# How can Polycentric Governance of Spectrum Work?

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# It’s all about sharing…

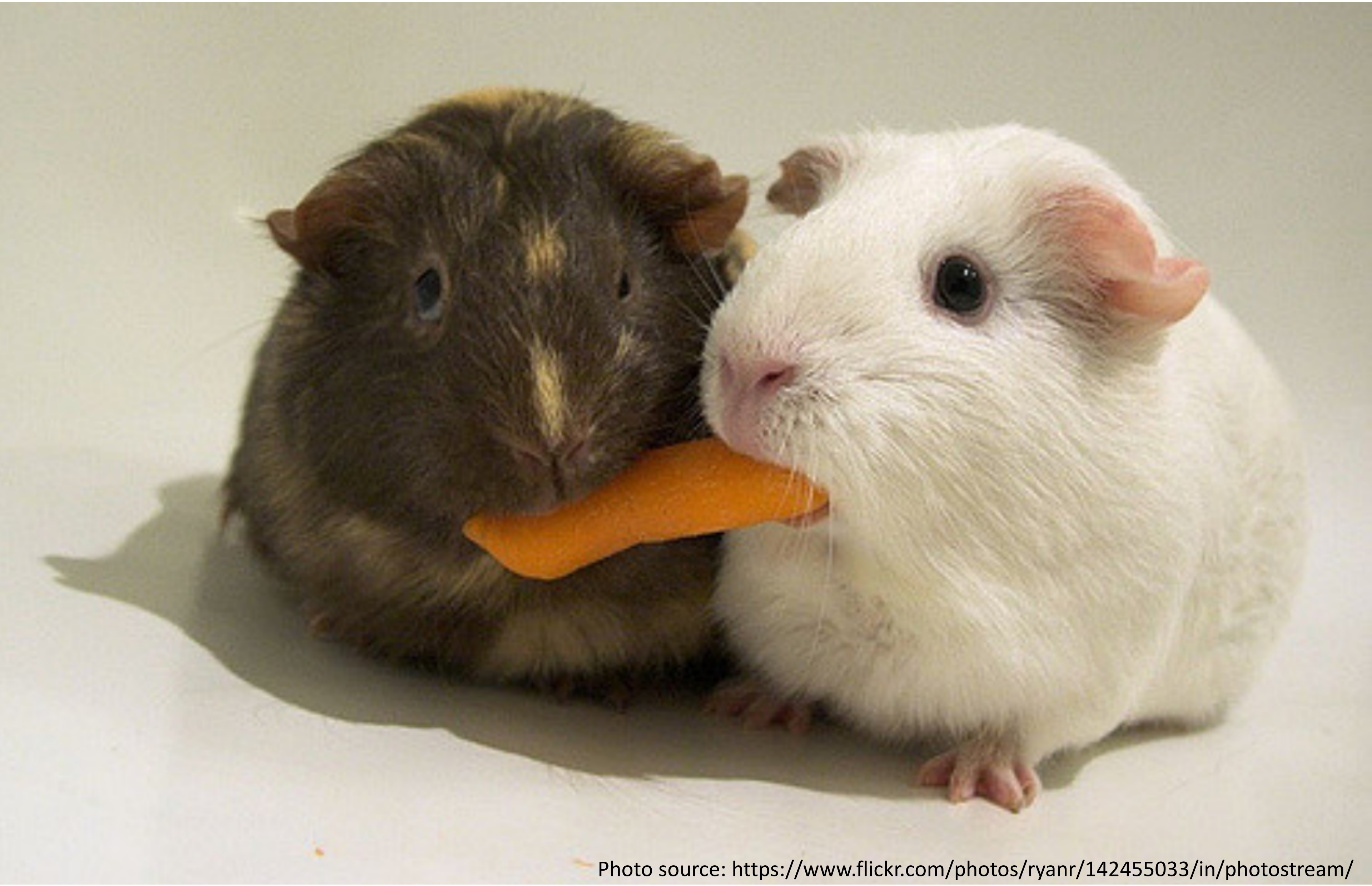

Photo source: https://www.flickr.com/photos/ryanr/142455033/in/photostream/

…and sharing is about redefining or constructing (bundles of) rights

## Diverse sharing regimes

# DIVERSE ENFORCEMENT CHALLENGES

# USAGE RIGHTS

- Right to detect & process EM energy (**reception**)
- Right to emit EM energy (**transmission**)

- ***"harmful interference"***
- Spatio-temporal measurement of signal energy
- Event focused

The SAS was designed to implement *ex ante* control over a defined electrospace

- Enforce a set of usage rights
- Protect from interference events

What if we take a look at the bigger picture?

https://www.galaxyexplorer.net.au

# Interference beyond the *harmful interference* perspective

# COLLECTIVE ACTION RIGHTS

- Right to determine *how* authorized users may use the spectrum (**management**)
- Right to determine *who* may use the spectrum (**exclusion**)
- Right to sell the spectrum (**alienation**)

- Often process focused
- Procedural and behavioral norms

# OBJECTIVE

In SAS-enabled sharing environments, find a mechanism that permits to create and distribute collective rights dynamically

- Adaptive to local conditions and negotiations

# BACKSTORY

## Dimensions of cooperative spectrum sharing: Rights and enforcement


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## Wireless Network Virtualization: Opportunities for Spectrum Sharing in the 3.5 GHz Band


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## Socio-Technical considerations for Spectrum Access System (SAS) design


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**Elinor Ostrom**

Governance of Common Pool Resource Systems

# COMMON POOL RESOURCES

High subtractability of use

Difficult to exclude external users

CPR GOVERNANCE

# When does it work?

- Resource system characteristics
- Group Characteristics
- Relationships between group and resource characteristics
- Institutional arrangements
- External Environment
- Nested levels of appropriation, provision, enforcement, governance

# POLYCENTRIC GOVERNANCE

*“Polycentric systems are the organization of small-, medium-, and large-scale democratic units that each may exercise considerable independence to make and enforce rules within a circumscribed scope of authority for a specified geographical area.”*

Ostrom, Elinor. "Vulnerability and polycentric governance systems." *IHDP Update* 3.01 (2001): 1-4

## Can we refer to spectrum as a common pool resource?

*under current technology

# SYSTEM REQUIREMENTS

| Attribute (from Ostrom) | System feature |
|---|---|
| Well defined boundaries | Operating boundaries determined by transmit power and antenna characteristics |
| Congruence with local conditions | Locally determined spectrum assignment and usage |
| Collective Choice Arrangements | Open source software for radio appliance and open protocol standard process |
| Monitoring Users and the resource | Identifying users and documenting transmission (not content) and spectrum sensing |
| Graduated Sanctions | Back off protocol and explicit coordination |
| Conflict resolution mechanisms | Protocols for negotiating interference protection |
| Minimal recognition of rights | Delegation of local spectrum control by FCC, NTIA and SAS operators |
| Nested Enterprises | Ability to self-organize and delegate regional spectrum controller |

CASE STUDY

- Components:
  - Radio Appliance (RA)
    - Geo-located base station
    - SAS functionality
    - Registers with super-regional SAS
- Operation
  - No interference: SAS does what is needed in terms of power, bandwidth, etc.
  - Interference: affected RAs negotiate power, sub-bands, protocol, etc.
  - Too many RAs: elect one RA as a regional coordinating SAS

# CASE STUDY: CBRS

Case A: Low density rural application

- Cattle monitoring in hypothetical Wyoming ranches

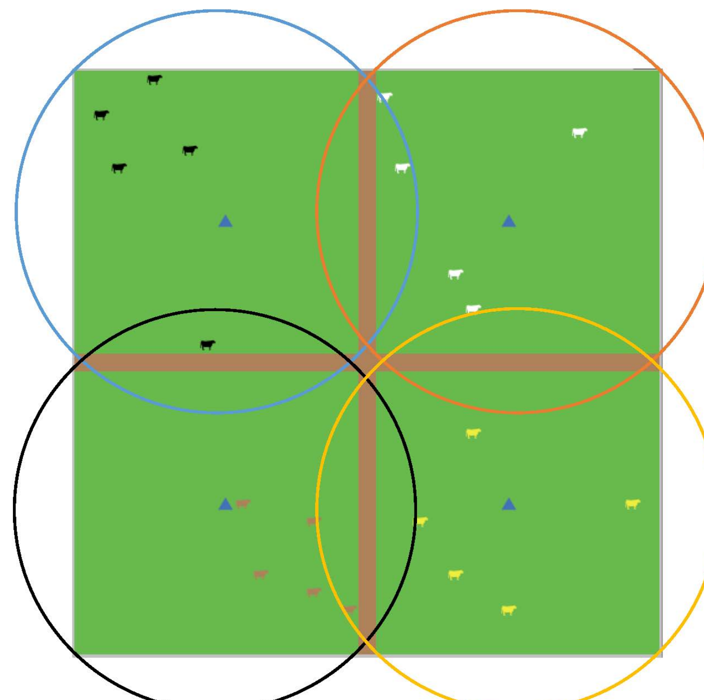
Case B: Medium density application

- Semi-urban area

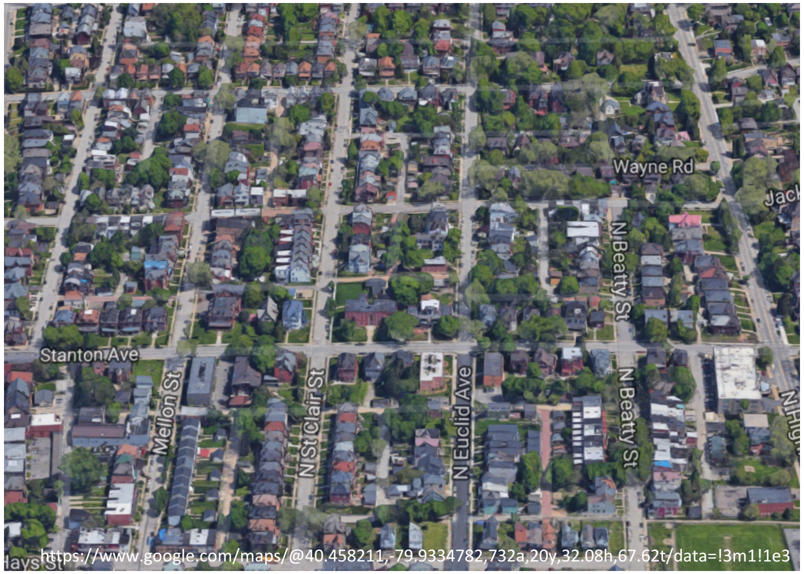
# CASE STUDY A


Real Life

NetLogo Interpretation

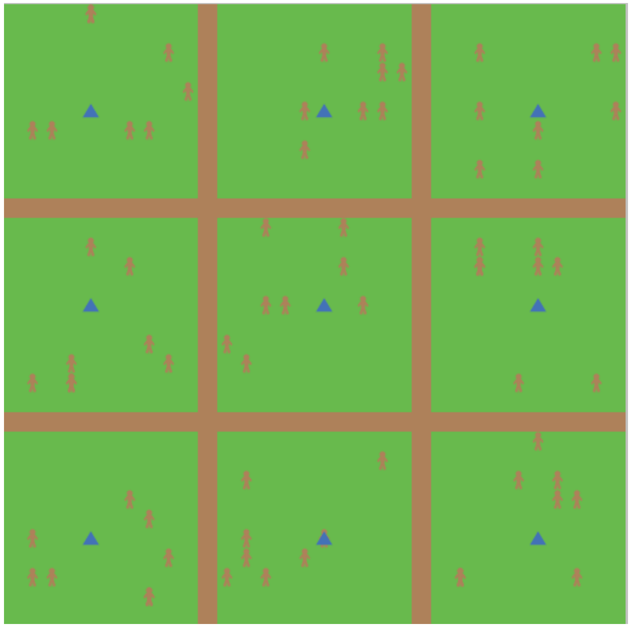


# CASE STUDY B




Real Life

NetLogo Interpretation



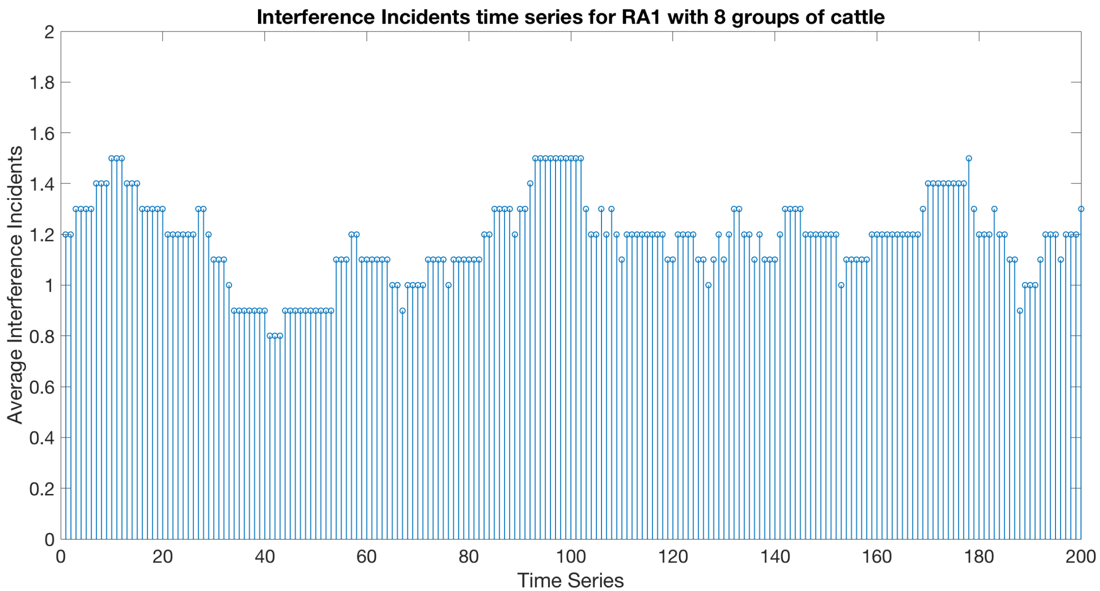
# NETLOGO SIMULATIONS

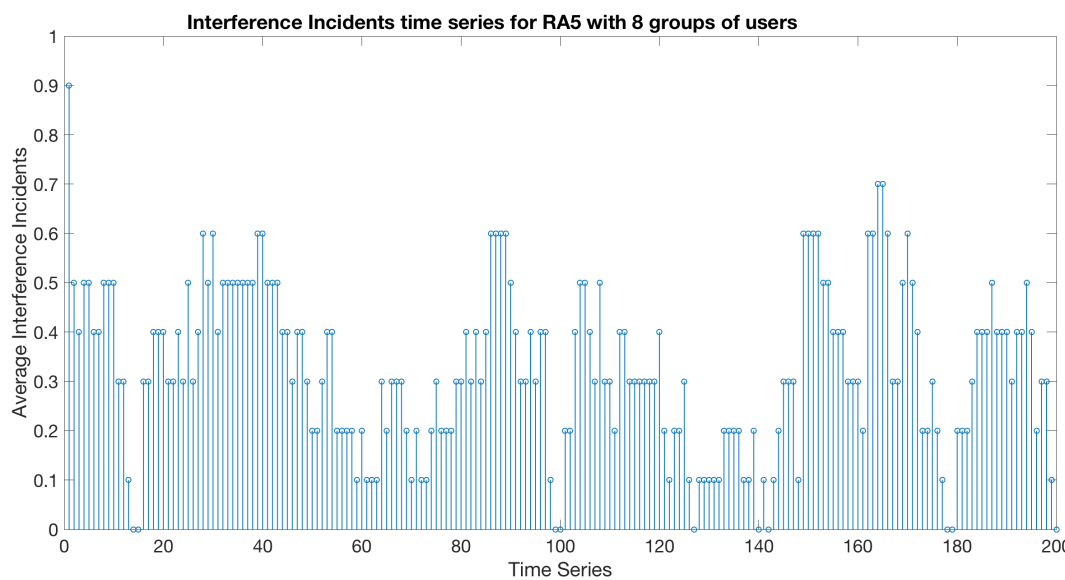
- Simulation Parameters:
  - “Turtles”: Cows, users and RAs
  - Patches: Ranches or required coverage area

- Transmit power options:
  - Minimum required to cover entire area
    - Path loss calculations using Extended Hata Model
  - Limit established by the FCC
  - 10 dB above the maximum allowed by regulation

- Coordination (Interference) Events
  - Power received by cow or user agents > agents’ sensitivity threshold
  - Cows/Users are within the maximum coverage area of the RA of a neighboring ranch/cell.

# Interference Events – Worst Case

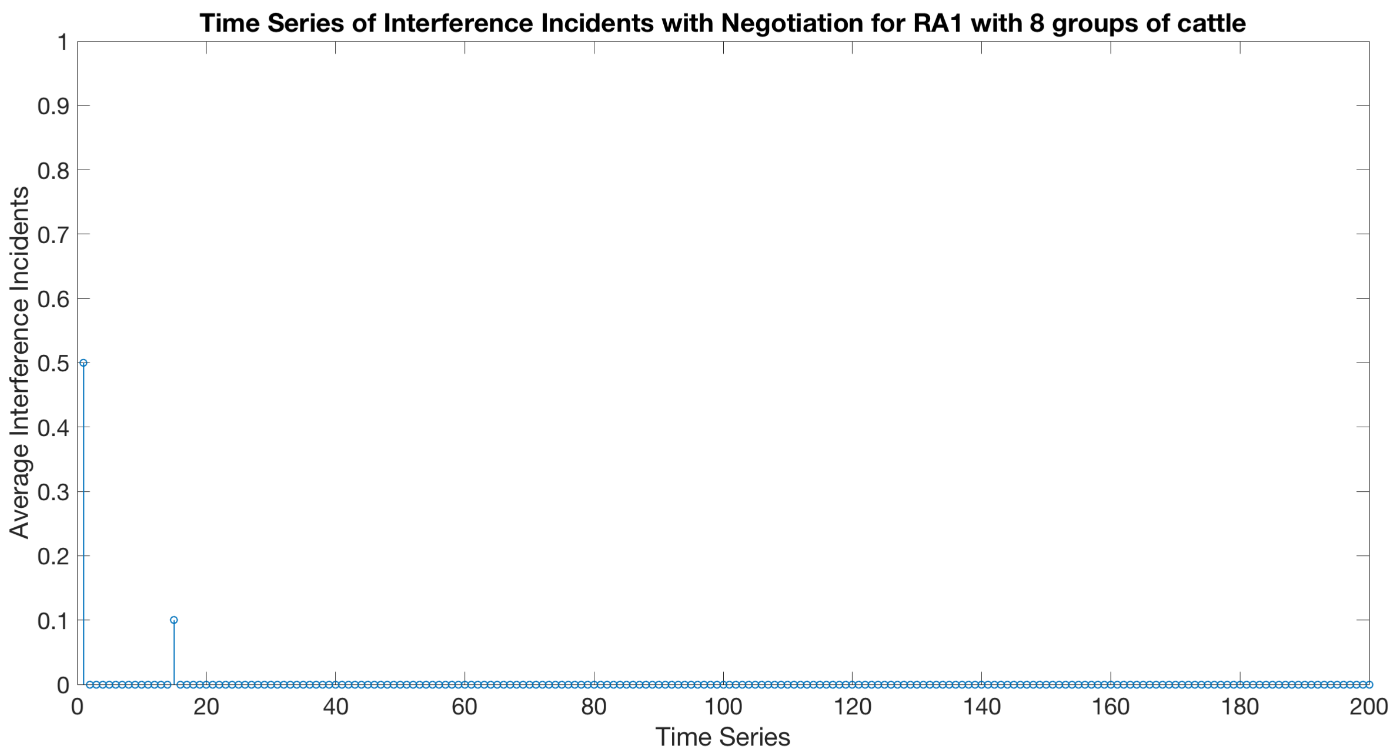



RESULTS

A CASE STUDY

# Interference Events after we implement negotiation



# DISCUSSION

**Boundaries:**

geographical, technical and regulatory limits

**Appropriateness to local conditions:**

Explore settings in rural and semi-urban environments

Adapt transmit power to local interference events

**Monitoring:**

Interference event tracking

Negotiation effectiveness monitoring

# DISCUSSION

**Collective Choice arrangements:**

Negotiation to solve interference problems.

Results from coordination and resource management

**Conflict Resolution:**

Prompted by the first party detecting interference

Modify transmit power or switch bands

# CONCLUSION

- We explore the feasibility of using SAS to implement a decentralized, locally driven spectrum policy.
  - Dynamically adapt to the needs of particular areas
  - Manage resource access, interference and assignment

- Power limits established by the FCC avoid the need for negotiation, BUT reduce the coverage area
  - Is this a valid tradeoff in rural Wyoming?

# CONCLUSION

- Frequency of interference events leaves room for negotiation and coordination
  - Even more so heterogeneity of uses/users.
- IEEE 802.11 systems may benefit from polycentric governance
  - Local governance suitable for diversity of performance requirements, QoS and resource usage

# FUTURE DIRECTIONS

So far, negotiation looks promising…

Will it hold in more *complex* environments?

- Further technical parameters
- Additional conflict-resolution actions

What is the actual cost of coordination?

- Performance and economic