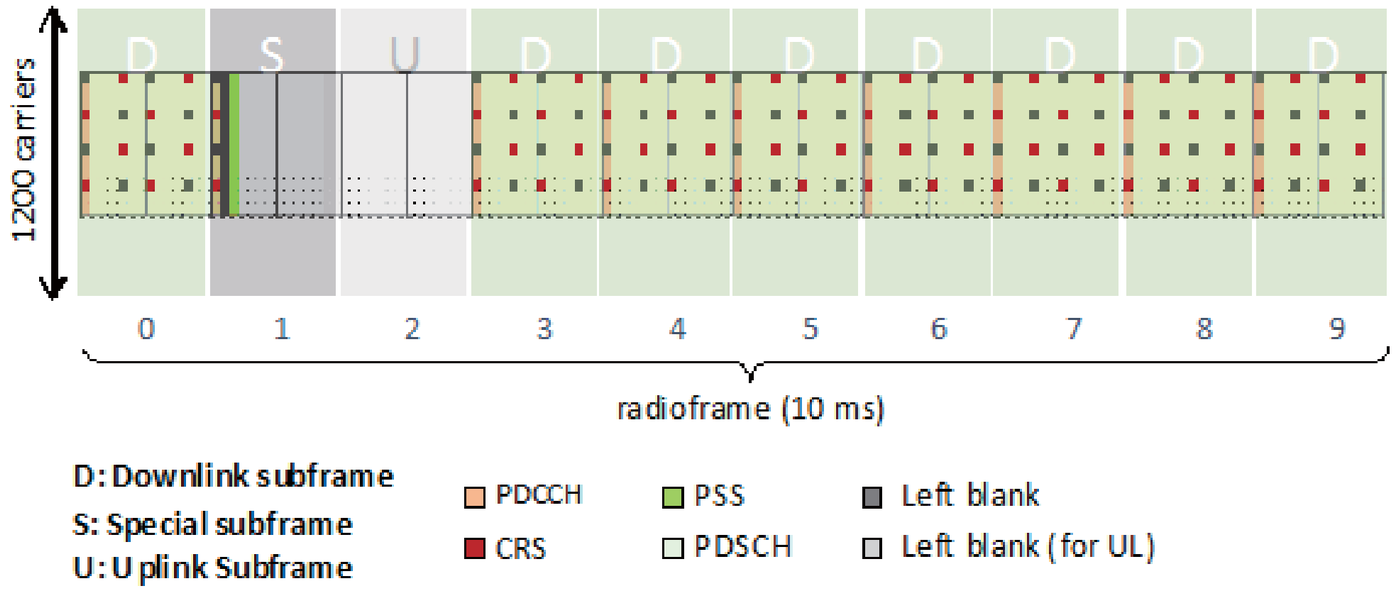
Wideband SDR Network Testbed

- 2 NI PXIs + 12 NI USRP RIO 2953R
  - Tunable center frequency from 1.2 GHz to 6 GHz with 40 MHz channel bandwidth
  - DSP-focused high-performance Xilinx Kintex-7 FPGA
  - LabVIEW Comms, LTE & WiFi App Frameworks
- Up to 24-node networks



Distributed Spectrum Sharing Framework

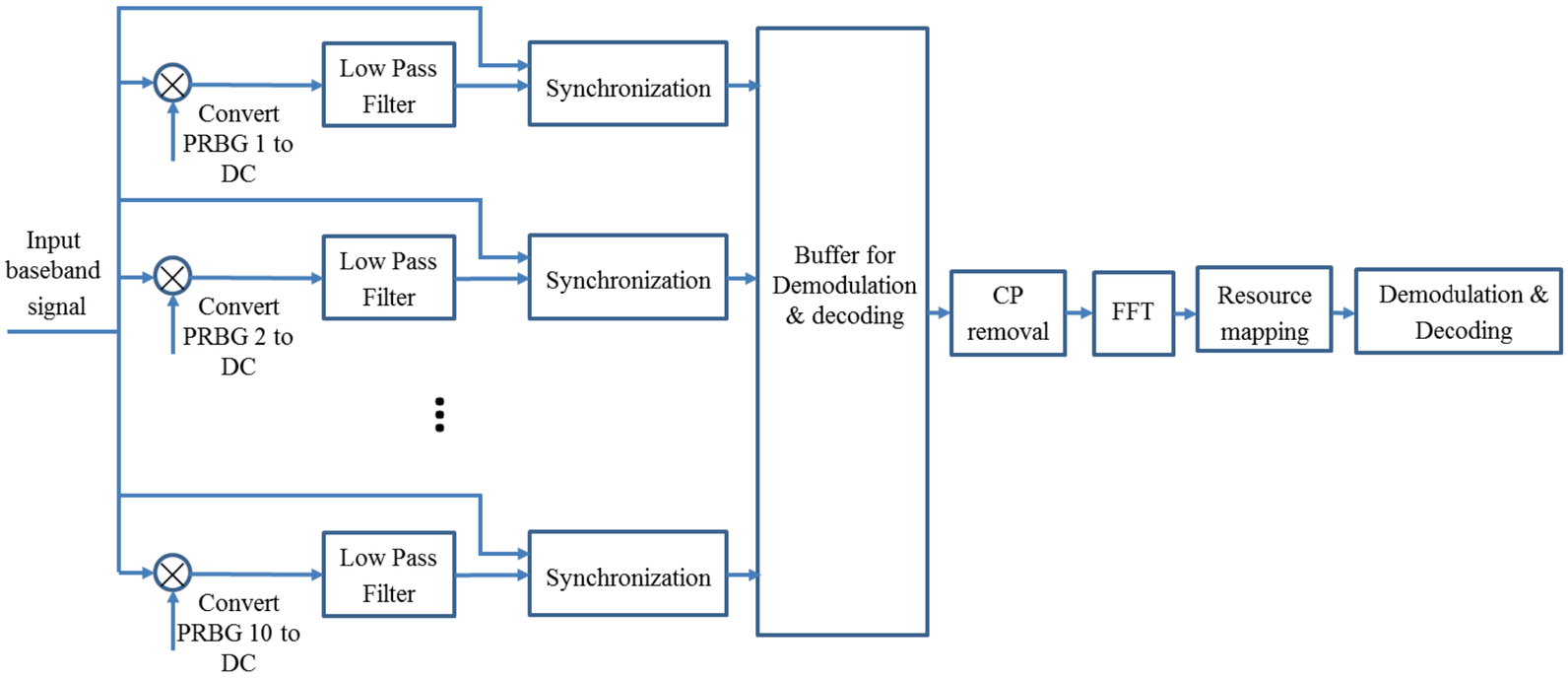
- LTE AF Modifications
  - Channelize 100 PRBs into 10 PRBGs in PHY
  - Energy detection for wideband spectrum sensing
  - Various multi-channel random access protocols, e.g., CSMA, MRAH
- More details in paper



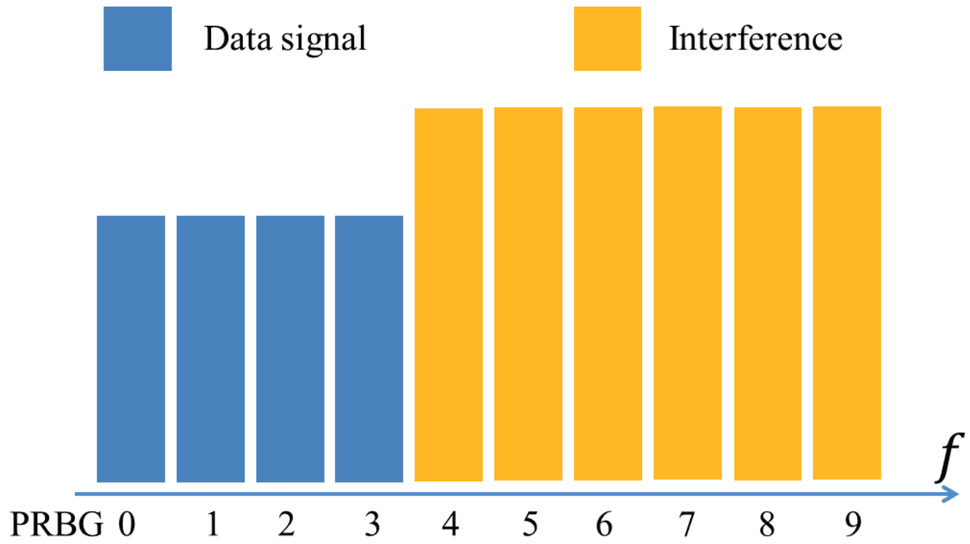
National Instruments, “NI LabVIEW Communications LTE Application Framework White Paper,” Oct. 2015. [Online]. Available: http: //www.ni.com/white-paper/52524/en/

RX Physical Layer Block Diagram

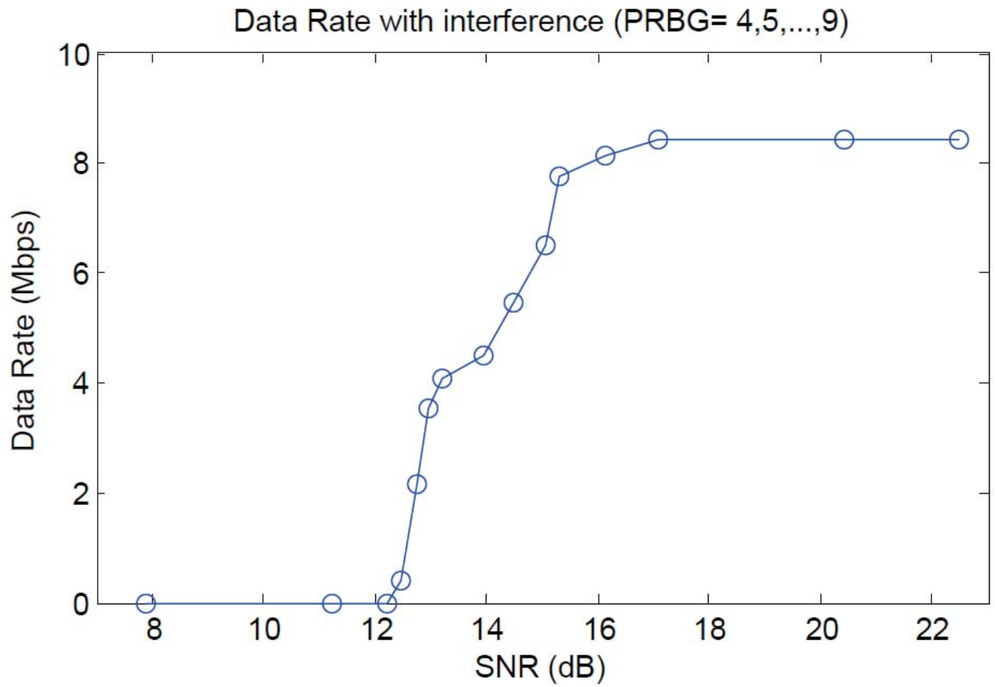
- Multiple Sync loops for immediate rendezvous
- Single demodulation & decoding loop to save FPGA resources



Test of Physical Layer



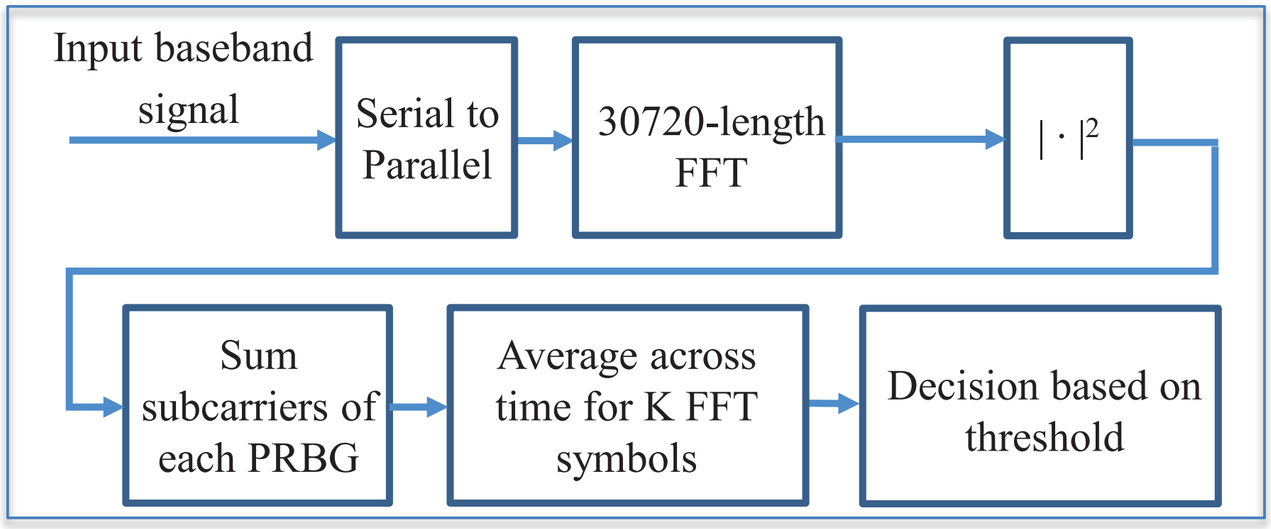
Spectrum allocation

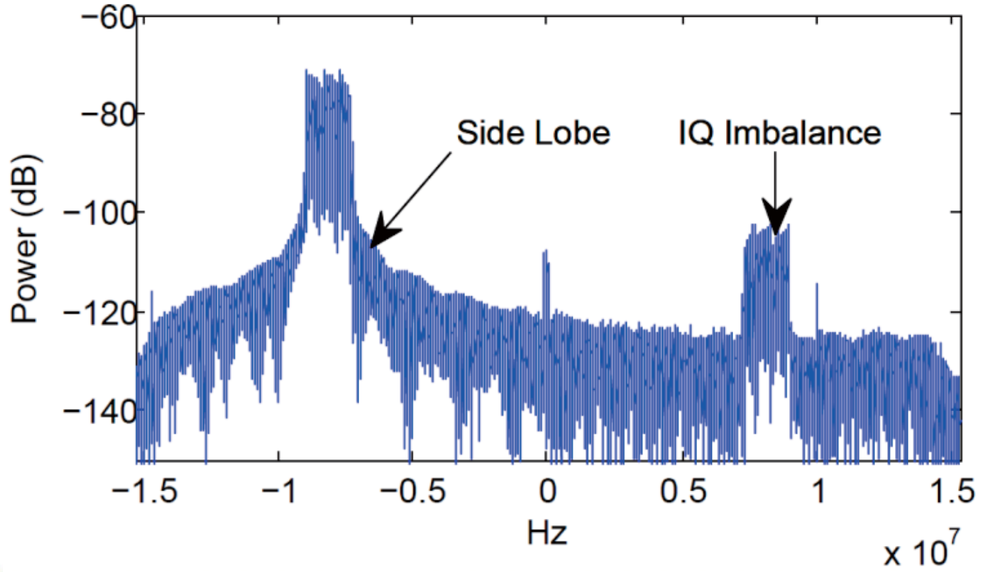


PSS PRBG = 0 and MCS = 16 (16QAM and coding rate 0.64)

Spectrum Analyzer

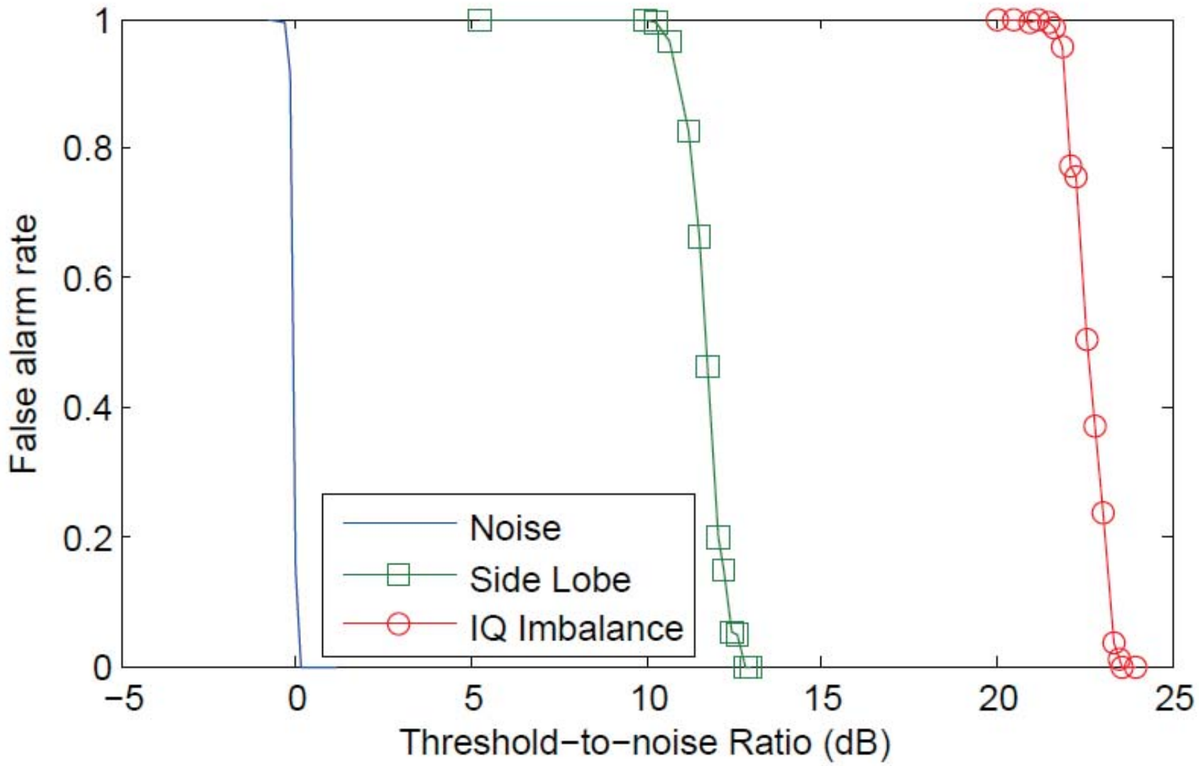
- Spectrum sensing based on energy detection
- Side lobes and IQ imbalance cause detection issues requiring fine tuning





Test of Spectrum Analyzer

- IQ imbalance reduces channel usage or causes interference to data signal
- Threshold that is 3 dB below the average signal power, provides 0.000 miss detection rate



Multichannel CSMA

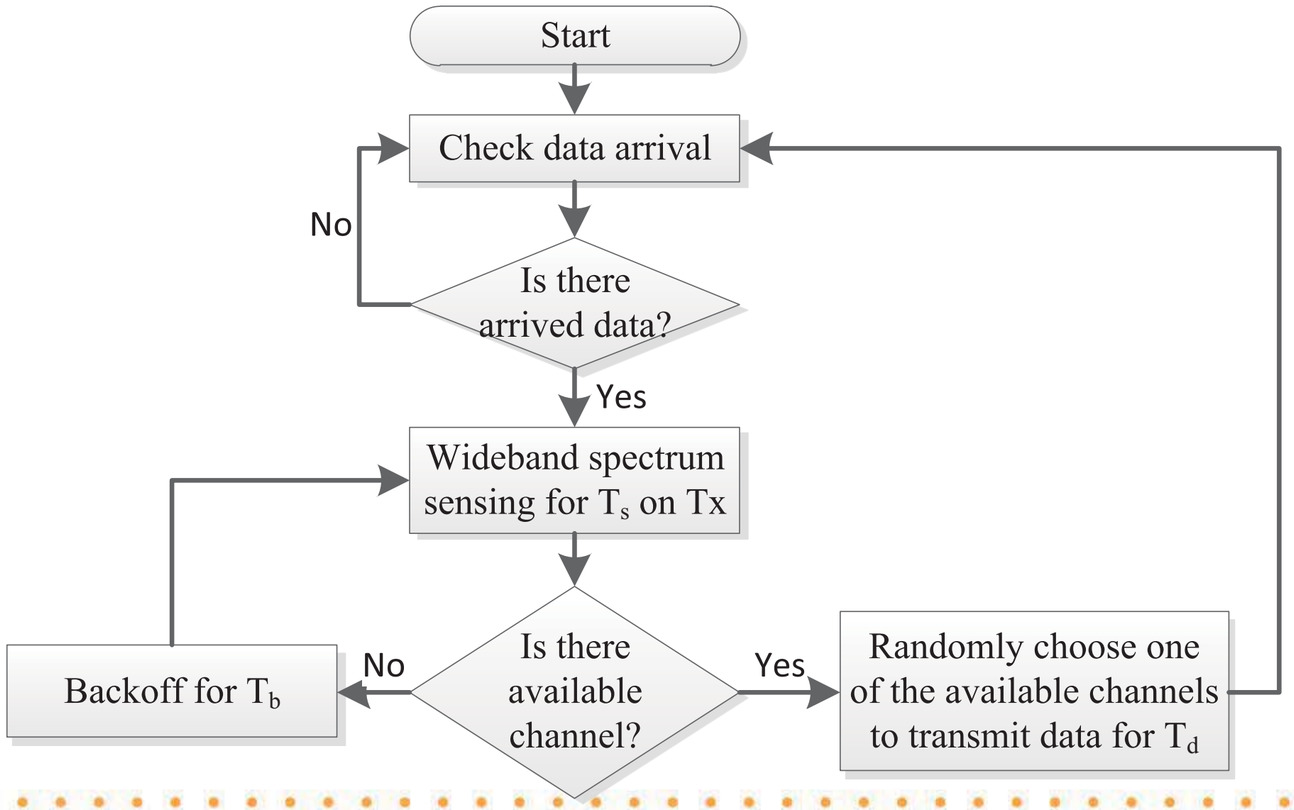
- Spectrum Sharing Efficiency:

$$E = \lim_{t \to \infty} \frac{\sum_{m=1}^{M} D_m}{t \sum_{m=1}^{M} R_m}$$

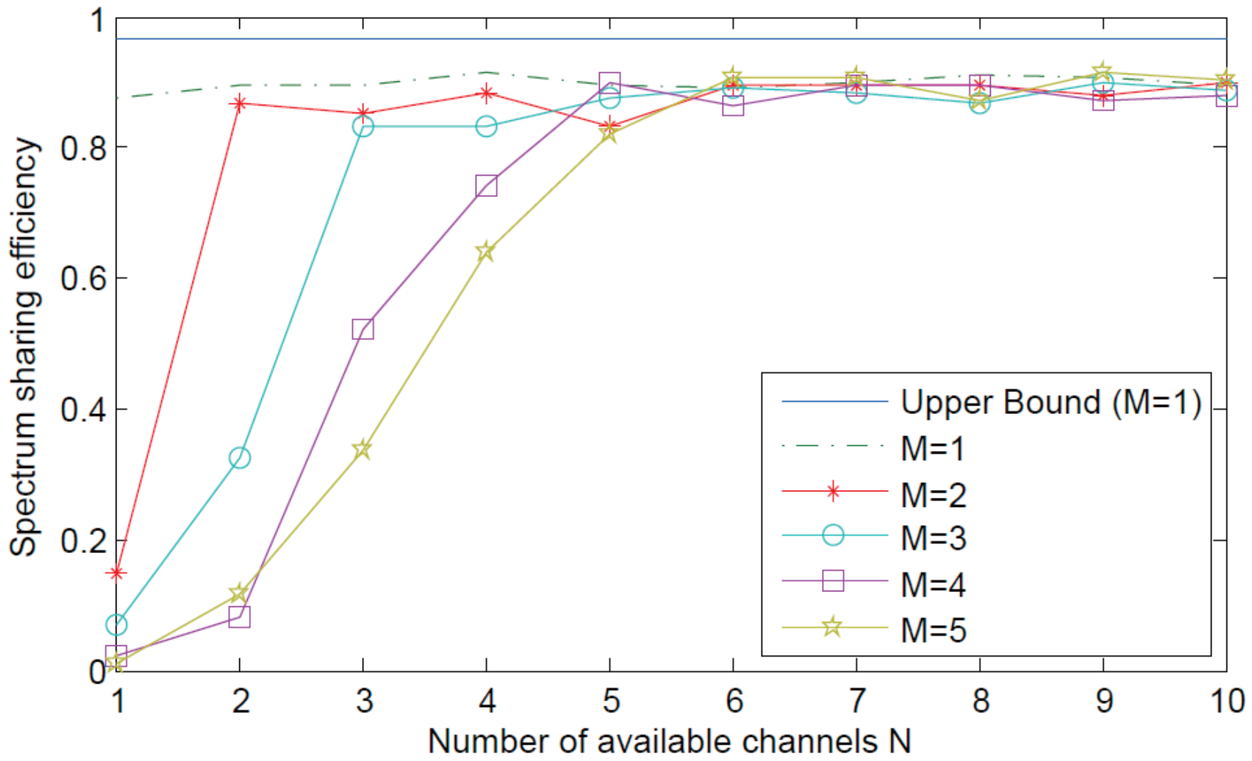
where D_m is the amount of data SU m successfully received in t, and R_m is Tx data rate for SU m.

- Upper bound:

$$E \le \min\left(1, \frac{N}{M}\right) \frac{\mathbb{E}[T_d]}{T_s + \mathbb{E}[T_d]}$$



Test of Whole System



M: number of SU pairs

N: number of available channels

- Spectrum sharing efficiency increases as N increases
- The system has better performance when $N \geq M$

Wrap Up

- Evolving system architecture for database- & sensing-aided distributed spectrum sharing implemented using NI platform
- Flexible, LTE-based physical layer
  - Agile frequency access
  - Fast rendezvous
  - Interference robustness
- MAC layer
  - Wideband spectrum sensing
  - Multi-channel CSMA and MRAH
- Building a sandbox, bring us your ideas!

Acknowledgements

- NSF Grant CCF11-17365
- National Instruments
  - RF / Communications Lead User Program
  - Jörg Hofrichter, Amal Ekbal, & Ian Wong