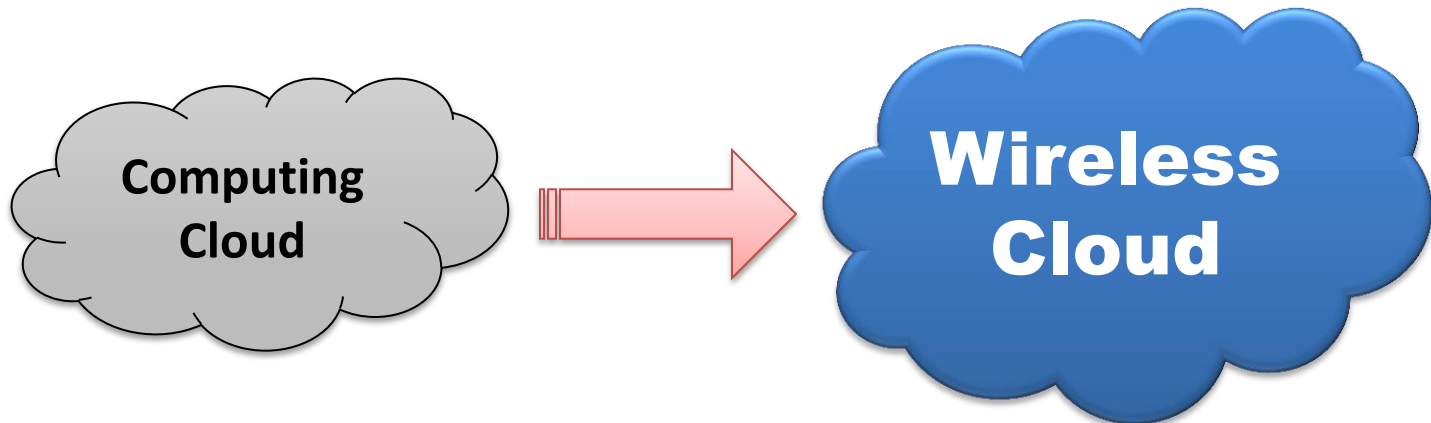


Smart Wireless Interrogators



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Cooperating Professor of Computing and Information Sciences
The University of Maine, Orono

Overview

- Motivations
- Preliminaries
- Scientific Method
 - Device
 - Interrogation System
 - Coding and cooperation
- Project Team
- Q&A



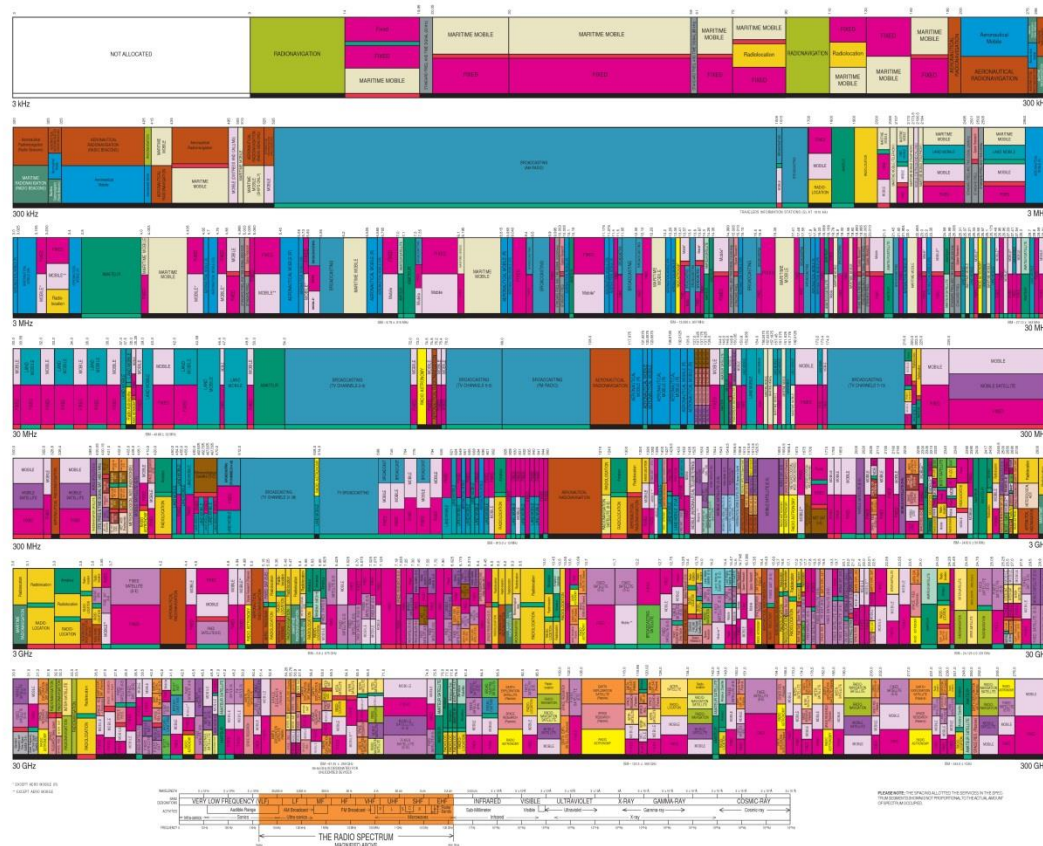
Motivations

- Wireless Sensor Networks can play a crucial role to
 - transform our society to be more energy efficient,
 - provide us with new tools for scientific research,
 - enable an array of new safety and security applications
- Major hurdles in wide spread use of wireless sensing are limited available resources including
 - Power and spectrum
 - Scalability and reliability
- Cognitive cooperation concept is a new approach for efficient use of idle spectrum while allocating optimum power to the wireless interrogators making them SMART*

* **S**pectrum **M**anagement **A**nd **R**esource **T**iming

Scarce Radio Spectrum

UNITED STATES FREQUENCY ALLOCATIONS THE RADIO SPECTRUM



Big Stick Policy



Good Citizen Policy

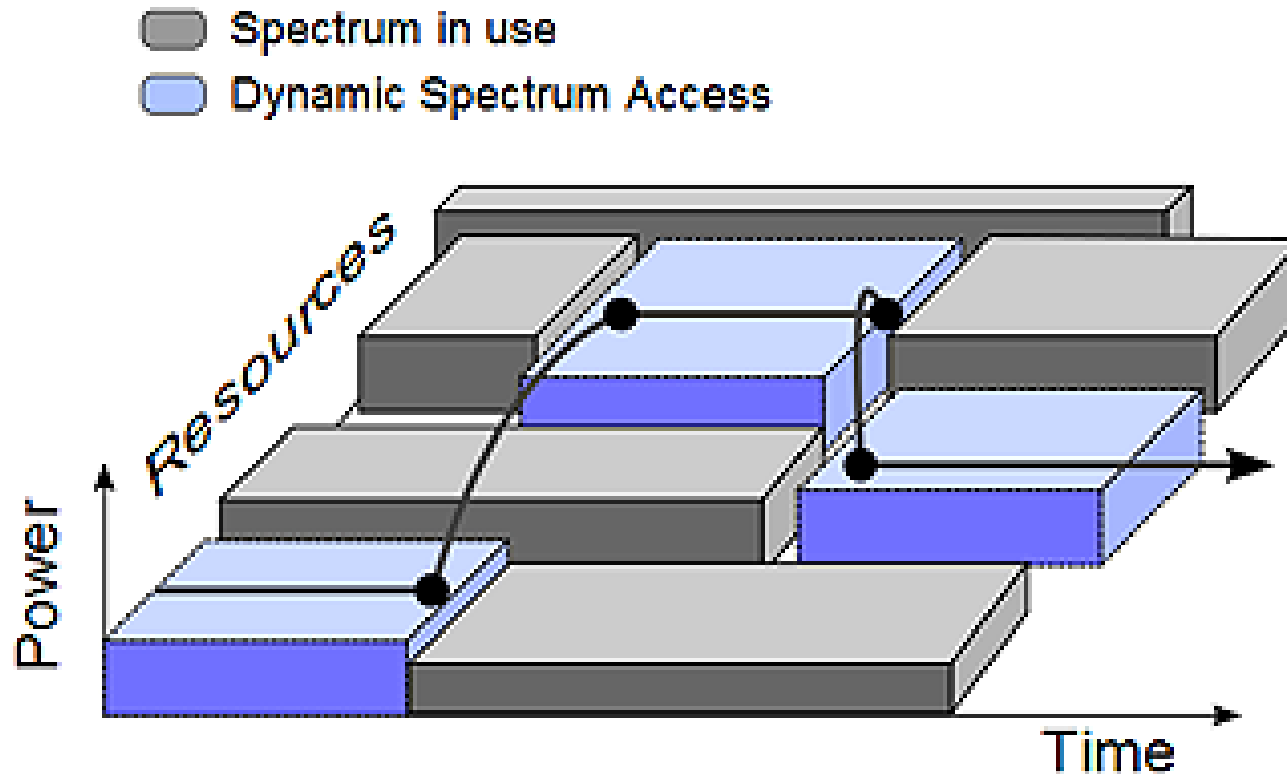
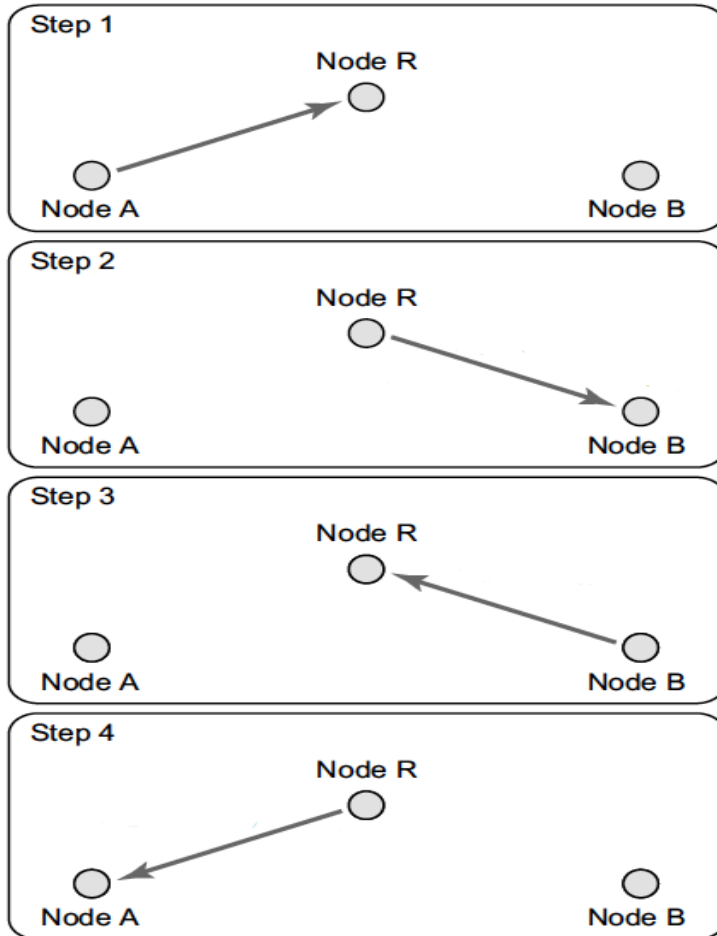


Image Source: <http://www.gonzalo-vazquez-vilar.eu/files/11thesis-gvazquez.pdf>

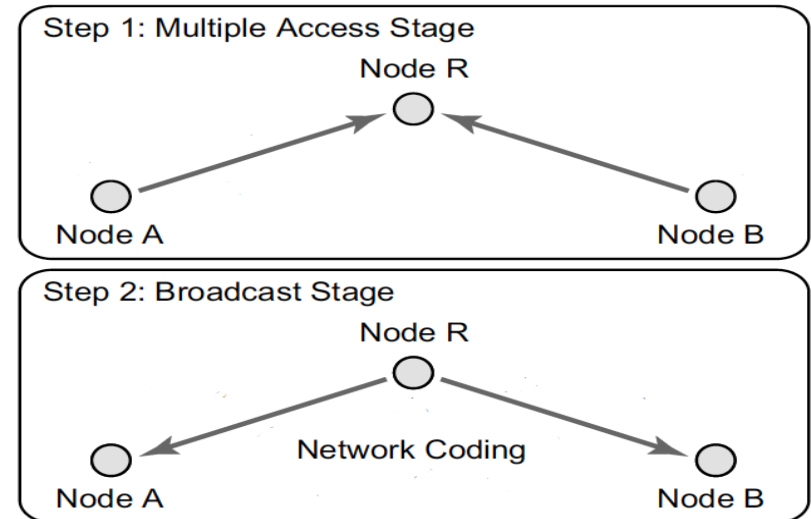
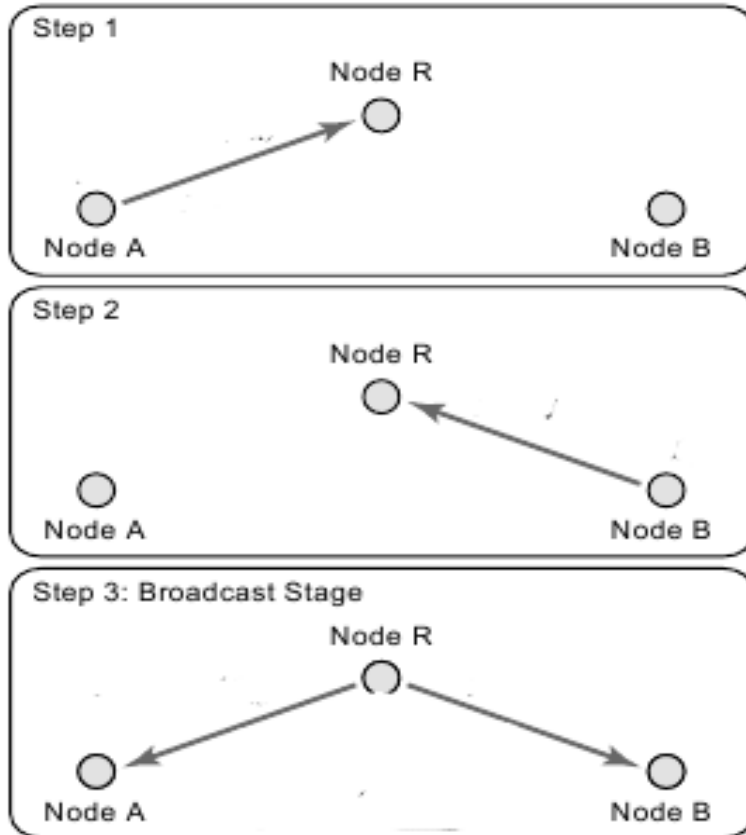
Preliminaries

- Unlicensed interrogators may operate in licensed spectrum as long as
 - they do not interfere with primary licensed users
- Statistics show that licensed spectrum is idle over 70% of the time
- Challenges
 - Imperfections in sensing the spectrum hole
 - time synchronization issues
- What if we allow interference to happen?
 - In return, secondary users can relay primaries' packets
- Methods of game theory can be used for modeling and analyzing
- Efficient spectrum utilization enables a tradeoff between performance and latency in the network, which translates into higher data rates with less power consumption in wireless sensor systems.

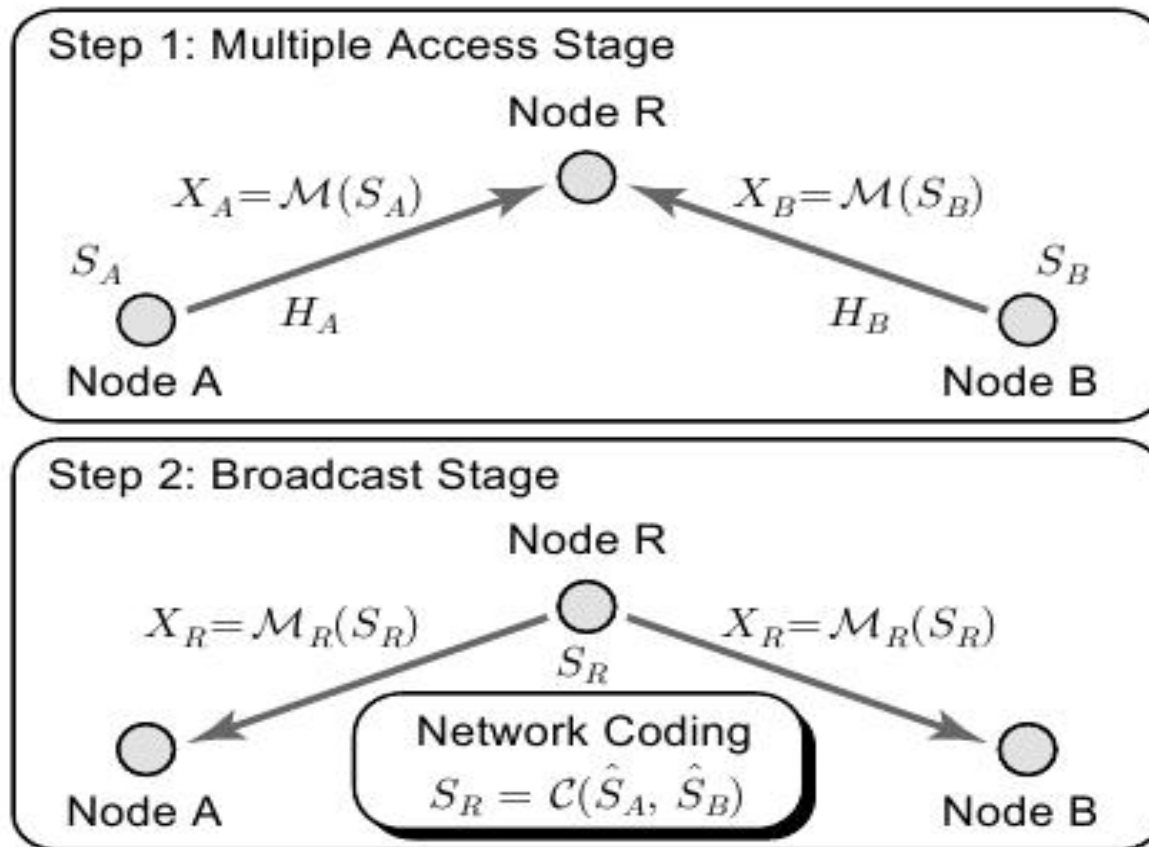
Today: No Interference



Tomorrow: Allowing Interference



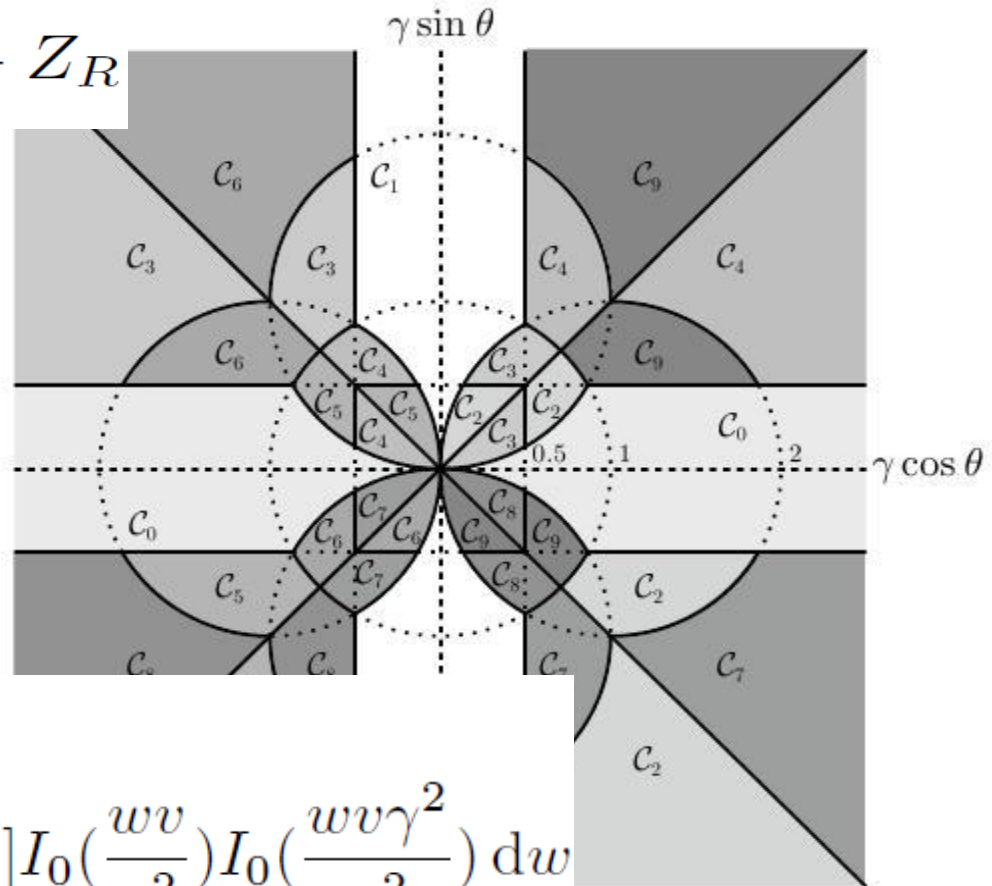
Network Coding



Coding Map

$$Y_R = H_A X_A + H_B X_B + Z_R$$

$$H_B / H_A = \gamma \exp(j\theta)$$

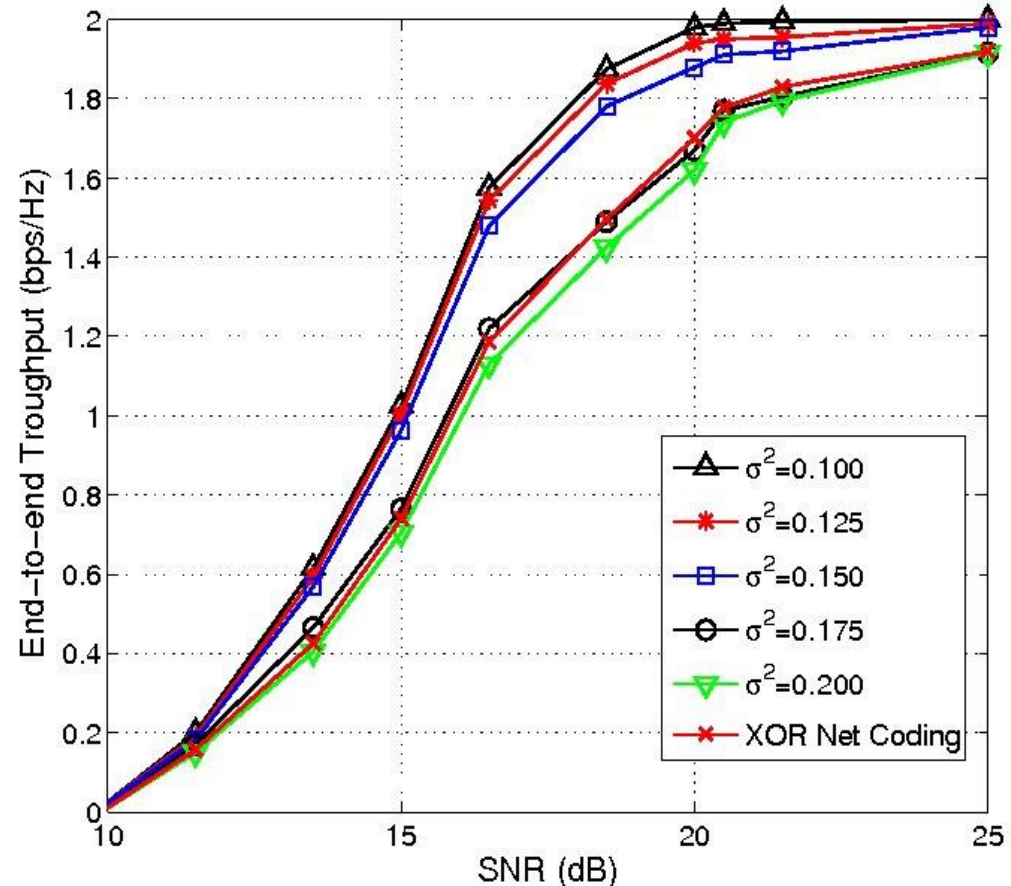


$$f_{X,Y}(x,y) =$$

$$\int_0^\infty \frac{w^3}{\sigma_r^4} \exp\left[-\frac{(\gamma^2 + 1)w^2 + 2v^2}{2\sigma_r^2}\right] I_0\left(\frac{wv}{\sigma_r^2}\right) I_0\left(\frac{wv\gamma^2}{\sigma_r^2}\right) dw$$

Robustness

Channel Estimation Error

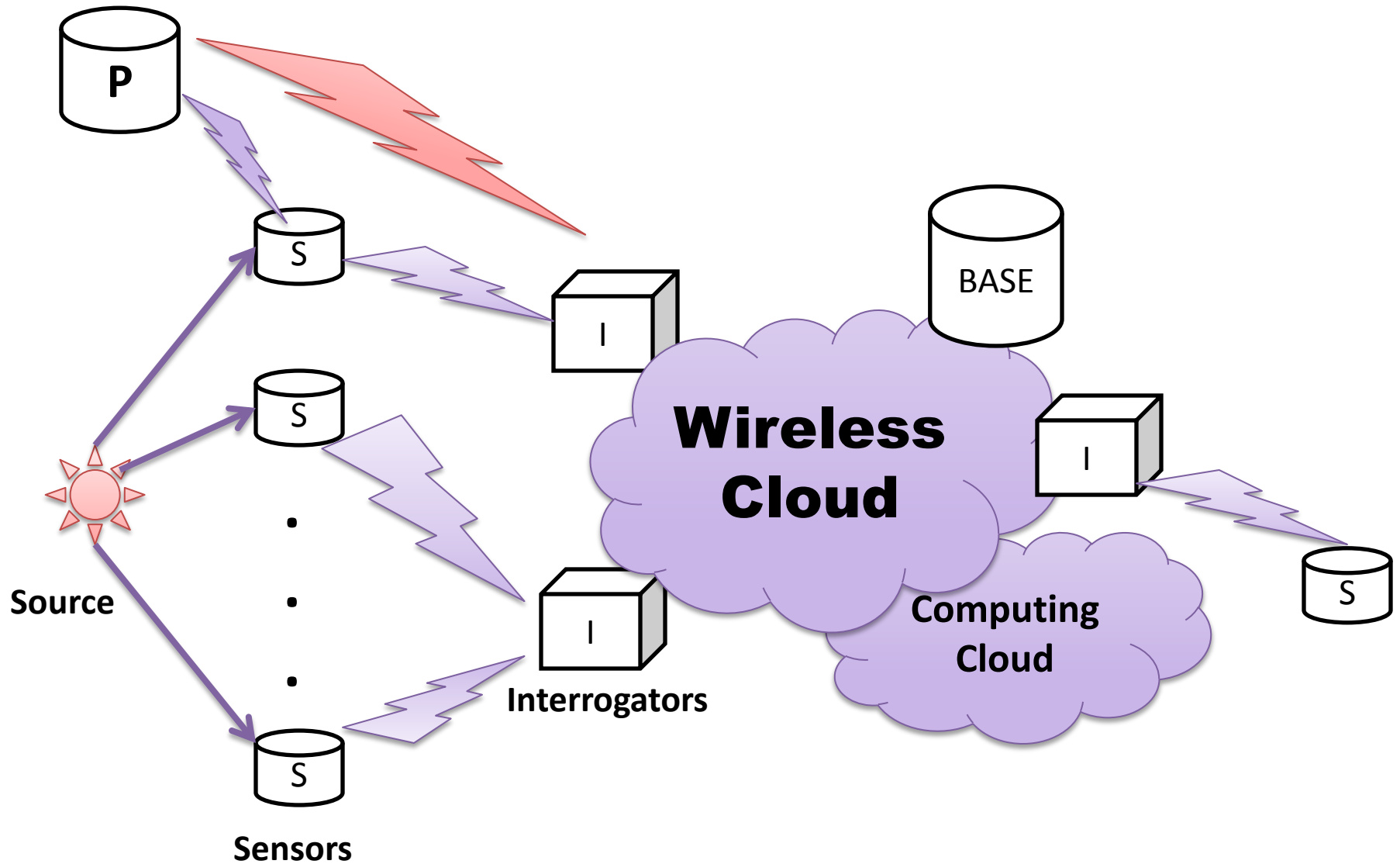


Yasami, Razi, Abedi, "Analysis of Channel Estimation Error in Physical Layer Network Coding," IEEE Communications Letters, vol. 15, no. 10, pp. 1029-1031, October 2011.

Preventing this....

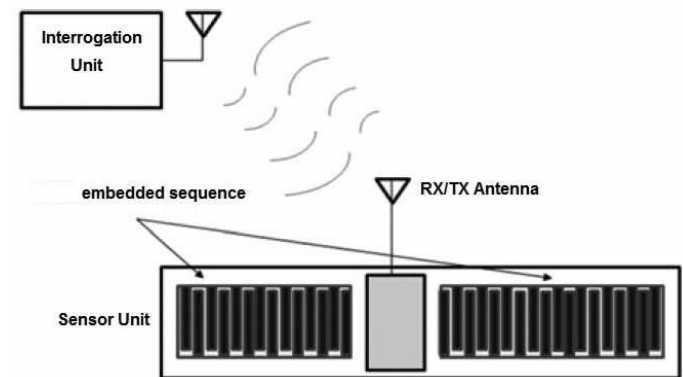
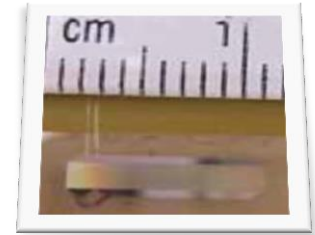


Smart Interrogators



Passive Wireless Device

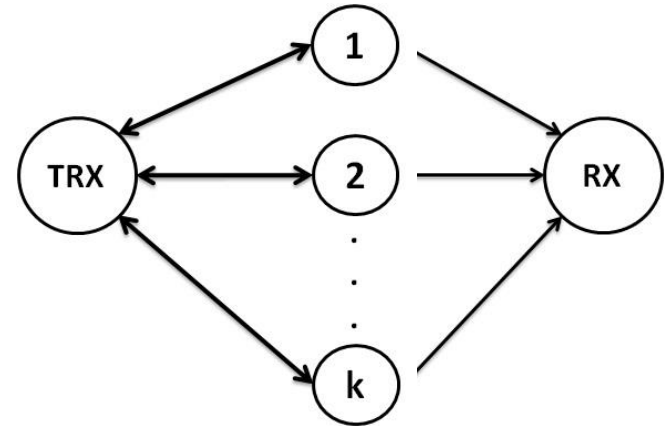
- Coded multi-sensor operation*
- Passive sensors can be designed for measuring physical parameters such as temperature, humidity, pressure, and strain
- Passive sensors can be read
 - In groups at the same time; or
 - One at a time



* Dudzik, Abedi, Hummels, da Cunha, "Wireless Multiple Access Passive Coded Sensor System," IEEE IUS'08, Nov 2008, Beijing, China, pp. 1116-1119.

Interrogation System

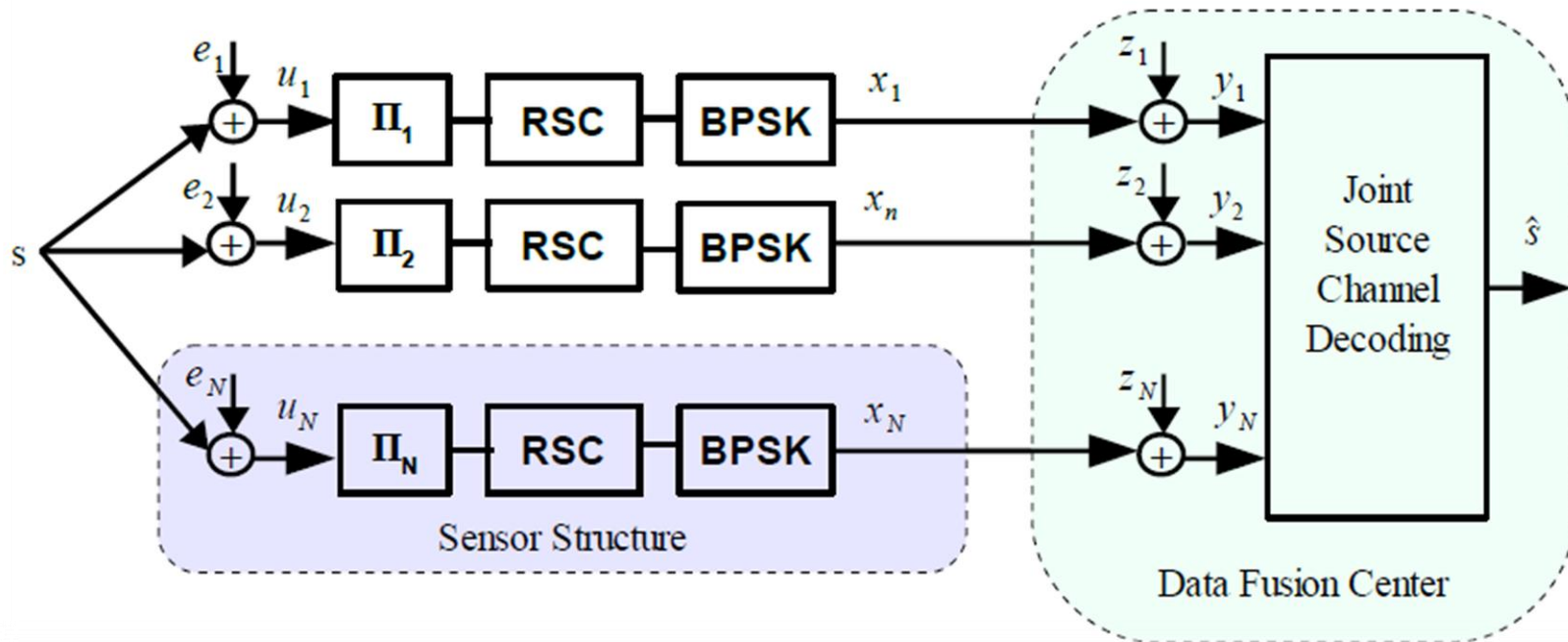
- Depending on the signal to noise and interference ratios, one of the following two interrogation modes can be chosen:
 - **Impulse mode:** a wide band read signal will invoke all sensors
 - **Singular mode:** a narrow band coded read signal will invoke one specific sensor at a time



Diamond Channel: conventional wireless relaying model

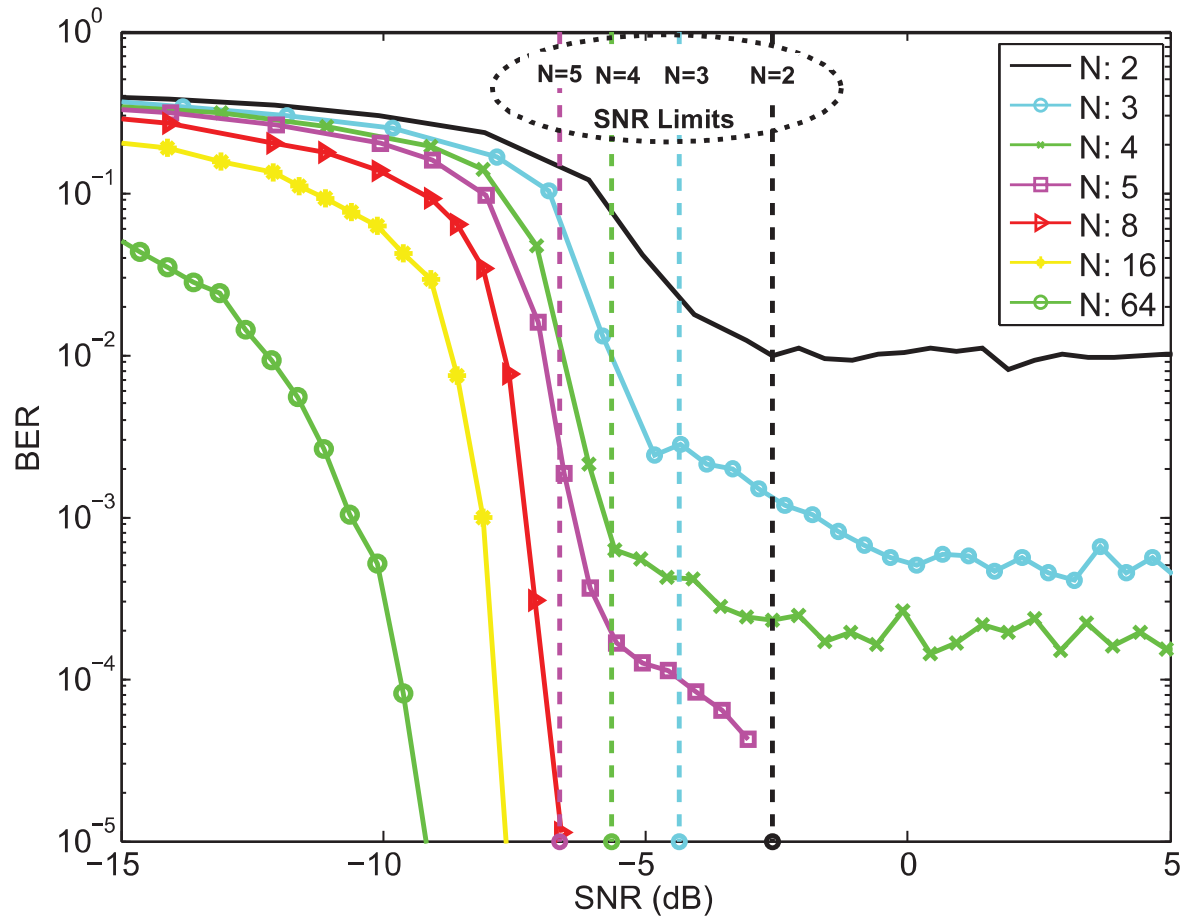
Folded Diamond Channel: a more accurate model proposed in this project for the first time

Distributed Coding

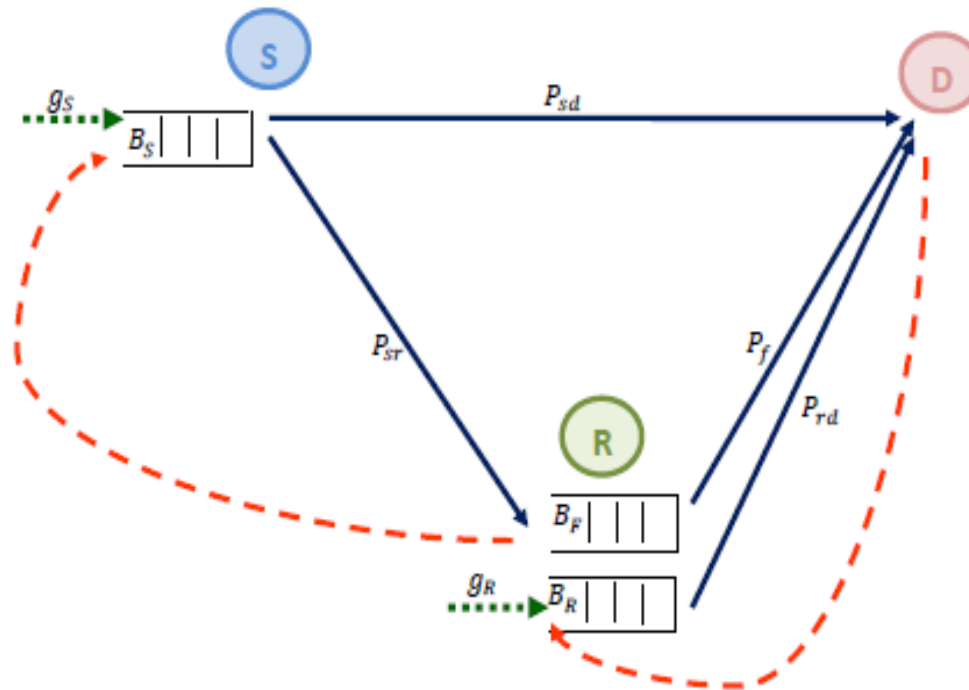


Razi, Yasami, Abedi, "On Minimum Number of Wireless Sensors Required for Reliable Binary Source Estimation," IEEE WCNC'11, March 2011, Cancun, Mexico, pp. 1852-1857.

How many sensors?

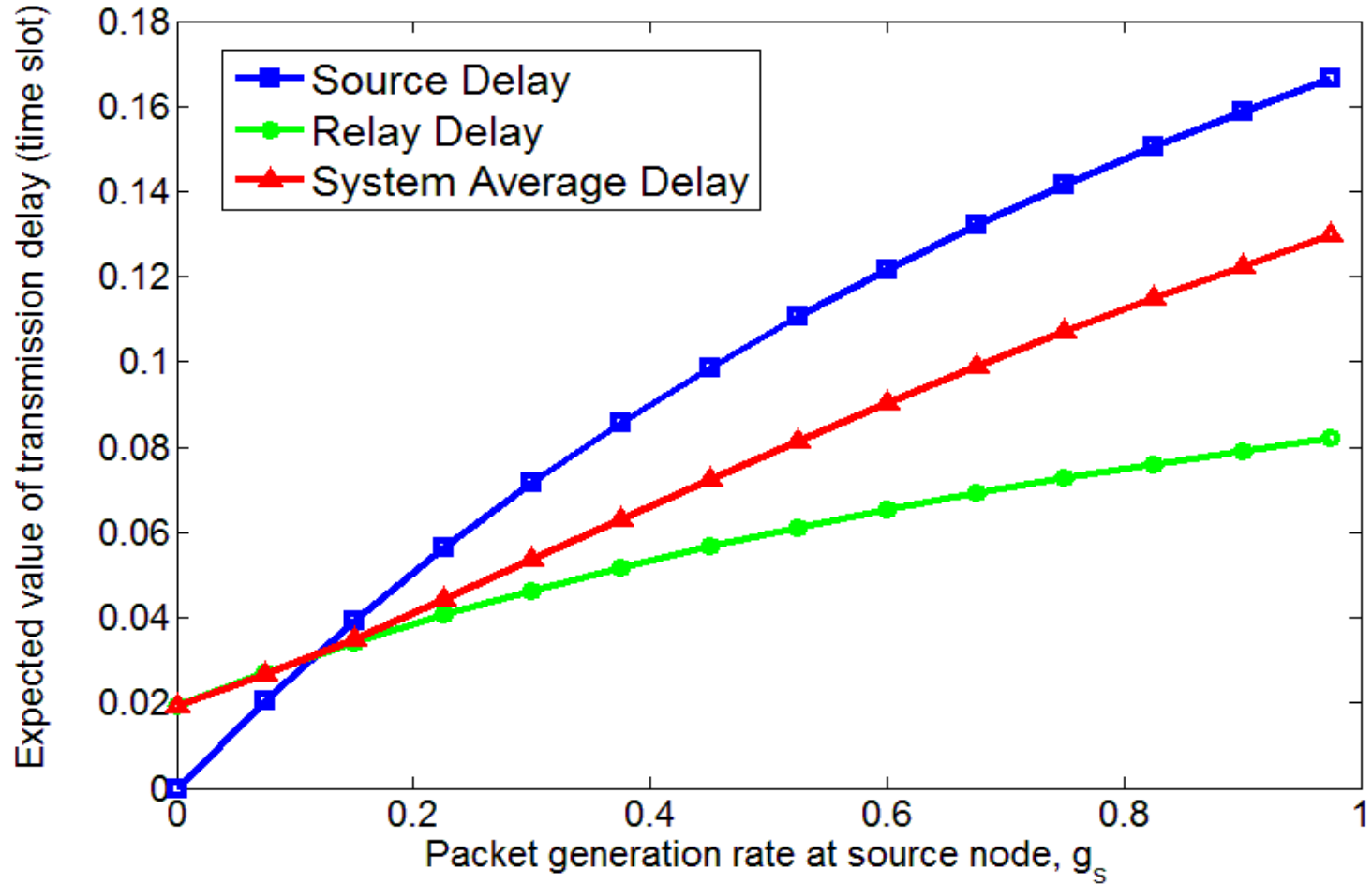


Cooperating Relaying

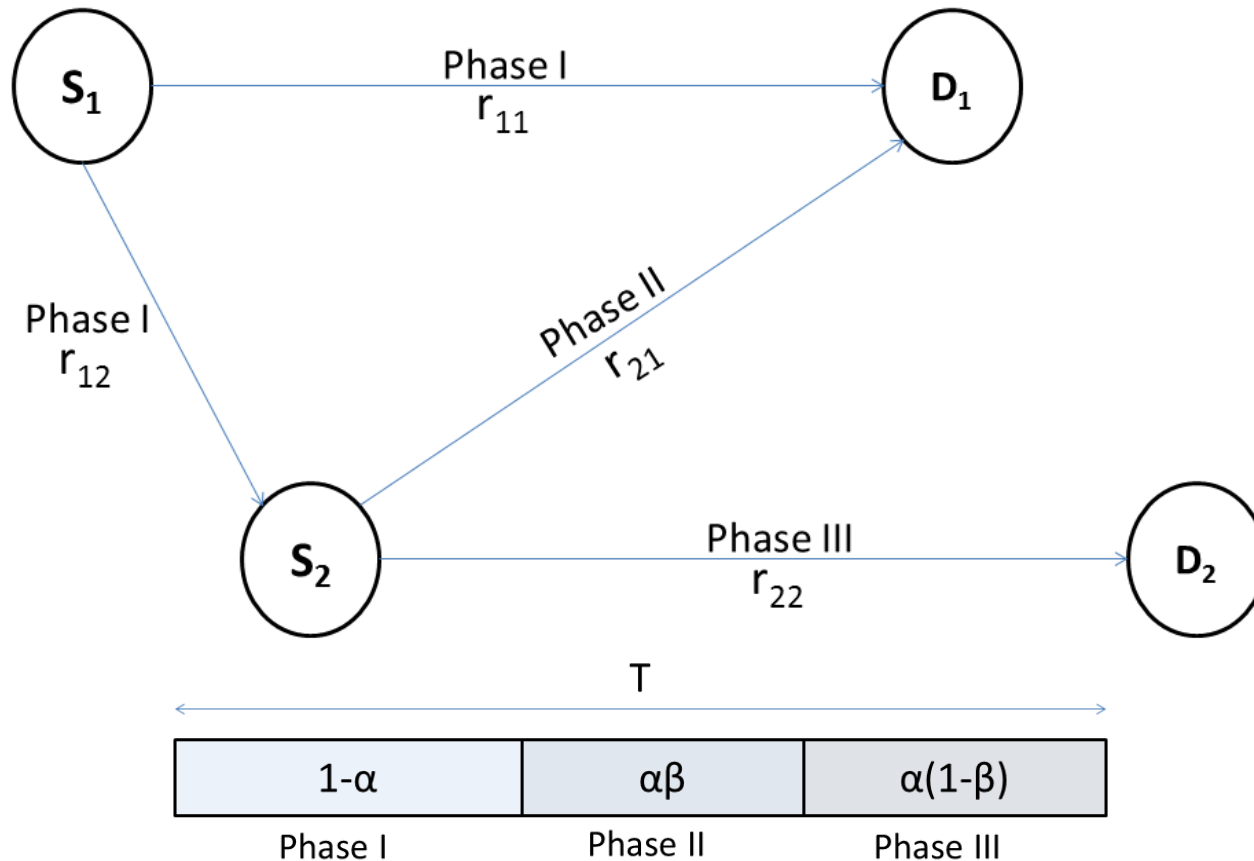


Afghah, Razi, Abedi, "Throughput Optimization in Relay Networks Using Markovian Game Theory," IEEE WCNC'11, March 2011, Cancun, Mexico, pp. 1080-1085.

Latency Reduction

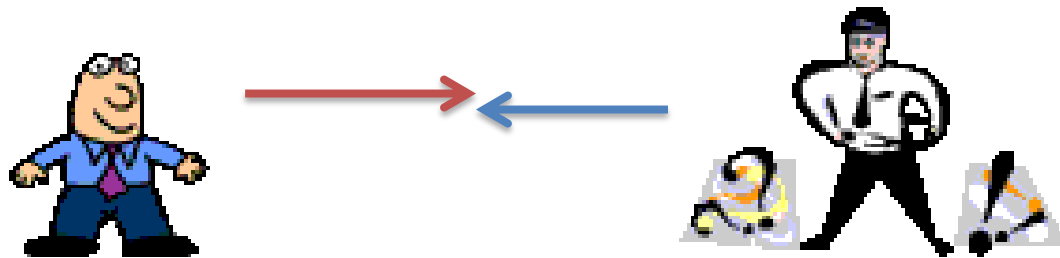


Cognitive Cooperation

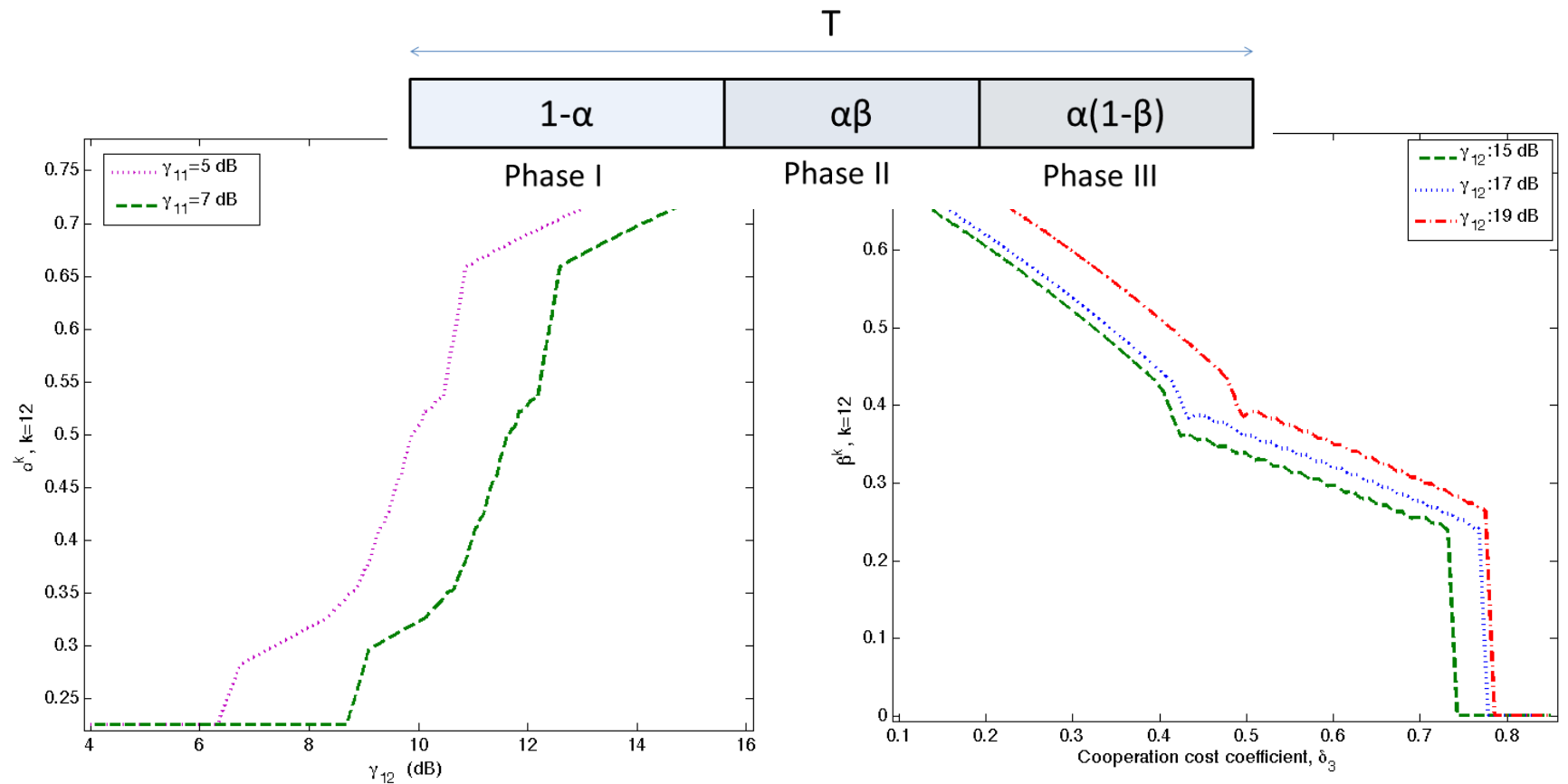


Afghah, Costa, Razi, Abedi and Ephremides, "A Reputation-based Stackelberg Game Approach for Spectrum Sharing with Cognitive Cooperation", IEEE CDC 2013, Submitted

Game Theory



Some Results

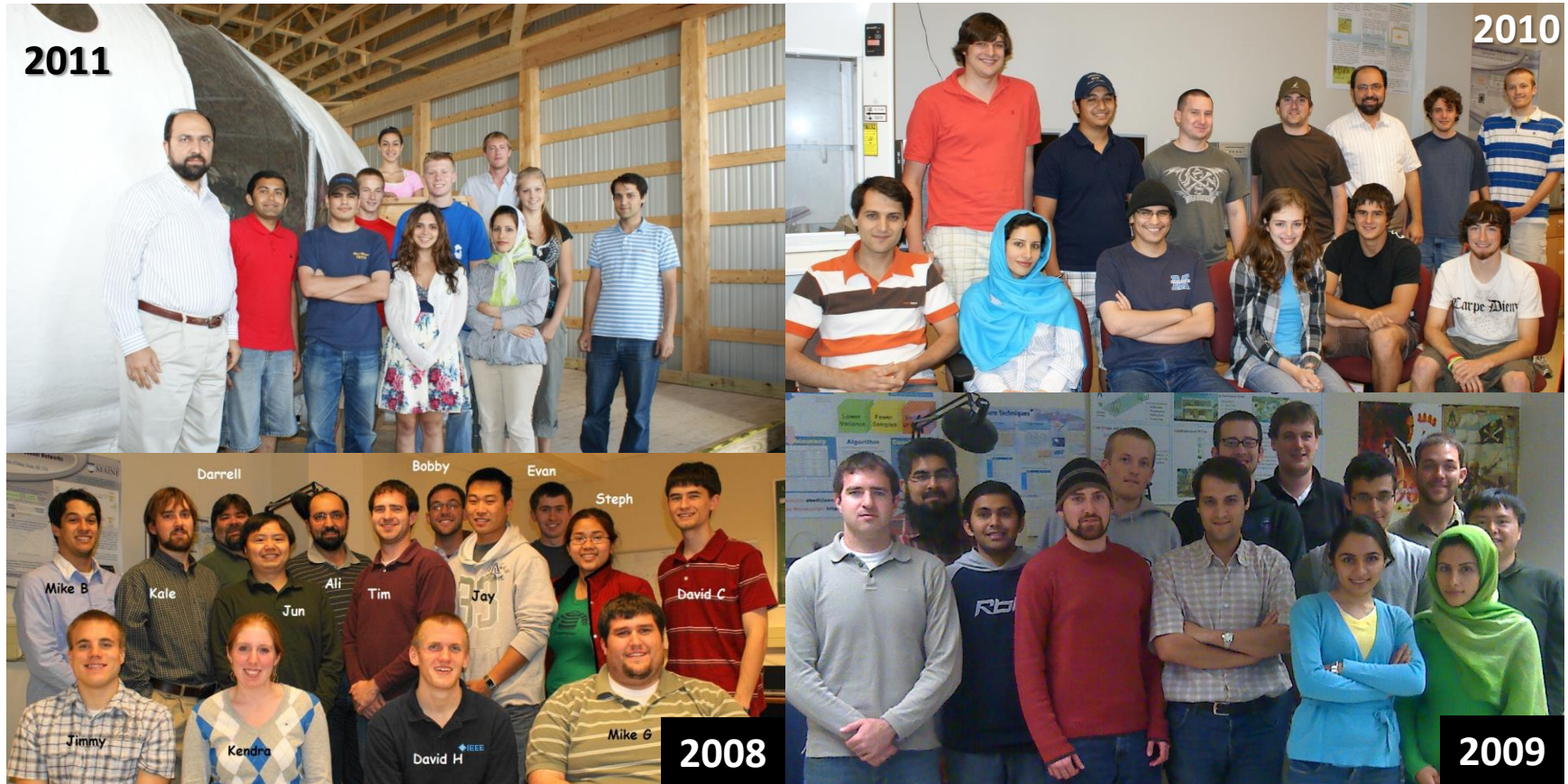


Effect of relay channel quality

Effect of cooperation cost coefficient

Project Team

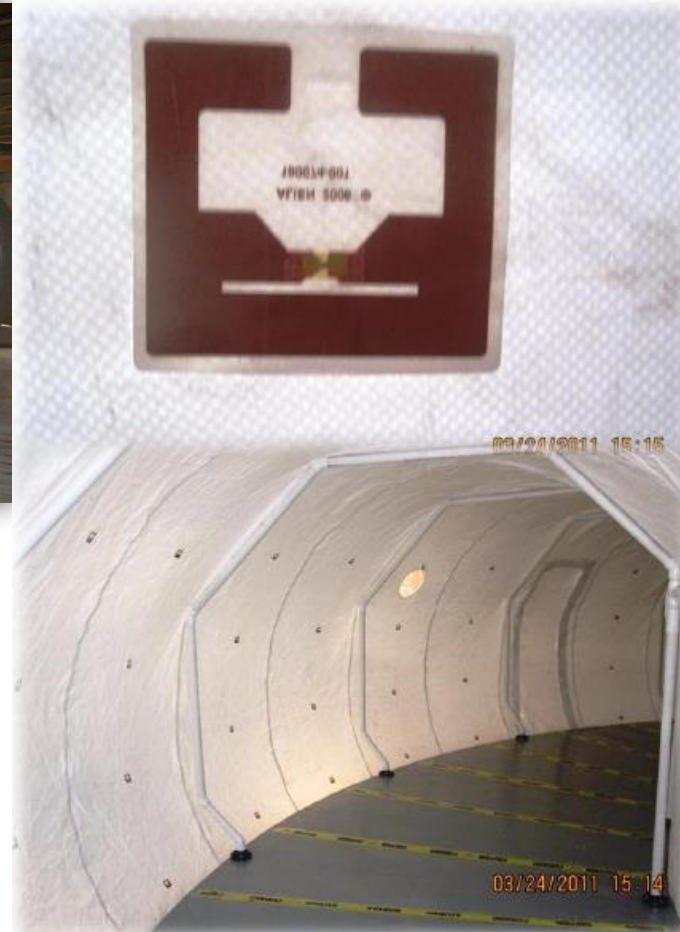
(70 students from US (ME,KS,AZ,FL,VA), Canada, Europe, Asia,...)



Inflatable Lunar Habitat with Live Web Link



42 ft diameter concentric torus built at NASA JSC (Houston) and instrumented with 124 wireless tags (900 MHz) and 16 temp/humidity sensors (2.4 GHz) by WiSe-Net Lab student team.



in Collaboration with IEEE, NASA, CSA, ESA

WiSEE
2013

**IEEE International Conference
on Wireless for Space and
Extreme Environments**
Baltimore, Maryland
November 7–9, 2013

 **IEEE**
<http://sites.ieee.org/wisee>

2013 in Baltimore, MD
Right after IEEE Sensors Conference (same venue)

2014 in Barcelona, Spain

2015 in Montreal, Canada
and 2016 in Orono, ME

Q&A

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<http://WISENET.EECE.MAINE.EDU>

