Improved Bootstrapping Approach in Multichannel Cognitive Radio Ad Hoc Networks

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Motivation

- **Problem**
  - Establishment and maintenance of common control channels (CCC) in a dynamic environment
- **Research Focus**
  - Investigation of spectrally efficient distributed schemes for establishing and maintaining CCC in CRAHNs

Outline

- Related Work
- Previous Work
- New Problem
- Improvement
- Simulation Results
- Summary

Related work

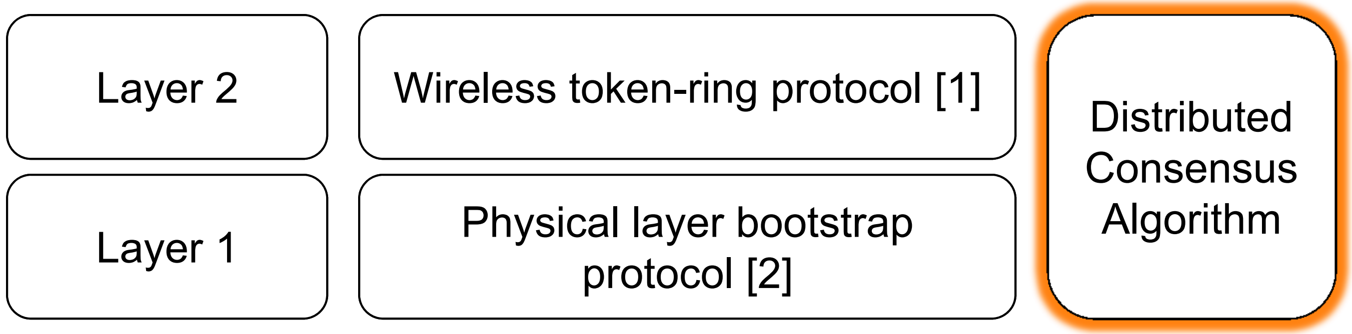
Common Control Channel Design
for
Cognitive Radio Ad Hoc Networks

Approach	Advantages	Disadvantages
Dedicated	Design simplicity	Single point of failure
Ultra-Wide Band	Robust to PU activity	Transmission range
Sequence-Based	Bounded rendezvous time Low network overhead	Hopping sequences not adaptable to PU activity
Group-Based	Efficient broadcasting of control information	High network overhead

Design Goals!

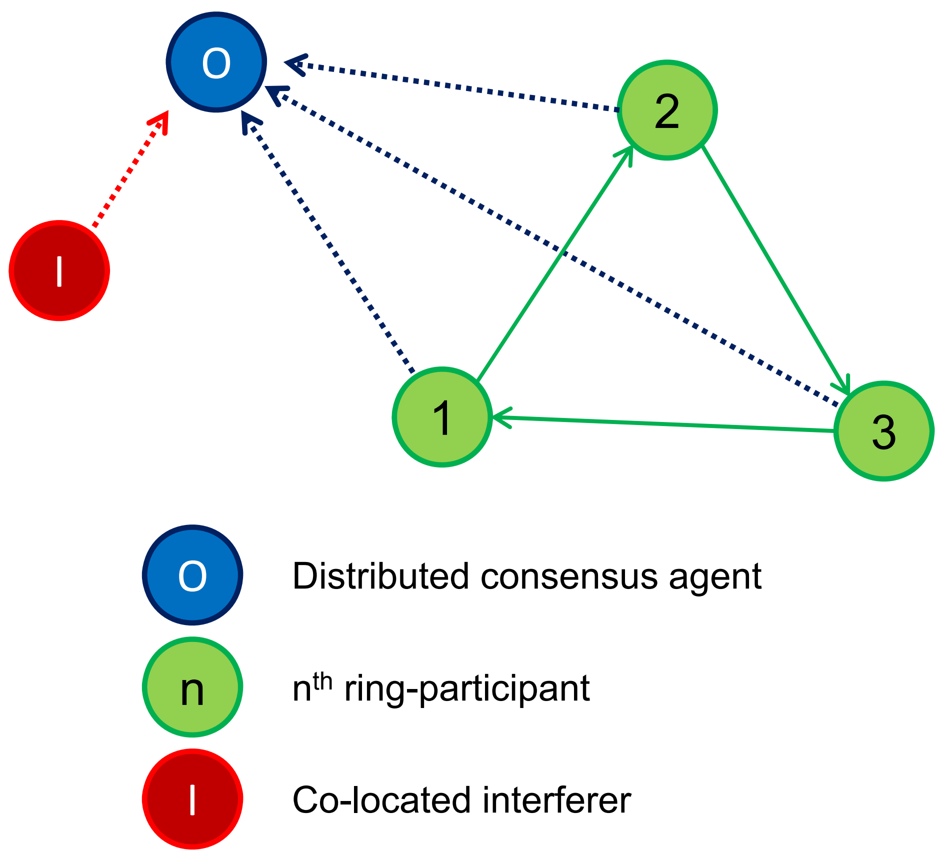
B. Lo, “A survey of common control channel design in cognitive radio networks,” *Physical Communication*, vol. 4, no. 1, pp. 26–39, Mar. 2011.

Previous Work



[1] M. Ergen and D. Lee, “WTRP-wireless token ring protocol,” *Vehicular Technology, IEEE Transactions on*, vol. 53, no. 6, pp. 1863–1881, 2004.
[2] R. Doost-Mohammady et al., “Physical Layer Bootstrapping Protocol for Cognitive Radio Networks,” *Consumer Communications and Networking Conference (CCNC), 2010 7th IEEE*, pp. 1–5, 2010.

Distributed Consensus Algorithm [1]



Set of spectrum opportunities

$$M = \{1, \ldots, m\}$$

Utility Function

$$U(m) = \frac{B_m}{|N_m|} \sum_{n \in N_m} \log_2 (1 + SINR_n)$$

Handover solution

$$\arg\max_m U(m)$$

Received signal vector

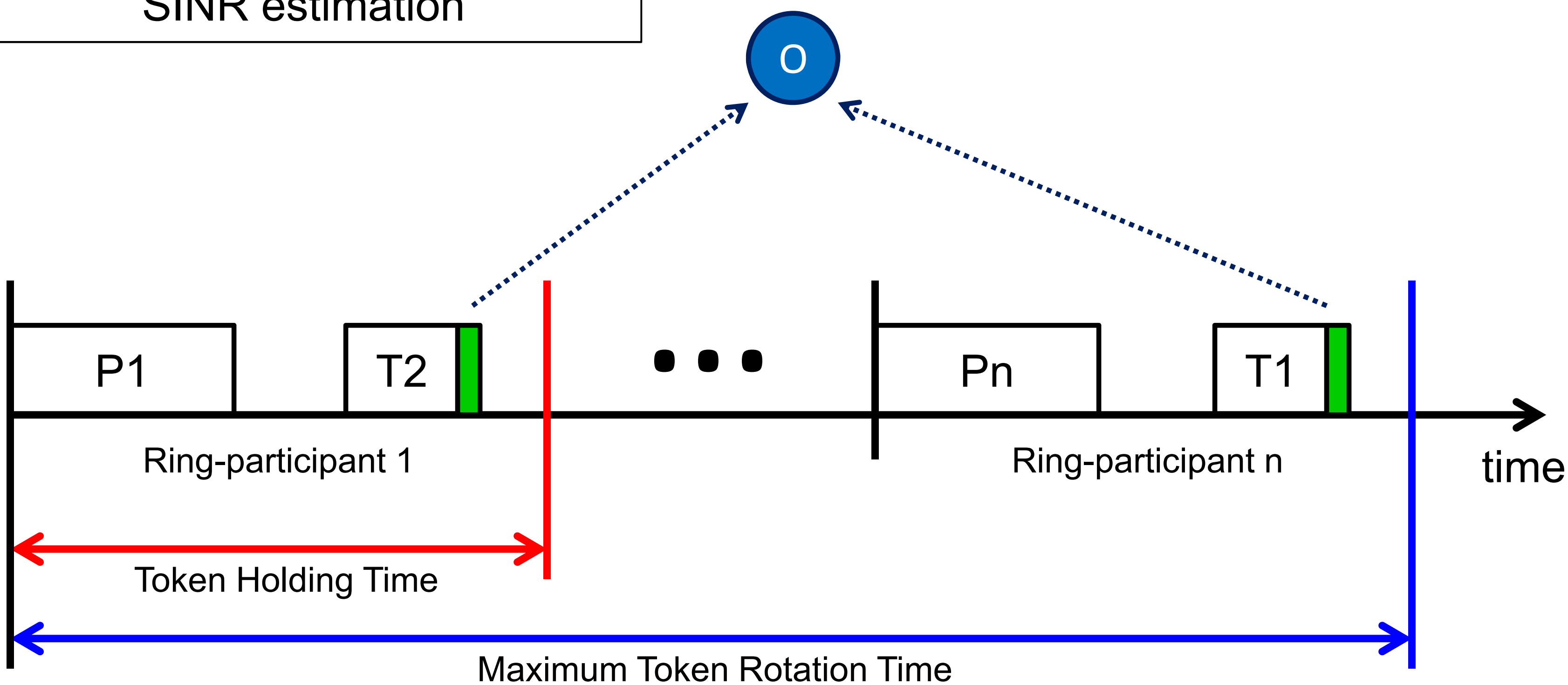
Interference vector

Direction of token rotation

[1] P. M. R. dos Santos, M. A. A. Kalil, O. Artemenko, A. Lavrenko, A. Mitschele-Thiel: "Self-Organized Common Control Channel Design for Cognitive Radio Ad Hoc Networks", 2013 IEEE PIMRC, London September 2013

Token-Ring Timing Diagram

Research Idea:
Token-embedded pilot tone
for
SINR estimation



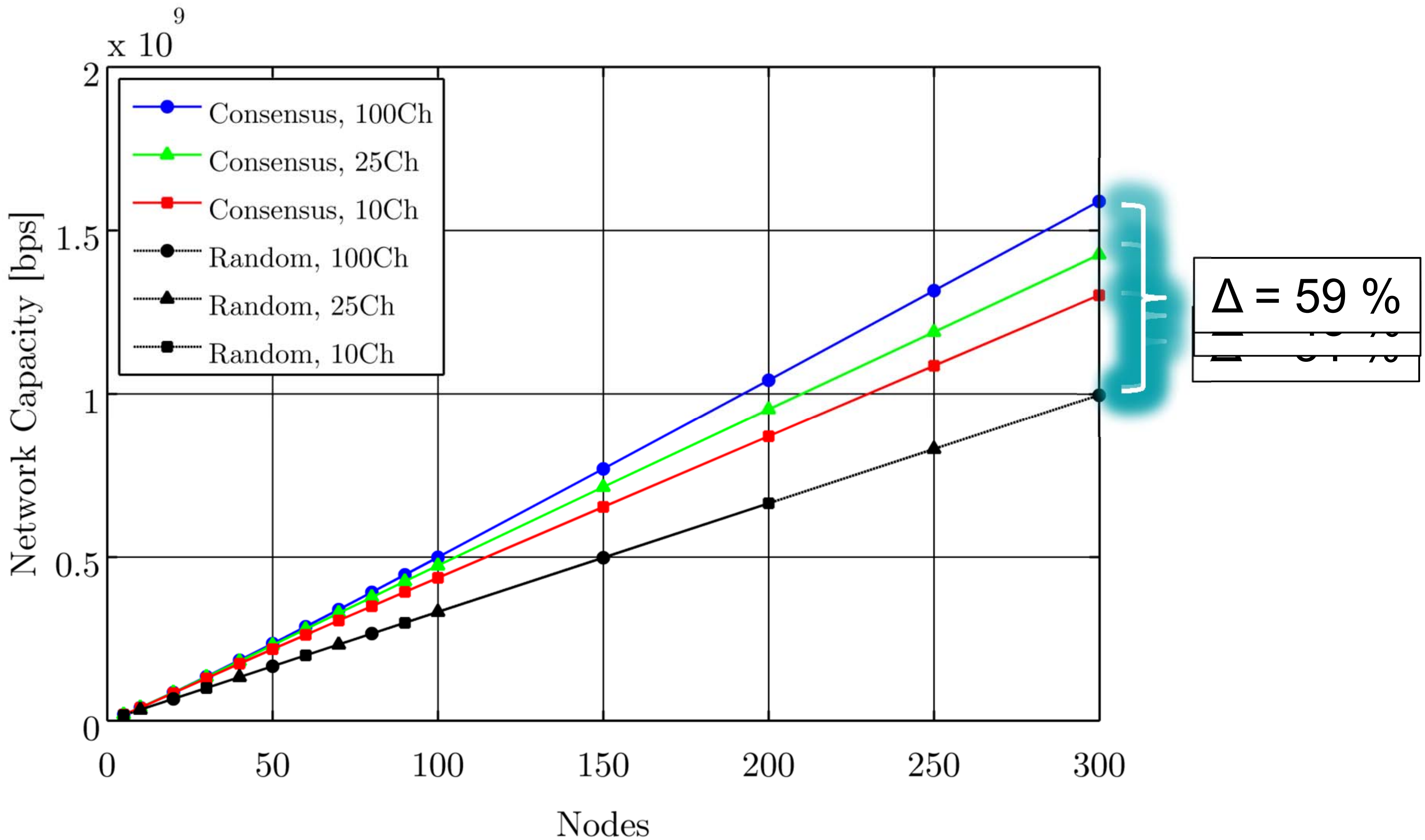
[1] P. M. R. dos Santos, M. A. A. Kalil, O. Artemenko, A. Lavrenko, A. Mitschele-Thiel: "Self-Organized Common Control Channel Design for Cognitive Radio Ad Hoc Networks", 2013 IEEE PIMRC, London September 2013

Simulation Results

Simulation parameter	Value
Simulation area	1 km^2
Network spatial deployment	Random
Propagation model	Free space path loss
Channel bandwidth	200 kHz
CR TX power (EIRP)	30 dBm
SINR threshold	20 dB
Receiver noise floor	-147 dB
Network mobility model	None (static network)

[1] P. M. R. dos Santos, M. A. A. Kalil, O. Artemenko, A. Lavrenko, A. Mitschele-Thiel: "Self-Organized Common Control Channel Design for Cognitive Radio Ad Hoc Networks", 2013 IEEE PIMRC, London September 2013

Simulation Results – Network Capacity



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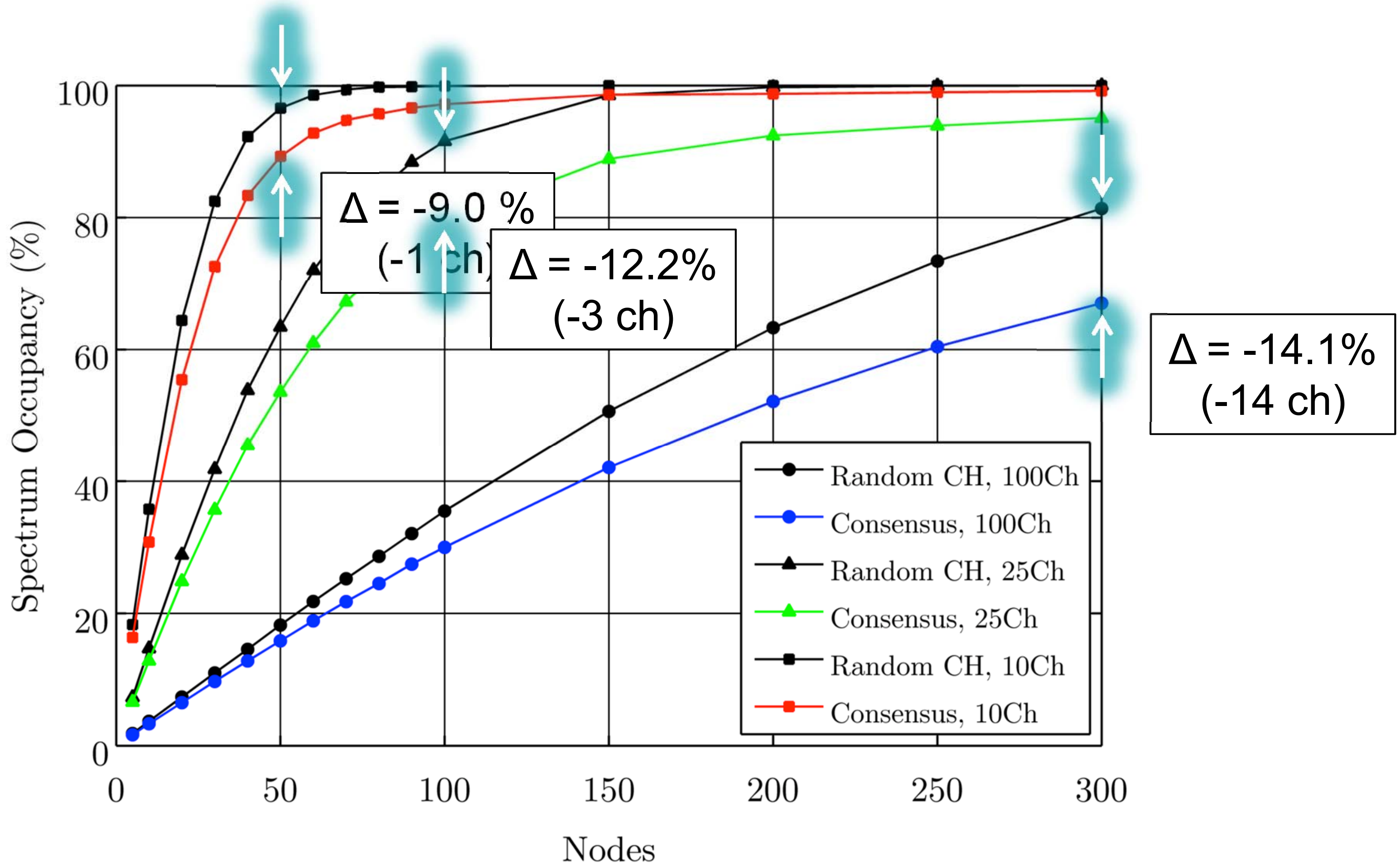
Simulation Results – Spectrum Occupancy

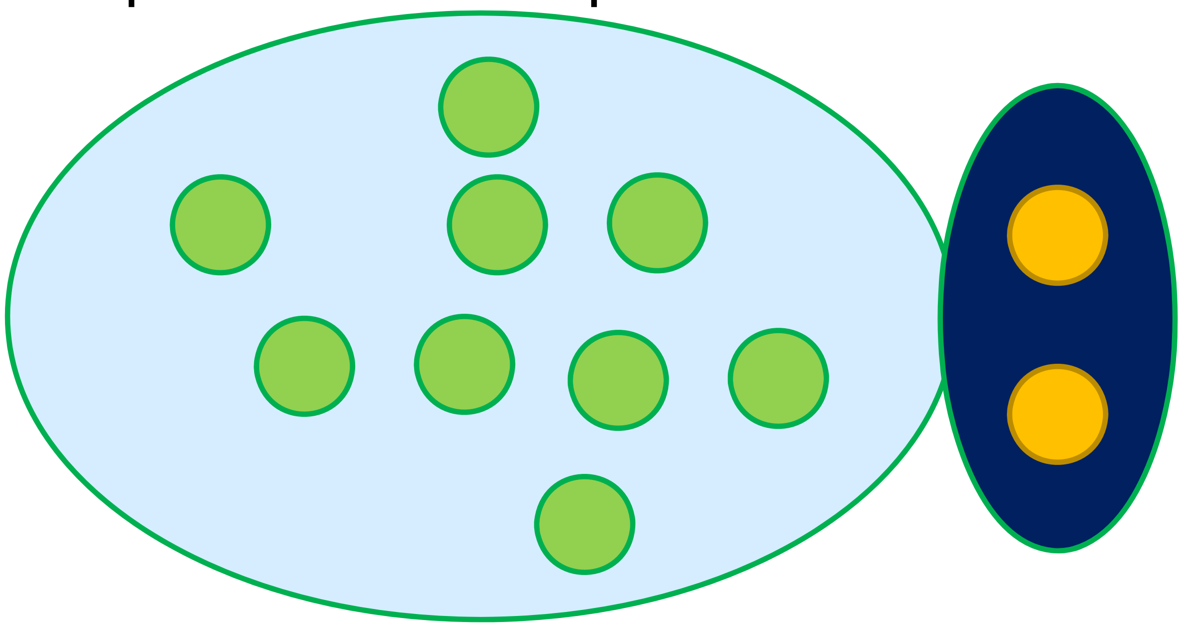


[1] P. M. R. dos Santos, M. A. A. Kalil, O. Artemenko, A. Lavrenko, A. Mitschele-Thiel: "Self-Organized Common Control Channel Design for Cognitive Radio Ad Hoc Networks", 2013 IEEE PIMRC, London September 2013

New Problem

- Old scheme:
  - Good for bandwidth equaly deployed amoung subnets
  - Bad otherwise

- Improvement is required



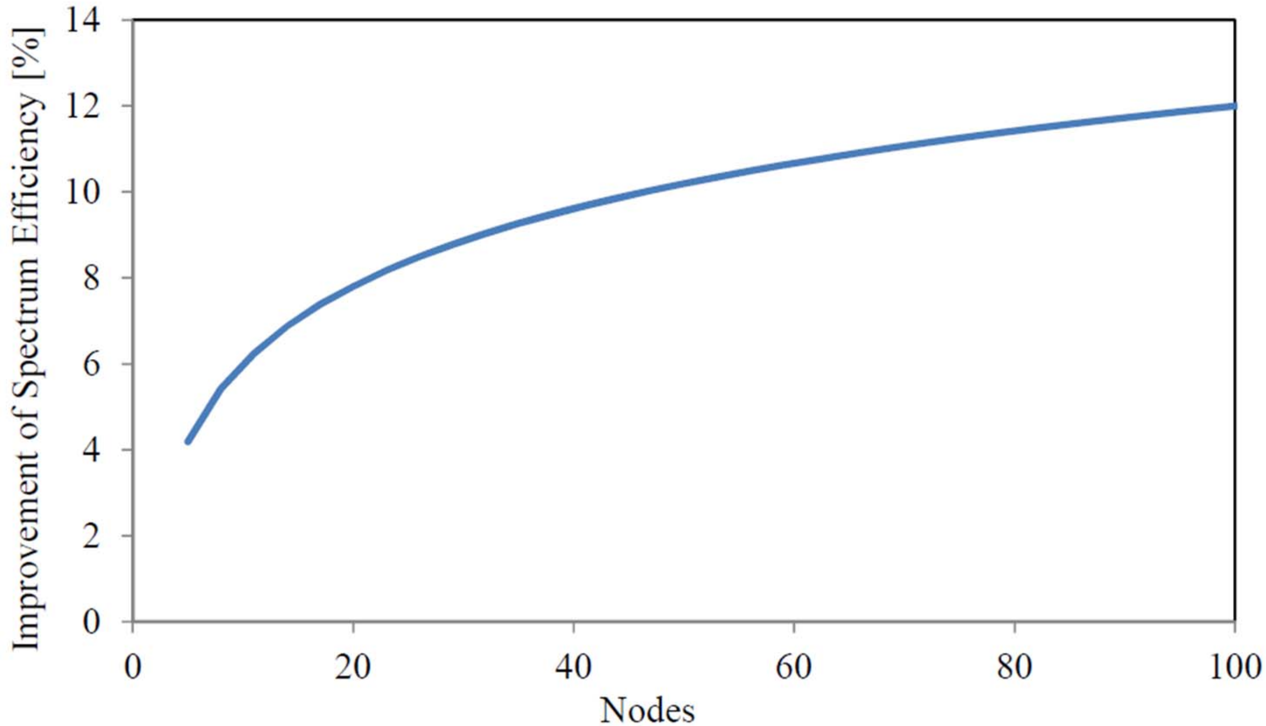
Improved Distributed Consensus Algorithm

- Takes into acount number of ring-participating nodes
- Provides fairness

New Utility Function

$$U_{new}(m) = \frac{B_m}{{N_m}^2} \sum_{n \in N_m} \log_2\left(1 + SINR_n\right)$$

Simulation Results – Spectrum Efficiency



$$\Delta = \frac{\eta_{new} - \eta_{previous}}{\eta_{new}} \ [\%]$$

$$\eta = \frac{C_{net}}{M \cdot B} \ [\text{bps/Hz}]$$

C_{net} – total network capacity

M – number of spectrum opportunities

B – bandwidth of each spectrum opportunity

Demonstration Video

- Random channel hopping vs distributed consensus

- Simulation parameters
  - 200 Cognitive Radios
  - 1 km^2 simulation area
  - Free space path loss propagation model

1 min video

Summary

- Efficient CCC for CRAHNs
- Idea: Distributed Consensus Algorithm
- New utility function:
  - Better efficiency (4-12%)
  - Provides fairness

- Further steps:
  - SINR estimation
  - Upper bound efficiency estimation as benchmark

Questions?
Thank you for your attention!

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