How can Polycentric Governance of Spectrum Work?

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It’s all about sharing...
...and sharing is about redefining or constructing (bundles of) rights
Diverse sharing regimes

DIVERSE ENFORCEMENT CHALLENGES
• 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?
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
In SAS-enabled sharing environments, find a mechanism that permits to create and distribute collective rights dynamically

- Adaptive to local conditions and negotiations
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

http://www.onthecommons.org/magazine/elinor-ostroms-8-principles-managing-commons
High subtractability of use

Difficult to exclude external users
When does it work?

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

Can we refer to spectrum as a common pool resource?
*under current technology
<table>
<thead>
<tr>
<th>Attribute (from Ostrom)</th>
<th>System feature</th>
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<tbody>
<tr>
<td>Well defined boundaries</td>
<td>Operating boundaries determined by transmit power and antenna characteristics</td>
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<tr>
<td>Congruence with local conditions</td>
<td>Locally determined spectrum assignment and usage</td>
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<td>Collective Choice Arrangements</td>
<td>Open source software for radio appliance and open protocol standard process</td>
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<td>Monitoring Users and the resource</td>
<td>Identifying users and documenting transmission (not content) and spectrum sensing</td>
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<td>Graduated Sanctions</td>
<td>Back off protocol and explicit coordination</td>
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<td>Conflict resolution mechanisms</td>
<td>Protocols for negotiating interference protection</td>
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<tr>
<td>Minimal recognition of rights</td>
<td>Delegation of local spectrum control by FCC, NTIA and SAS operators</td>
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<tr>
<td>Nested Enterprises</td>
<td>Ability to self-organize and delegate regional spectrum controller</td>
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</table>
**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 A: Low density rural application
  • Cattle monitoring in hypothetical Wyoming ranches

Case B: Medium density application
  • Semi-urban area
Real Life

http://www.biostandups.com/agricultural/white-gold-Ireland-best-world/

NetLogo Interpretation
CASE STUDY B

Real Life

NetLogo Interpretation

https://www.google.com/maps/@40.458211,-79.933478,732a,20y,32.08h,67.62t/data=!3m1!1e3
• 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

Interference Incidents time series for RA1 with 8 groups of cattle

Interference Incidents time series for RA5 with 8 groups of users
Interference Events after we implement negotiation
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
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
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