Protection and Fairness Oriented Cognitive Radio MAC Protocol for Ad Hoc Networks (PROFCR)

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Summary

- Spectrum Problems
- Cognitive Radio
- PROFCR MAC Protocol
  - Desicion of next operating channel
  - Agreement over the control channel
  - Competetion for the data channel
- Simulation
- Numerical Results and Discussion
- Conclusion

Spectrum Problems

- Comprehensive progress in wireless world
- Allocate distinct frequency bands for each new technology
- Natural limit of spectrum resources
- Problems
  - Spectrum scarcity (eg. price of 3G licenses)
  - Allocated spectrum: underutilized or unused most of the time

Cognitive Radio

- Solution: Dynamic Spectrum Access (DSA) technologies
- Most promising is Cognitive Radio (CR) [Akyildiz01]
  - Sense available spectrum parts time cost!
  - Select most appropriate frequency channel(s) how?
  - Share channel resources with other users fairness!
  - Limit harm against the QoS of primary users protection!
- Focus on MAC layer design, our motivation:
  - Decrease time cost of sensing
  - Stay more on the most appropriate channel?
  - Supply fairness among secondary users (SUs)?
  - Protect the QoS of primary users (PUs)?

Cognitive Radio
Previous Research

- Assumption of reliable sensing of the environment
  - Has an undeniable cost (about 20ms or more) [Cordeiro01]
  - Sufficient number of channels to sense? [Jia01]
- Beacon intervals --> Synchronization Cost [Le01]
- Hard to obtain fairness in oppurtunistic usage [Le01]
- Hard to protect PUs (how to recognize PUs?) [Hung01]
- Change data channel after each collision!
- Prefer known methods that we are experienced before

PROFCR MAC Protocol

- Protection and fairness oriented cognitive radio MAC protocol
- Decreases the sensing overhead
- Minimizes the congestion in the common control channel
- Improves the quality and performance of data transmission
- Quarantees the protection of PUs
- Three operation steps:
  - desicion, negotiation and transmission

PROFCR MAC Protocol

Desicion of next operating channel

- Instead of sensing the channel and decide on the most appropriate one
  - Use a linear model to select next data channel

$$U_c(i) = \alpha S_c(i) + (1-\alpha) U_c(i-1)$$

$U_c(i)$: state variable of channel *i*

$S_c(i)$: result of current attempt $\in \{0: succ, 1: coll\}$

α : constant system factor $\in [0,1]$

  - If $U_c(i) > U^{\text{limit}}$, select channel *j* with min $U_c(j)$
  - Decrease all $U_c(i)$ with a const. multiplier $U_D \in [0,1]$

PROFCR MAC Protocol

Agreement over the control channel

- Desicion of next data channel decreases frequency of handovers
  - Decreases the negotiation on common control ch.
- Negotiation (may use a simple backing off alg.)
  - After deciding next data channel
  - Announce selected data channel to its pair
  - Agree to transmission on the selected channel
  - Adjust CR parameters to selected channel

PROFCR MAC Protocol

Competetion for the data channel

- SUs compete for the channel resources, also with PUs
  - Quarantee PUs to affect under a tolerable limit
- Three protection schemes
  - Choosing larger congestion window (CW) size
  - Limiting maximum packet length of SUs
  - Waiting before attempting to access the channel

PROFCR MAC Protocol

Competetion for the data channel

- Choosing larger congestion window (CW) size
  - $PU_{CW} = \{2^n\}$, choose $SU_{CW} = \{k.2^n\}$
  - For k=4, accrding to lemma, $P_{PU} \rightarrow 31/32$
- Limiting maximum packet length of SUs
  - protect PUs from long-lived excessive SU transmissions
- Waiting before attempting to access the channel
  - Wait extra interframe spacing (IFS) t_{wait}
  - Average wasted ratio is:

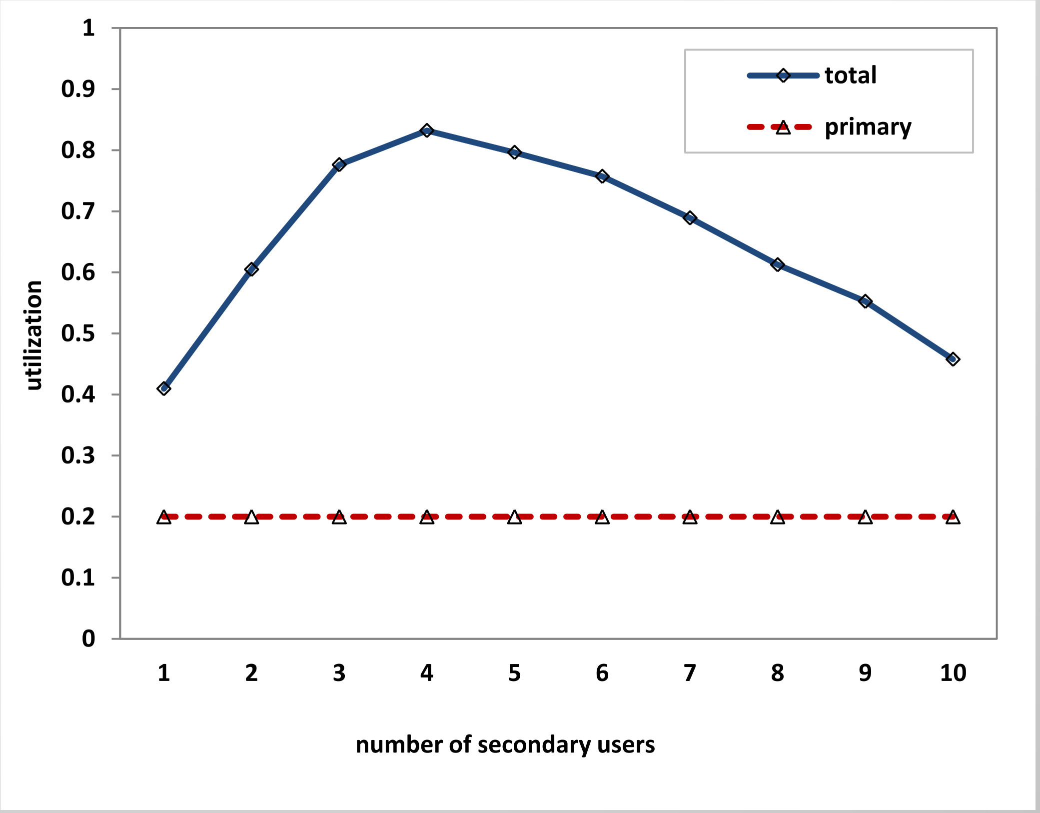
$$Q = \frac{t_{wait}}{t_{wait} + t^{SU}_{\text{renewal cycle}}}$$

Simulation

- Create a discrete time simulator
  - N equivalent channels
  - Deal PUs as a primary gruop
  - SUs comminicate with their peers
  - Data arrival: Poisson, packet size: exponential
  - CW multiplier k = 4
  - t_{cc} = 5ms only (duraton of channel change and adjustments)
  - Use t_{TTL} = 250ms (time to live for each packet)
  - Other parameters can be found in the paper.
- Rival protocol: smart random selection CR (SRS-MAC)
  - Know the entire spectrum environment
  - Select one of the available channel without extra sensing
  - Change channel after each collision

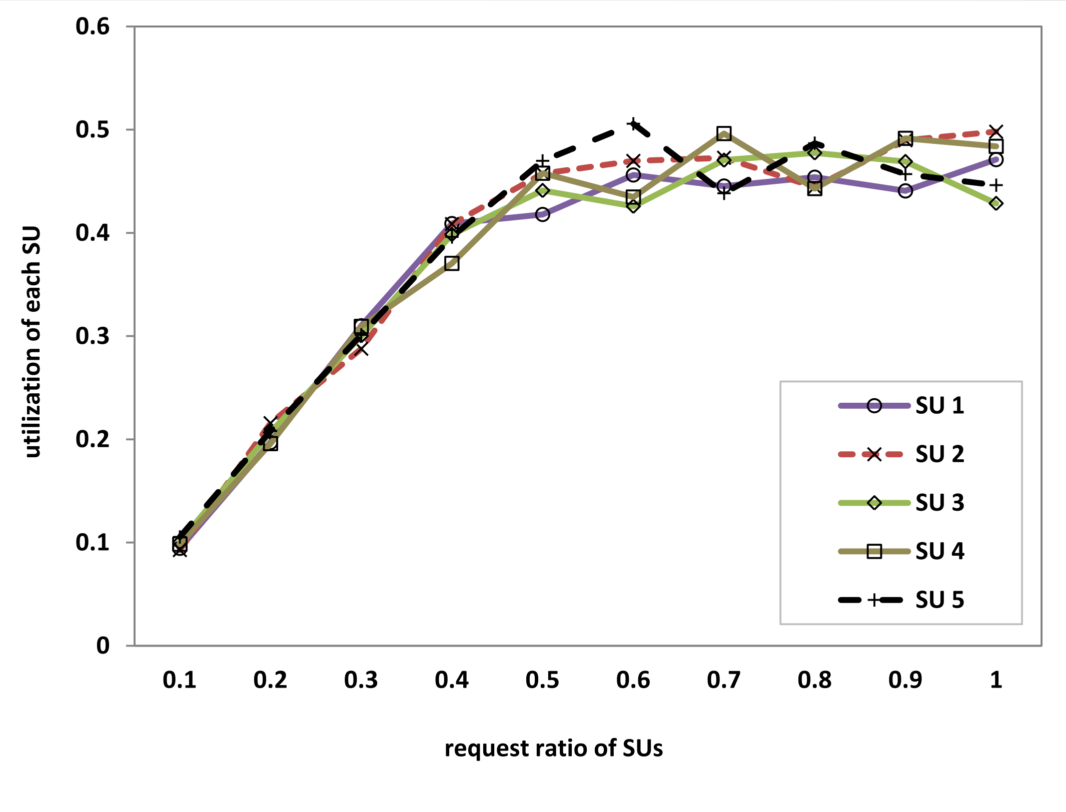
Numerical Results and Discussion

- **Pressure of SUs on PG**
- 1 channel
- User normalized request ratio = 0.2 for each user
- Number of SUs increase from 1 to 10



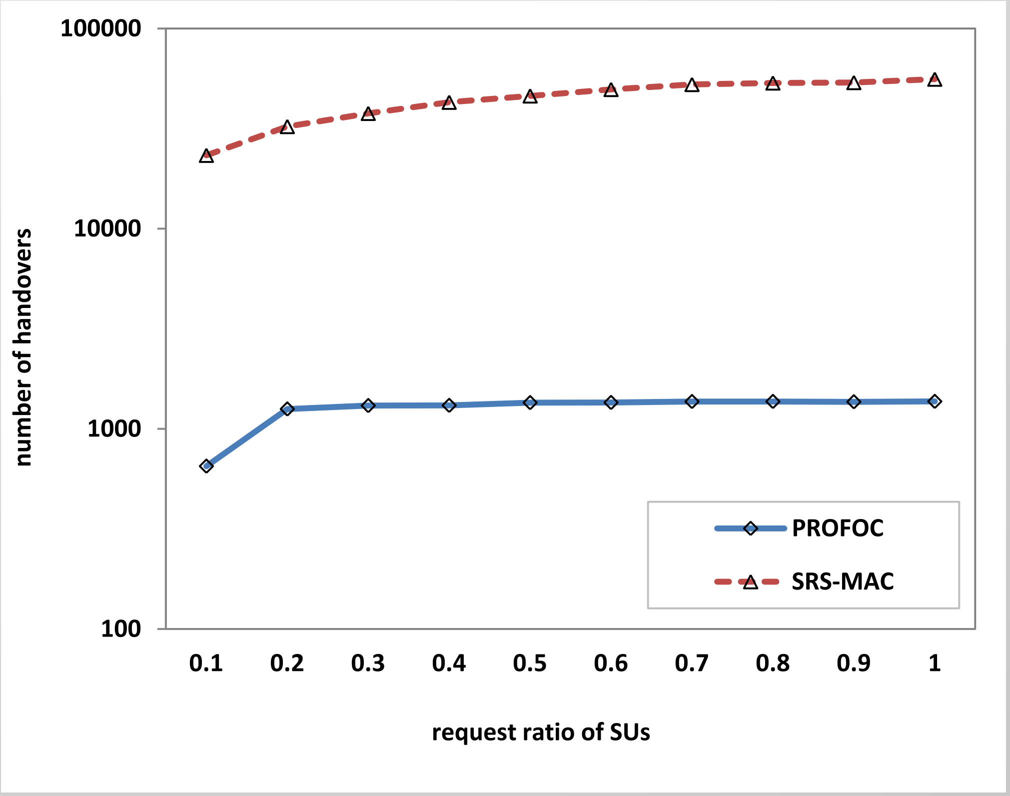
Numerical Results and Discussion

- **Fairness in secondary communication**
- 3 channels
- 2 PGs on 2 of the channels with request ratio of 0.2
- 5 identical SUs, have request ratios changed from 0.1 to 1.0



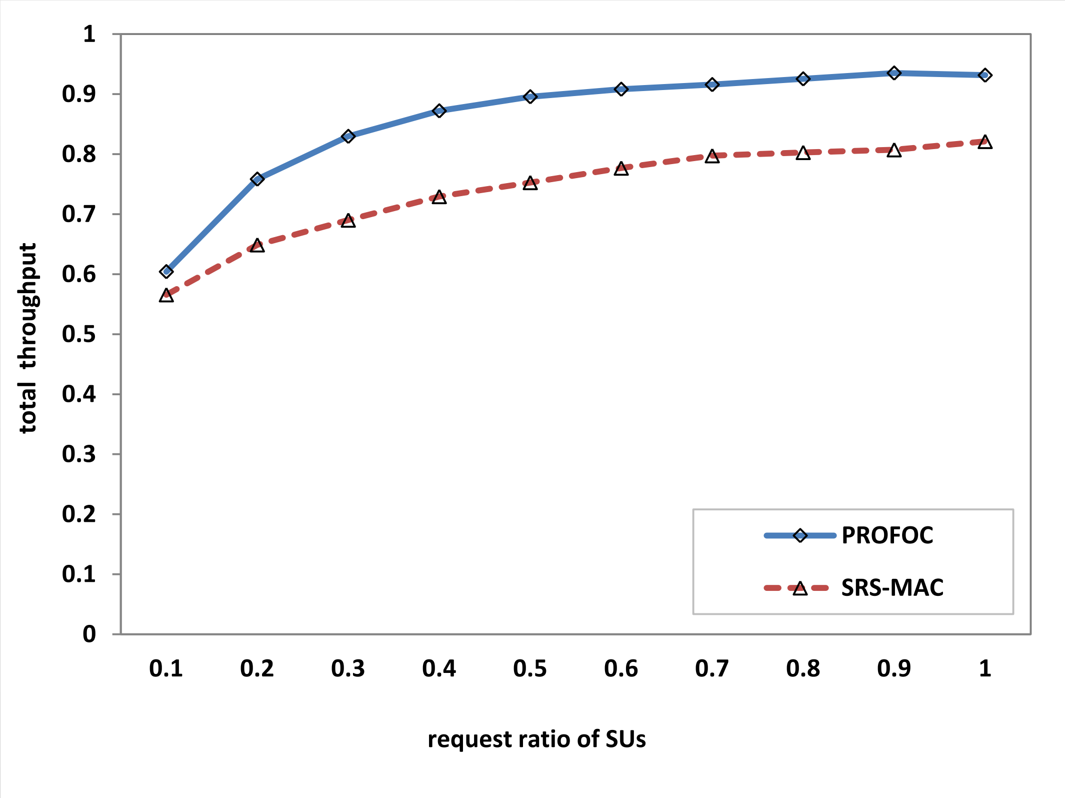
Numerical Results and Discussion

- **Reduction in the number of handovers**
- 2 channels
- 1 PGs on one of the channels with request ratio of 0.3
- 10 identical SUs, have request ratios changed from 0.1 to 1.0



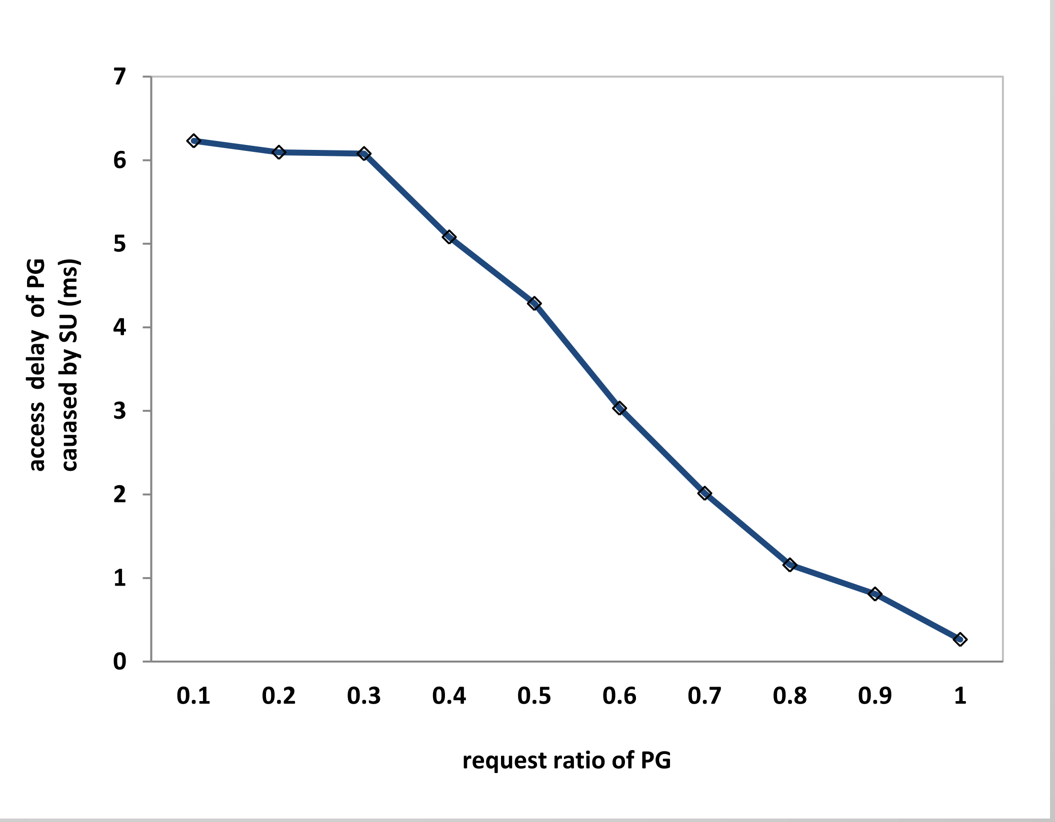
Numerical Results and Discussion

- **Impact of handovers on total throughput**
- 2 channels
- 1 PGs on one of the channels with request ratio of 0.3
- 10 identical SUs, have request ratios changed from 0.1 to 1.0



Numerical Results and Discussion

- **Access delay of PG** (packet at the head of the queue waits)
- 1 channel
- 1 PG request ratio change from 0.1 to 1.0
- worst case scenario: 1 SU, have request ratios of 1.0 (always has a packet to send)



Conclusion

- Propose a protection and fairness oriented cognitive radio MAC protocol (PROFCR)
  - Handles spectrum problems in a simpler way
  - Benefits from well-known prioritization schemes
  - Decreses the sensing overhead
  - Decreses frequency of handovers
  - Supplies fairness among SUs
  - Protects primary transmission
- Simulation results present the success of the protocol under different scenarios

References

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End of the Slides

Thank you for your attention!

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