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Emerging Technology and Spectrum Policy Reform

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Opportunities for Reform

- In many nations, there is a severe shortage of available spectrum
- Much of the useful spectrum is idle at any given time and location
- New technology will support far more efficient use of spectrum.
- To alleviate scarcity, policies must
  - exploit the realistic capabilities of current technology, and
  - rely on sound economic theory

Approaches to Reform

- Debate over “commons” and “property” is counter productive
  - Both approaches have merit if applied appropriately
  - Both approaches lead to problems if taken to extremes
    - Such that assumptions about current technology are invalid
  - The debate obscures another important class of reforms
    - Sharing between a primary spectrum user and one or more secondary users
- In this talk
  - Spectrum property
  - Spectrum commons
  - Sharing between primary and secondary

Spectrum Property

- Market-based mechanisms have many advantages
  - Allocate resources
    - to those who value them the most
    - in the amount that maximizes value
    - for the purpose that maximizes value
- But spectrum is not like most property
  - Occasionally need regulatory intervention to change how spectrum is used, e.g.
    - to redefine how spectrum can be shared as technology evolves
    - to insure that large contiguous blocks are available for useful purposes
  - This means that “property rights” must be limited
    - Maximal flexibility is not always best.
    - More importantly, licenses should expire. No permanent rights.
      - License expiration is an opportunity to act.

Spectrum Commons

- In a commons, spectrum is shared.
- Two *very* different types of commons
  - based on cooperation of devices
  - based on coexistence of devices

Spectrum Commons based on *Coexistence*

- Devices cannot all communicate with each other
- Proven to be useful in today's unlicensed bands
- Advantages
  - Allows spectrum sharing.
  - Makes mobile wireless systems possible:
  - No lengthy licensing process, promotes innovation.
  - Cost-effective when licensing cost would dominate
- Better than licensing for some applications.
- Completely inadequate for other applications.
- Technical rules governing the band are important
  - To promote efficiency, protect against tragedy of commons

Spectrum Commons based on *Cooperation*

- All devices communicate with shared protocol and coordinate
- Cooperative gain may yield much greater efficiency
- Promising but still immature technology
- Challenges
  - What if some devices do not cooperate?
    - Security issues for selfish or malicious nodes
  - Who will define the protocol?
    - A challenge for regulators. Perhaps easier for a license-holder

Primary-Secondary Sharing

- Primary gets guaranteed quality of service
- Secondary cannot cause harmful interference to primary
  - Uses spectrum that would otherwise sit idle
- Facilitated by emerging technologies
  - e.g. cognitive radio, software radio, GPS, sensor networks, secure payment technology
- Different sharing schemes, different policy regimes
  - License-holder permits secondary to operate
    - A new form of secondary spectrum market
  - Regulator gives license to operate *as secondary*
    - e.g. to operate when primary license-holder allows, or in white space
  - Regulator permits secondary to operate without a license
- Different approaches are suited to different applications

Primary and Secondary Coexist

- Secondary is invisible to primary
- All complexity in secondary devices.
  Good where legacy systems are not easily changed.
- Probably no QOS guarantee possible for secondary.
- Secondary transmits
  - at low power, or
  - *opportunistically* after sensing the environment
- Technology of opportunistic access is
  - challenging in some environments.
    An area of current research.
  - easier if primary transmitters are fixed,
    e.g. where broadcasters or fixed point-point are primary.

Primary and Secondary Cooperate

- Example: secondary requests permission to use spectrum before transmitting
  - an opportunity for primary to guarantee QOS
  - an opportunity to collect payment, if commercial
- Primary needs component that can act as gatekeeper.
  - e.g. more convenient for cellular than broadcaster
- We've analyzed scenarios where extensive communications among secondaries is possible with little impact on primary.
  - Use location technology to enhance frequency reuse, and secure payment system technology.

Primary-Secondary Models

Research at CMU has considered the following models.

Primary: blue Secondary: red	Secondary is unlicensed	Secondary is licensed
No coordination between primary and secondary	**Unlicensed underlay**. e.g. Broadcasters with site licenses and opportunistic devices w.o. QOS guarantees	**Licensed secondary** with exclusive access **in white space**, guard bands, e.g. Broadcasters and microcellular or cellular
Coordination between primary and secondary	**Real-time secondary market**, e.g. Cellular and devices with temporary QOS guarantees	Secondary with exclusive access but **interruptible access**, e.g. Public safety and cellular

Conclusion

- Great opportunities to relieve spectrum scarcity through policy reform
  - More market-based mechanisms in spectrum licensing
    - e.g. auctions, secondary markets
  - More use of commons based on coexistence (unlicensed spectrum)
    - Perhaps someday commons based on cooperation too
  - More sharing between primary and secondary users
    - There are multiple models. Each better for some applications and worse for others.
- Regulators should make a variety of different approaches available in different bands
- While both commons and property approaches have merit, taking either to extremes leads to problems.

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Some of the papers referred to in these slides are available at www.ece.cmu.edu/~peha/wireless.html

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