# Spectrum Commons:
## Unlicensed, Short-term, Dynamic, and Shared-Use...

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*Improving Spectrum Mgmt through*

*Market-based Incentive Mechanisms*

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# Commons: unlicensed, dynamic, shared-use
### (aka infrastructure owner not exclusive licensee)

- ❑ Commons are market-based too!

- ❑ Business models for "commons" are real important

- ❑ Lessons for how to manage commons access

# Future is shared spectrum:
## decoupling spectrum frequencies from
## infrastructure investment & applications

| | |
|---|---|
| **Technology**<br>(Capabilities) | Smart radio systems, spread spectrum, transition to broadband platform architectures → frequency agility, expanded capacity for sharing |
| **Revenue**<br>(Customer experience) | Heterogeneous networks (3G/WiFi, wireless/wired, global roaming) → 24/7 availability, simplicity of use, seemless mobility |
| **Costs**<br>(Network provisioning) | Bursty traffic, multimedia services, fat-tailed usage profiles → lower costs, take advantage intermodal competition |
| **Policy**<br>(Spectrum reform) | Transition to expanded flexible market-based licensing and unlicensed spectrum mgmt regimes→ reduced *artificial scarcity* due to legacy regulations |

# Managing Access to Shared Spectrum

GOAL: Market-based incentives to share efficiently
Incentives for efficient radio system design

## LICENSES

❑ market in exclusive spectrum licenses

## COMMONS

❑ marketplace for technologies and uses

Different MARKET mechanisms for pricing/allocating costs…

Interference Externalities?

❑ Internalize (strong)

❑ Shadow price for congestion (weaker?)

Transaction costs?

❑ Secondary market costs

❑ Protocol compliance costs (equipment design)

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# Spectrum scarcity is matter of perspective

User/Use …

Transaction
Costs
(relative to value)

Interference Protection Needed

|  | Weak | Strong |
|---|---|---|
| High | Unlicensed | C&C, subsidized licensed |
| Low | Licensed/Unlicensed ?? | Licensed |

Smart radio systems:
Greater interference robustness
More sharing options

Market success:
More congestion
Fast innovation

Off-diagonal cases more common? Weak/low or Strong/high
- Dynamic shared spectrum options
- Multiple, complementary regulatory options

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# Spectrum Commons : Business Models

**Public Commons**

- *WiFi* : Viral deployment by edge-users of wireless devices
  - 802.11x, Bluetooth, WiMax, ???..

- *Community networking*: Municipal wireless
  - Hot spots, WISPs, City-wide wireless (Philly, SF)

**(Semi-) Private Commons**

- *Mobile provider sharing 3G spectrum:*
  - Lower infrastructure costs for managing (a) interoperability (seemless connectivity across multiple platforms) and (b) bursty traffic, when (c) spectrum control no longer provides market power.
  - Software radio architectures for base stations (and handsets)

**Public or (Semi-) Private Commons**

- *Mesh networking*: Ad hoc and semi-fixed networks
  - Sharing public safety broadband networks
  - Ad hoc emergency networks

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# Ecosystem for Unlicensed Devices

❑ Technical (protocols/etiquettes )

- Sharing protocols for decentralized management of resource sharing
- Game theory (incentive compatible coordination/cooperation)
- Cognitive radios (smart/adaptive agents)

❑ Market mechanisms

- Business models
- Transaction/market infrastructure → "property rights"
  - Commons (right to use) vs. Licensed (right to exclude)

❑ Regulatory regime

- Minimalist (light-handed, technology neutral)
- Cognitive radio → certification → liability rules/enforcement
- Enhanced "Part 15" rules

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# Thank you!

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See:

Lehr, William and Jon Crowcroft (2005), "Managing a Spectrum Commons,"

IEEE DySPAN2005, Baltimore, November 2005.

(see http://cfp.mit.edu/resources/papers/Lehr_Crowcroft_SCD.pdf )

# Goals for a Successful Commons Mgmt Protocol

| | |
|---|---|
| ❑ **Promote Innovation** | ➢ Devices, services, & business models<br>➢ Complement C&C and Flexible Licensed |
| ❑ **Minimize spectrum access costs** | ➢ Min entry barriers for new nodes to access spectrum, new technologies to be deployed<br>➢ No real-time usage fees for access |
| ❑ **Manage Congestion** | ➢ Distributed/decentralized congestion management and coordinating usage (aka TCP-like) |
| ❑ **Manage etiquette/protocol rules** | ➢ Lack tradable licenses to allow market mediation of changing technical protocol<br>➢ Need structured process (industry standardization) to mediate change |
| ❑ **Promote fair, non-discriminatory access** | ➢ Promote open access<br>➢ Distributed/decentralized is inherently fair |
| ❑ **Minimalist regulation** | ➢ Decentralize to market forces<br>➢ As minimal regulation as necessary to provide structure<br>➢ Technology & business model neutral |

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# Rules for Mgmt of a Spectrum Commons (part 1)

| | |
|---|---|
| ❑ **No Tx only, No protection for Rx only** | ➢ Tx need feedback loop to respond to environment <br> ➢ Rx need ability to signal presence to gain protection |
| ❑ **Power** | ➢ Should anticipate multihop use, <br> ➢ Limits on individual Tx (dynamic), but also <br> ➢ "Interference Temp" (aggregate flux) |
| ❑ **Signaling** | ➢ Common channel signaling capability <br> ➢ Share global information & make pre-emptible <br> ➢ Will aid in supporting cooperation and enforcement |
| ❑ **Contention** | ➢ Manners, not protocol <br> ➢ "TCP-friendly" fair queuing |

# Rules for Mgmt of a Spectrum Commons (part 2)

| | |
|---|---|
| ❑ **Enforcement** | ➢ Protocol should support incentive compatible cooperation, which includes enforcement mechanism<br>➢ Legal sanctions and other institutional frameworks needed to complement protocol.<br>➢ Software radio cert & liability rules will be key. |
| ❑ **Reversibility** | ➢ Mechanism needed to de-allocate commons spectrum in short and long term.<br>➢ Pre-emptibility capability will aid short-term deallocation<br>➢ Term limits or regular regulatory review may be required for long-term |
| ❑ **Security/privacy** | ➢ Privacy/security protection will be critical<br>➢ Need secure out-of-band control channel?<br>➢ Minimal sharing of information to protect privacy<br>➢ Decentralized privacy mechanisms needed |

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