Social-aware Schemes for Higher CR Performance Leading to Higher Energy Efficiency

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Outline

Motivations

Two inevitable questions

- Q1: What is a social-aware scheme?

  Entities are considered in terms of their social relations, e.g., friendship, community, trust, encountering frequency.

- Q2: Why do we need social-aware schemes?

  Communication networks are mostly driven by human users, who generally act depending on their social ties.

Social-aware Cognitive Radio

- Being more than a decade-old concept, CR research has matured a lot. But CR research takes CRs as wireless devices with no *context*.
  - Who are the users of CR? Operators, humans, base stations, femtocells?
  - What are the relations/interactions among the network entities?
  - Can we exploit these relations?

Social Network

A social network views a network as a group of nodes with their interrelations (e.g., physical distance, contact frequencies) to benefit from these structural and social ties for higher efficiency.

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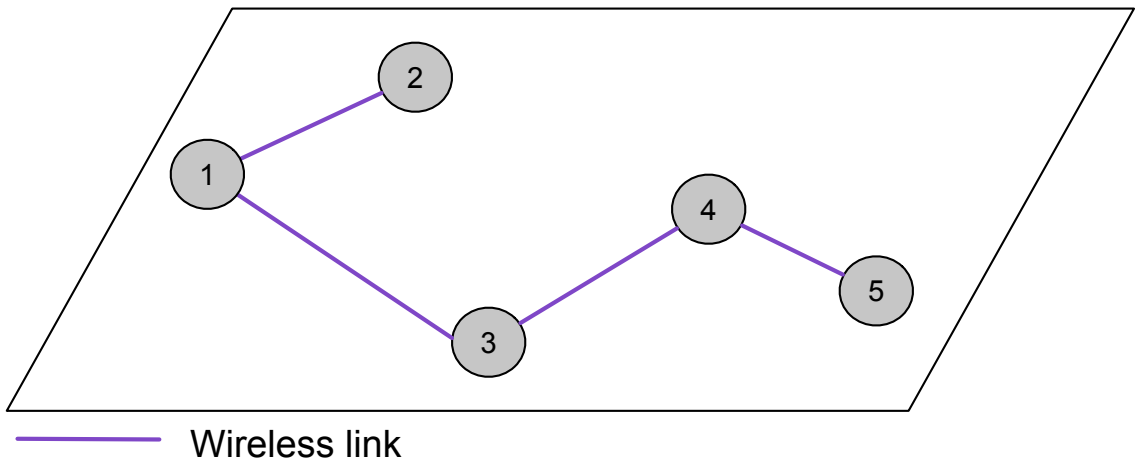
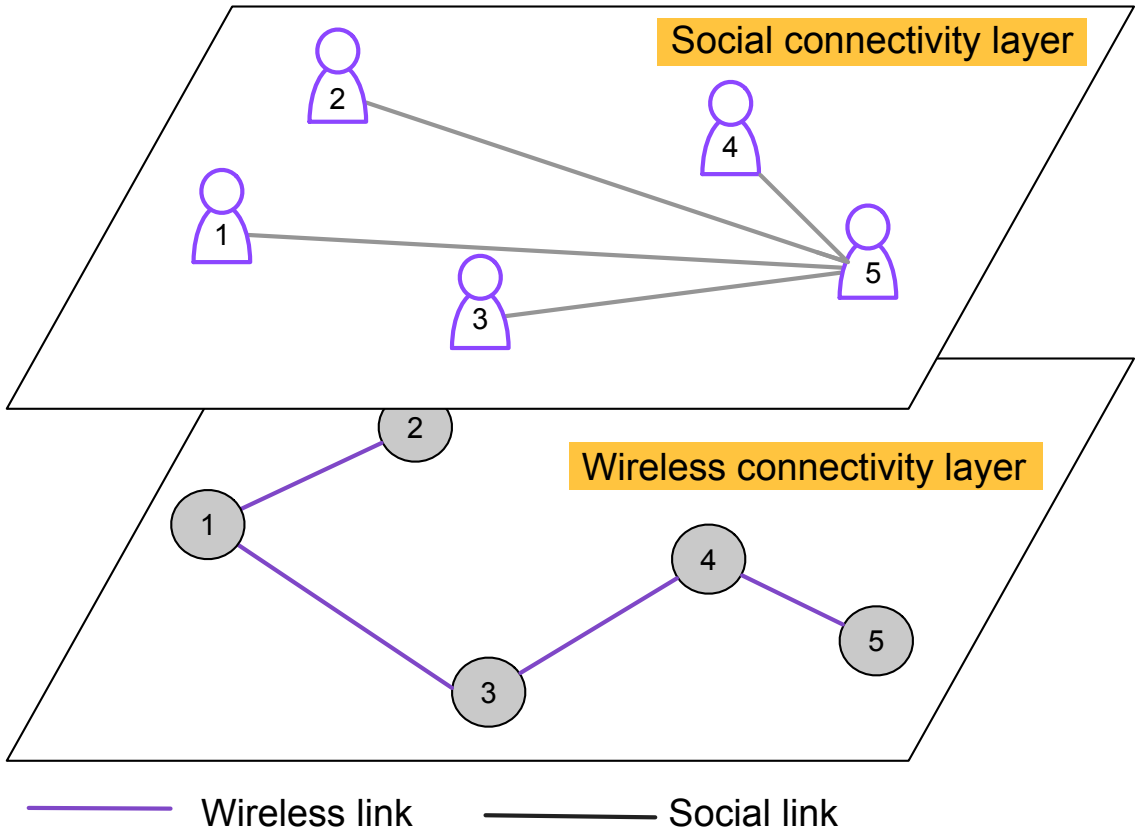
Social-Aware CRNs

- An example CR network topology: 5 CRs.



Two layers of a CRN

1. Wireless connectivity layer
2. Social connectivity layer



Our perspective

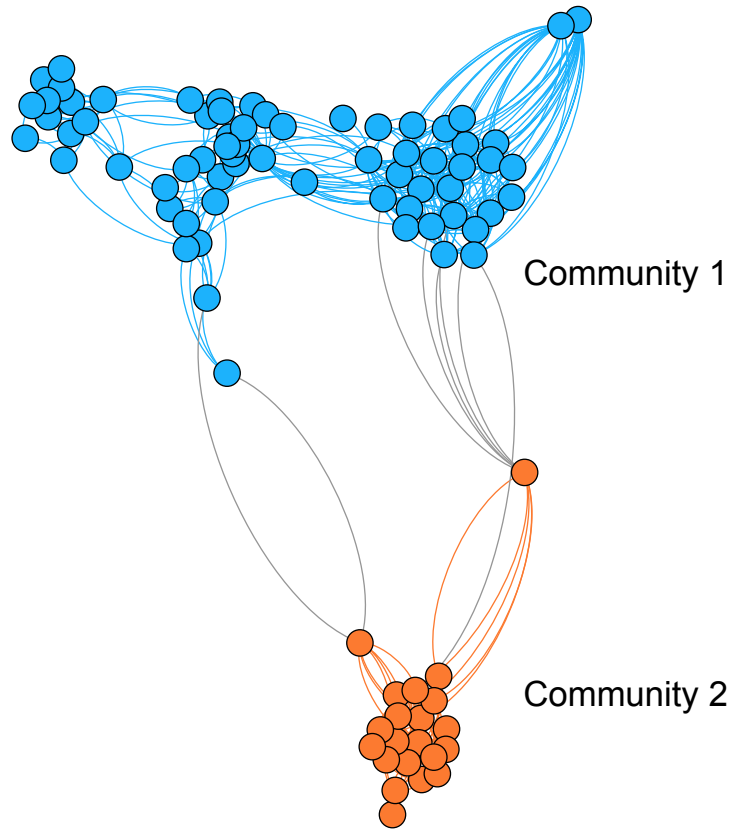
- Such a modeling approach fits better to today's communication paradigm
- We can discover the hidden information in the social graph to design more realistic CR protocols

Previous works

- Pocket switched networks [Hui2007]
- MANETs [Katsaros2010]
- Networks [Chen2013]
- CR spectrum occupancy state recommendation [Li2011]
- CR cooperative sensing [Guven2013]

Community, Selfishness, Social Selfishness

- Social graph: $\mathcal{G} = (\mathcal{V}, \mathcal{E})$ where $\mathcal{V}$ is the set of CRs and $\mathcal{E}$ their social relations, e.g. friend, neighbor, family member etc.
- Community: Group of entities that have higher relationship inside the community compared to the other members of the network.
- Selfishness: Degree of willingness to cooperate with any other node
- Social selfishness: Selfishness depending on the tie between two entities



Social-**A**ware **C**ooperative Sensing (SAC)

C. Guven, S. Bayhan, F. Alagoz, “Effect of Social Relations on Cooperative Sensing in Cognitive Radio Networks” in *BlackSeaCom*, 2013.

Social-Aware Cooperative Sensing (SAC)

- Cooperative sensing improves sensing reliability P_d owing to diversity gain
- Are CRs really *unconditionally* cooperative? Is this mode of operation energy-efficient (EE)?

Social-aware Sensing [Guven2013]: Basic idea

- We associate each CR with its user that has some social relations, e.g. friendship, community, selfishness.
- CRs request sensing from CRs that will *sense* for them and will sense *reliably*.

Social-Aware Cooperative Sensing (SAC)

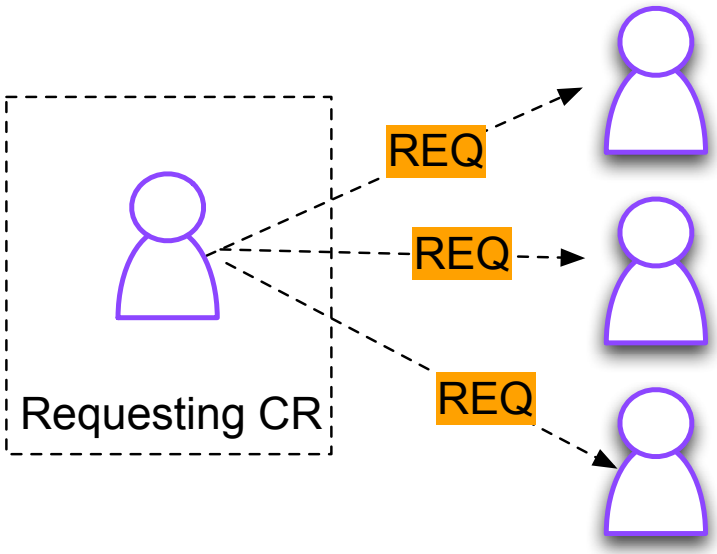
Two CR types in a cooperative sensing scenario:

1. Cooperation requesting CR $\Rightarrow$ How to select cooperators?
2. Requested CR $\Rightarrow$ How to respond to cooperation requests?

How to select cooperators?

Requesting CR

- Avoid non-cooperating CRs (waste of tx.energy)
- Avoid malicious CRs (decrease in reliability)
- Keep track of interactions (i.e., learning)



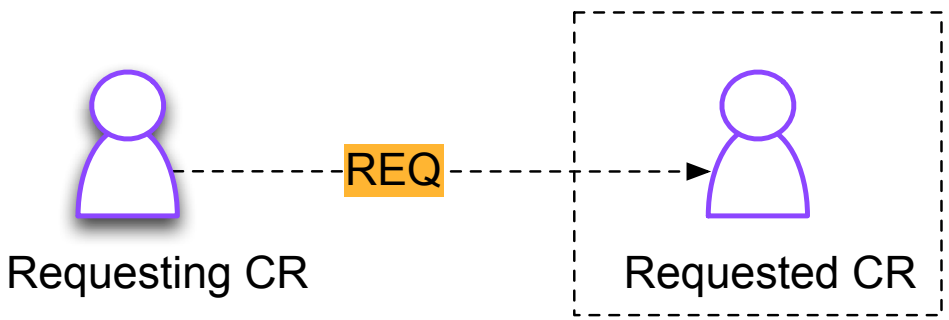
In traditional CRNs, decision based on wireless connectivity layer.

In SAC, consider both layers!

How to respond to sensing requests?

Requested CR

- Cooperate with CRs depending on *some* criteria.
- Self-state (e.g., remaining energy) or social-tie (e.g. a friend requests).
- Penalize non-cooperating CRs by not sensing for them in return.



CR model $z =< C, L_f, L_s, L_c, \beta >$

- C is the *community* of this CR,
- L_f is the *friend list*
- L_s is the *sympathy list* representing the willingness of this CR cooperate with a member of a specific community c_j,
- L_c is the *cooperation score* list showing the performance of each CR in previous cooperation requests initiated by this CR,
- β is the *cooperation tendency*

Community and friendship are public, all others are private to the CR.

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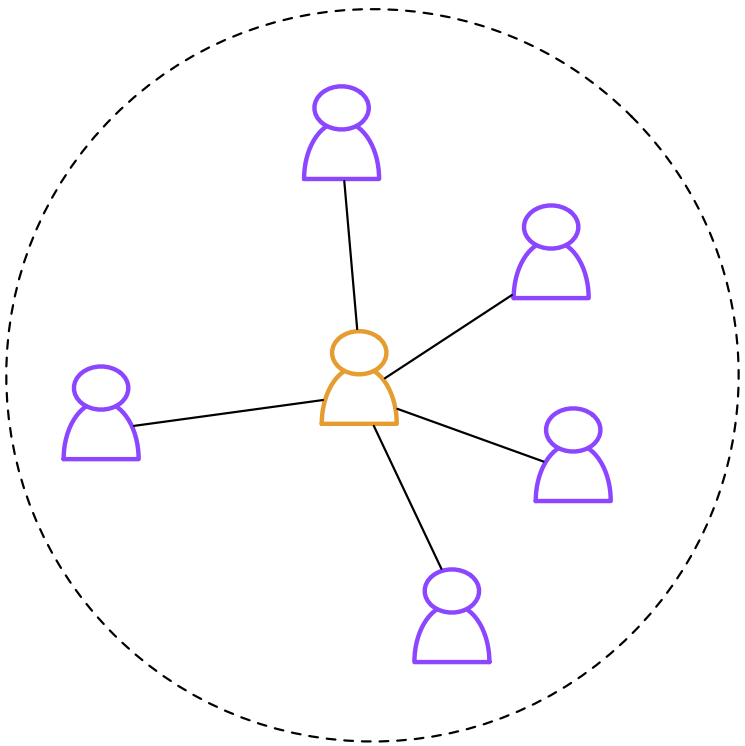
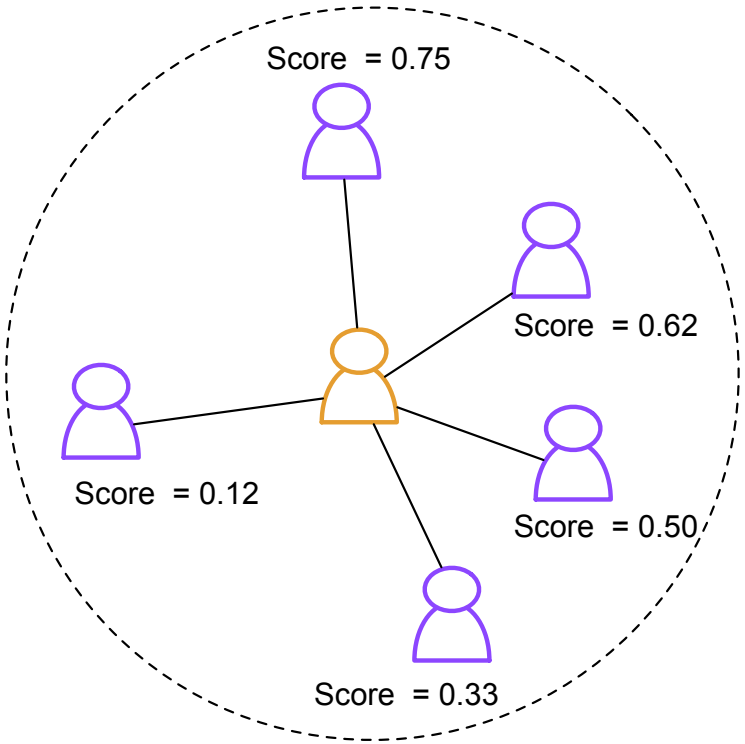
SAC Steps: Requesting CR



- *N* CRs in transmission range

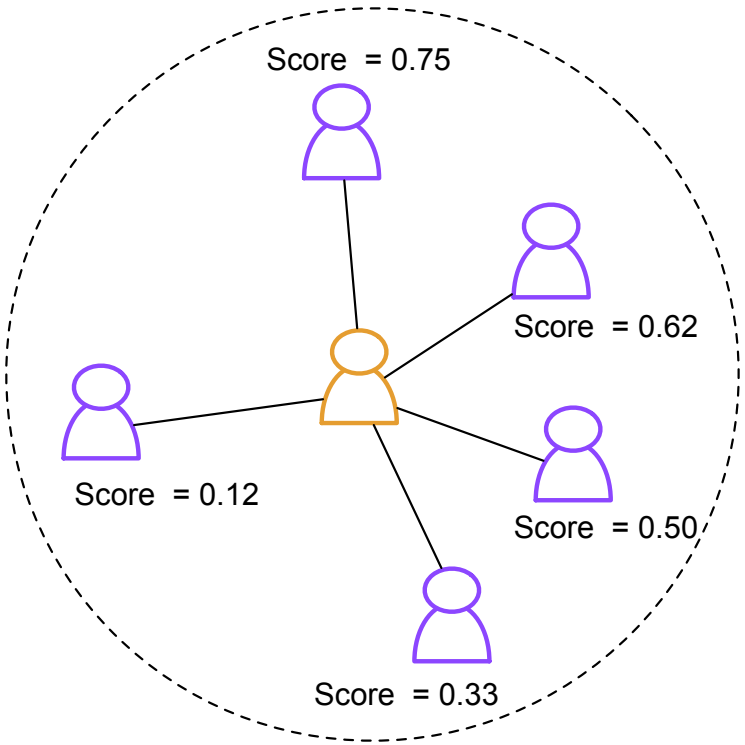
SAC Steps: Requesting CR



- *N* CRs in transmission range
- Calculate score of each CR

$$\text{Score} = \alpha^{f}\ \text{Score}_{friend} + \alpha^{c}\ \text{Score}_{community} + \alpha^{s}\ \text{Score}_{sensing}$$

SAC Steps: Requesting CR



Minimum cooperation score = 0.80

- *N* CRs in transmission range
- Calculate score of each CR
- Select the CRs with scores above cooperation threshold

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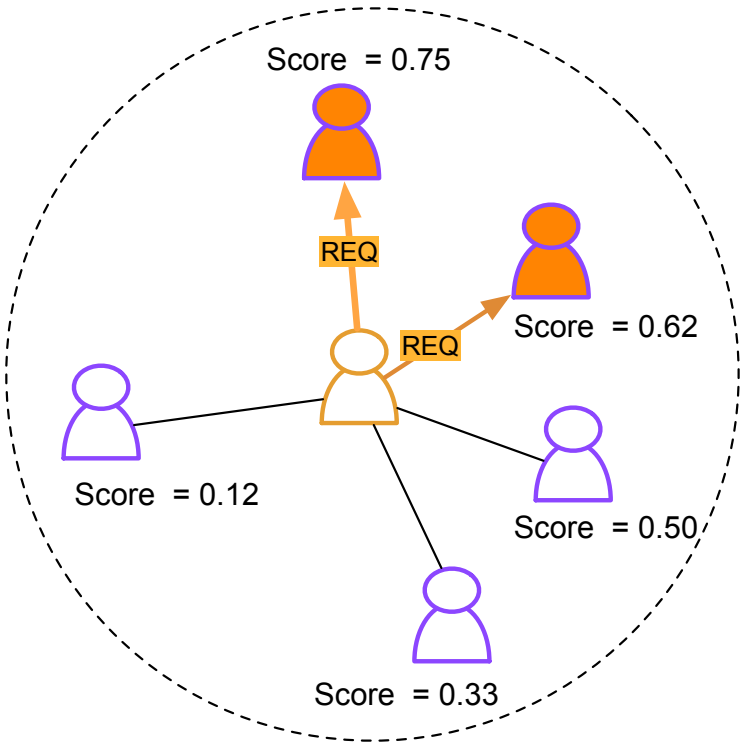

Minimum cooperation score = 0.60

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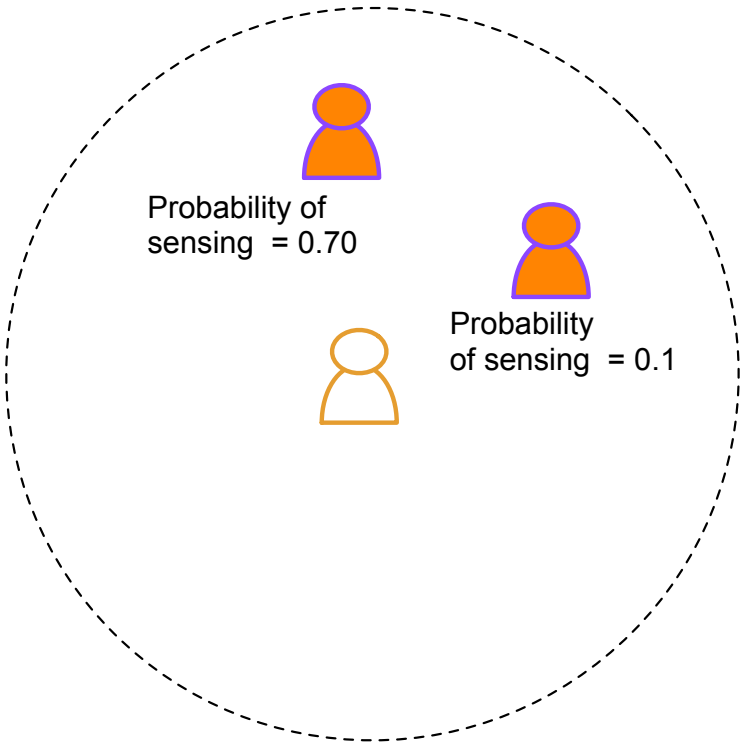
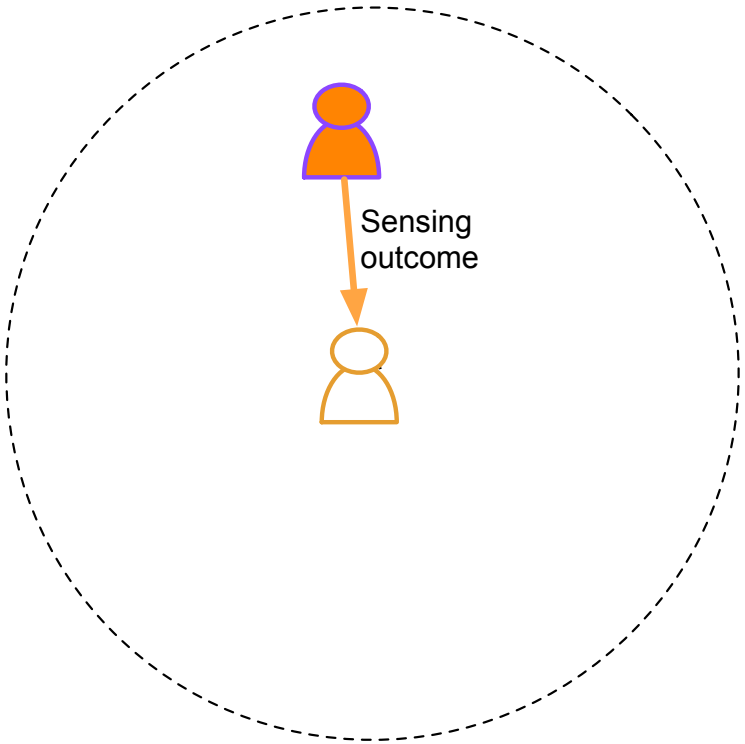
SAC Steps: Requested CRs



- *N* CRs in transmission range
- Calculate score of each CR
- Select the CRs with scores above cooperation threshold
- Evaluate the requesting CR

Probability of sensing= β + αSelfishnessModifier

SAC Steps: Requested CRs

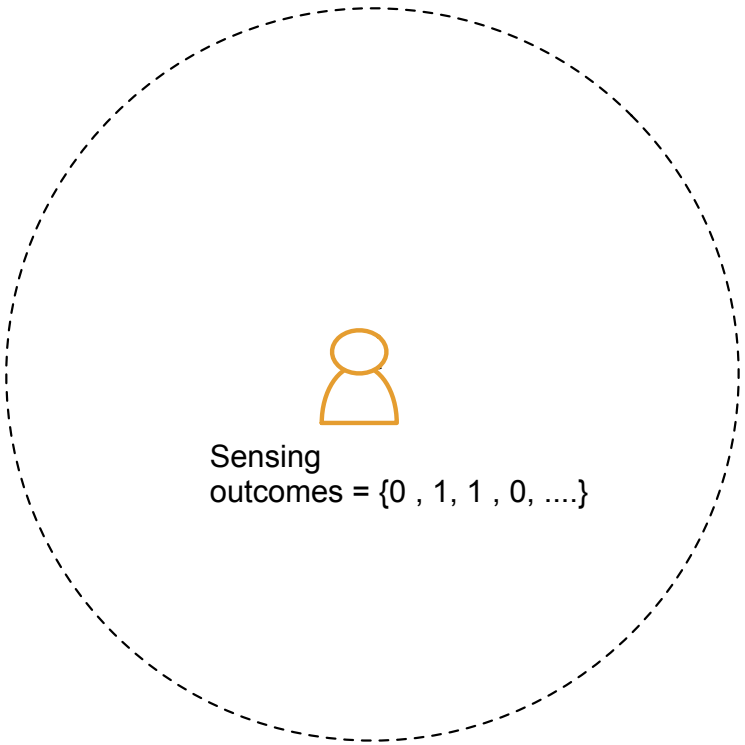


- *N* CRs in transmission range
- Calculate score of each CR
- Select the CRs with scores above cooperation threshold
- Evaluate the requesting CR (calculate probability of sensing)
- If sensed, send sensing outcome

Minimum cooperation score = 0.60

Probability of sensing= β + αSelfishnessModifier

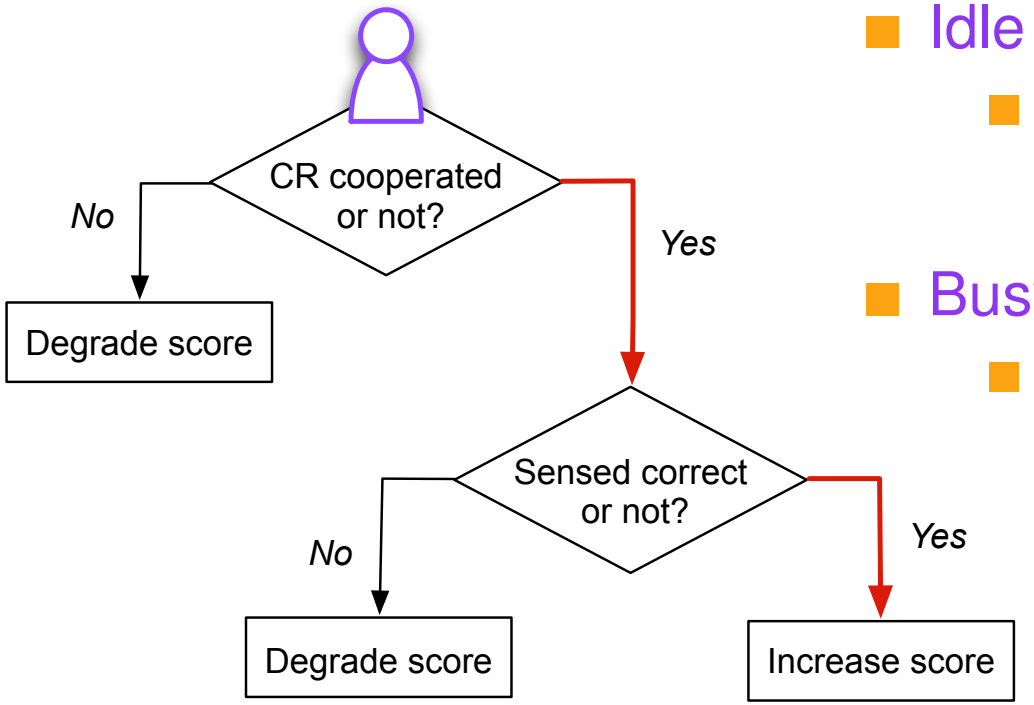
SAC Steps: Requesting CR



- *N* CRs in transmission range
- Calculate score of each CR
- Select the CRs with scores above cooperation threshold
- Evaluate the requesting CR (calculate probability of sensing)
- If sensed, send sensing outcome.
- Spectrum fusion (e.g., MAJORITY, K-out-of-N, OR logic)

Probability of sensing= β + αSelfishnessModifier

SAC Steps: Score Update



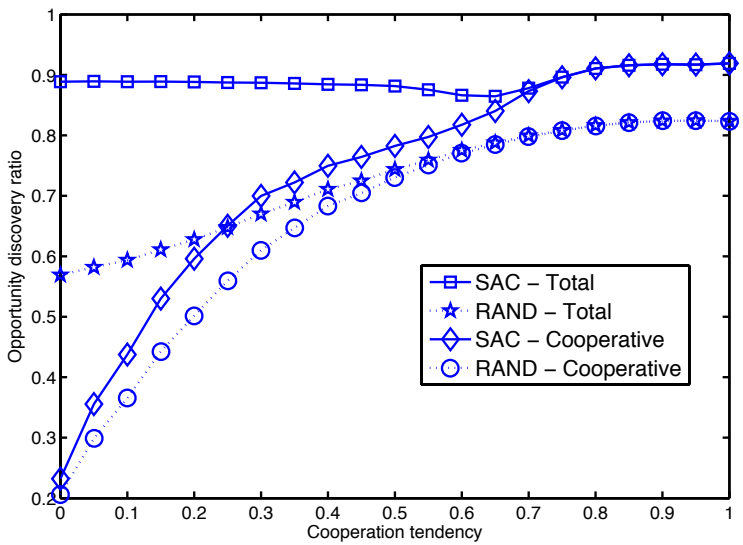
Spectrum decision

- Idle
  - Access the spectrum → Collision, Success
- Busy
  - Keep silent → Degrade the score of the CRs disagreeing spectrum decision

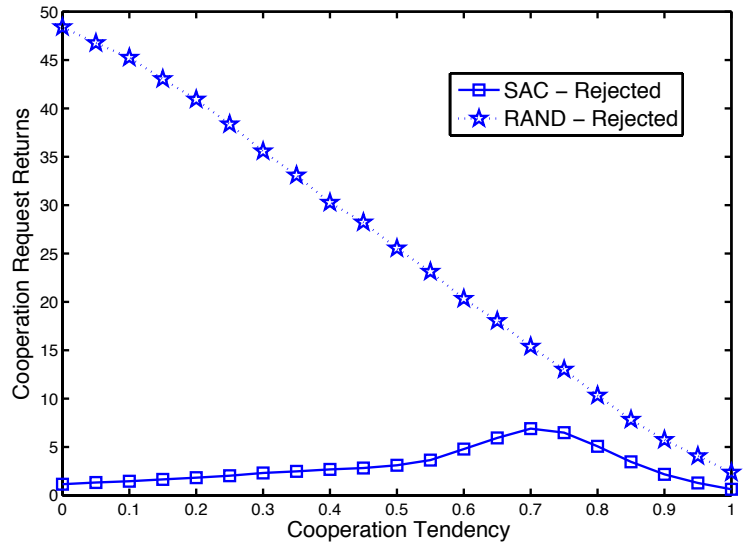
SAC vs Social-oblivious(RAND) selection

Scenario: Increasing cooperation tendency (β)

- Opportunity discovery



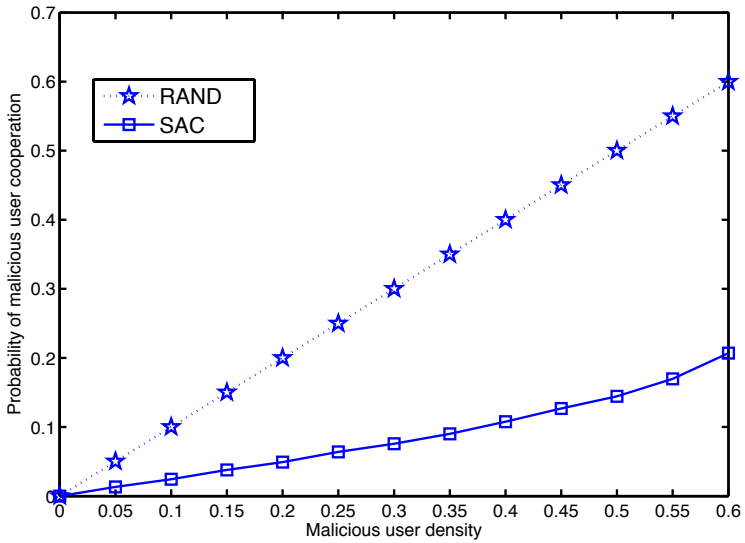
- Rejected requests



Malicious Users

Scenario: Increasing malicious user density

- Malicious user cooperation.



SAC can avoid malicious users
→ Better spectrum discovery.

Some Future Research Directions

How Can EE Research Embed SNA?

- We have not focused on EE in [Guven2013]
  - Lower number of rejected requests
  - Higher opportunity discovery
- We expect the following tasks to improve spectrum efficiency with lower energy consumption:
  - Cooperative learning
  - Cooperative transmission, i.e., relaying

Cooperative Learning

- Environmental awareness requires constant monitoring of the environment
- Energy burden of constant monitoring $\Rightarrow$ CRs share their experiences

To which extent a CR can trust to the other CRs' reports and what if the recommendations are inaccurate?

- Trust modeling based on social connectivity layer (e.g. same community CRs higher trust for each other)
- Trust update based on interactions

Cooperative Transmission

- CRN can be assisted by relays for better coverage
- Relays may be energy-efficient owing to their short distance bw. transmitter/receiver.

Similar to cooperative sensing, we can model relay selection and relaying behaviour of CRs based on wireless connectivity layer and social connectivity layer.

- Requesting CR: Who to choose as relay?
- Requested CR: Whose traffic to relay?

Summary

- CRNs can consider the social connectivity layer for higher efficiency protocols
- Social-aware cooperative sensing
- Ongoing work on optimal selection considering energy consumption

References I

- C. Guven, S. Bayhan, F. Alagoz, “Effect of Social Relations on Cooperative Sensing in Cognitive Radio Networks” in *BlackSeaCom*, 2013.
- Li, Husheng, Chien-fei Chen, and Lifeng Lai. "Propagation of spectrum preference in cognitive radio networks: A social network approach." *IEEE International Conference on Communications* (ICC), 2011.
- Chen, Kwang-Cheng, Mung Chiang, and H. Vincent Poor. "From technological networks to social networks." IEEE Journal on Selected Areas in Communications (2013).
- Katsaros, Dimitrios, Nikos Dimokas, and Leandros Tassiulas. "Social network analysis concepts in the design of wireless ad hoc network protocols." IEEE Network, 24.6 (2010): 23-29.

Thank you.

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