Flexible Spectrum Policy
and
Managing Shared Access

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CFP Plenary Meeting
Cambridge, MA
October 27, 2015

CSAIL

MIT COMPUTER SCIENCE AND ARTIFICIAL INTELLIGENCE LABORATORY

Flexible Spectrum Policy & Managing Shared Access

- **Everyone wants more spectrum...**
  - Commercial BB & Government users
  - Communications & Sensing
  - High & Low Power, Wide-area & Local, Planned & Ad hoc....
  - Licensed & Unlicensed (& lots of hybrid models)
- **Lots of ways to share access...**
  - Cellular/TV: single network manages spectrum for customers
  - Wi-Fi: uncoordinated sharing among independent APs
  - TVWS: 2-tiered sharing, unlicensed overlay TV broadcast
  - UWB: 2-tiered sharing, unlicensed underlay users (in noise floor)
  - 5GHz: Unlicensed DFS
  - 3.5GHz: 3-tiered sharing, enabled by Spectrum Access System (SAS)
- **Need flexible Spectrum Management framework**
  - Multiple classes of users/usage rights models....

Spectrum Access System (SAS): from static to dynamic

Today….

Tomorrow…

Source: PCAST
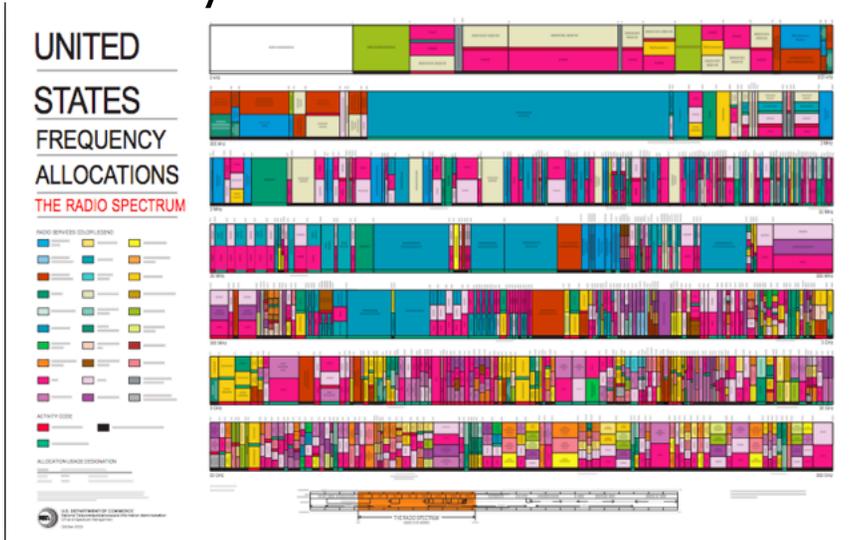
Today's "SAS":
- Static, Inflexible, Uninformative

Tomorrow's SAS vision:
- Dynamic, Flexible, Informative
- Better matching supply and demand on granular basis (time, space, context)

By enabling:
- Multiple usage tiers (extensible)
- Flexible, timely policy updates
- Automation of spectrum mgmt
- Flexible rights enforcement options
- Data sharing, learning
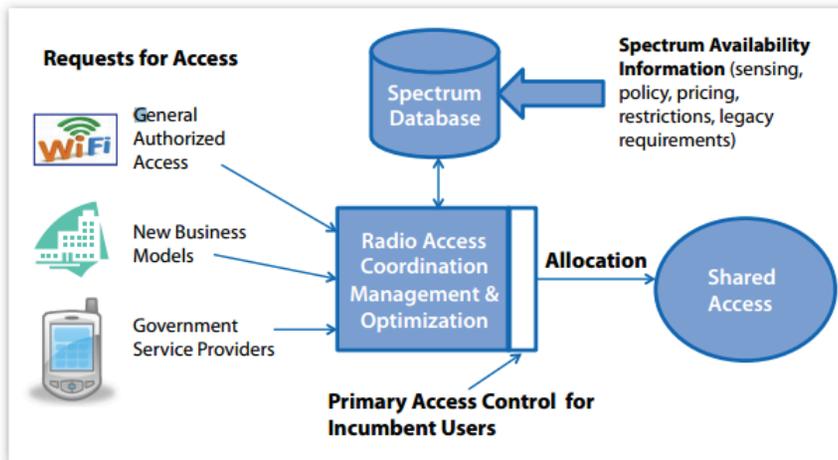
BUT, lots of details to work out…
- Interference protection models?
- How dynamic is SAS control? (sensing?)
- Who updates/manages SAS? Access?
- How many SAS? How to interoperate?

# Exclusion v. Interference Protection
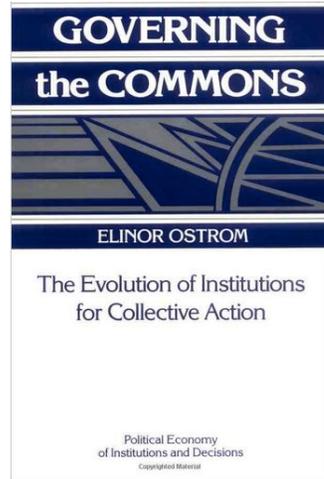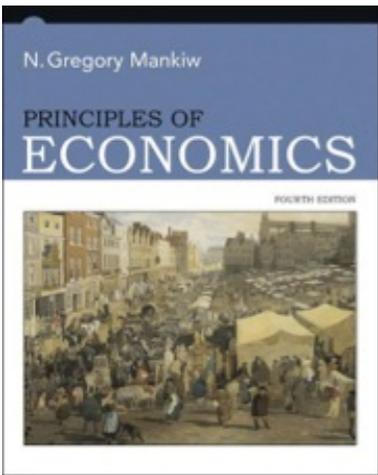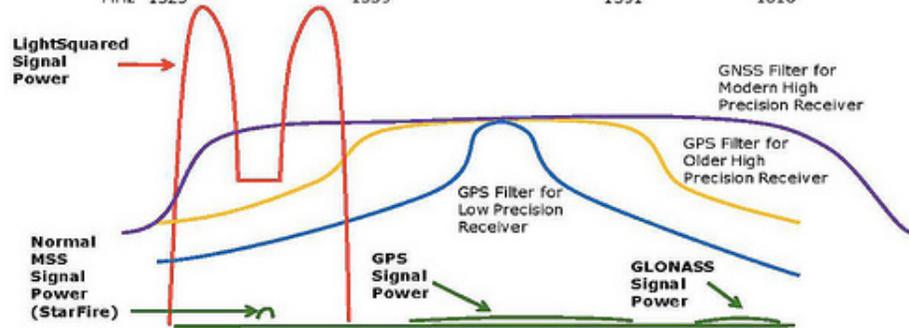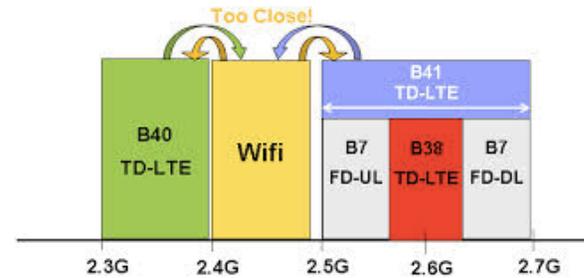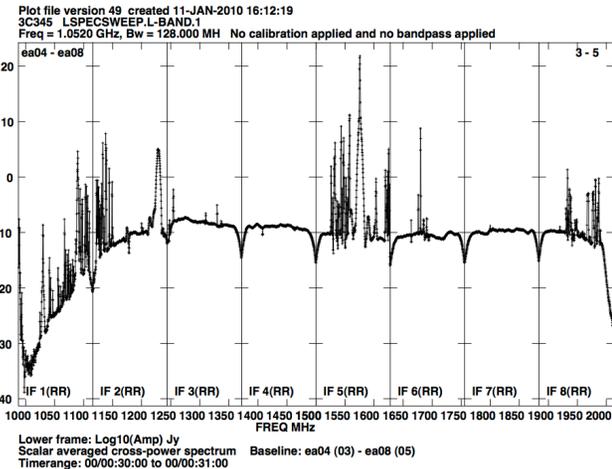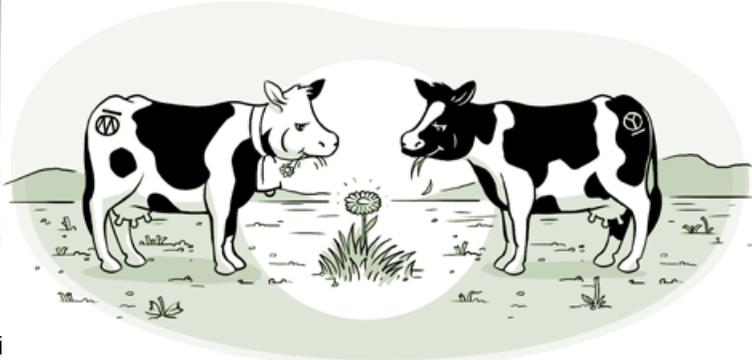
Summing up...

Future is shared spectrum

- Multiple paradigms needed (legacy, new, and future new...)
- Framework that can adapt as users/usage/technolgy/markets change
- New sharing models implies changing Property Rights assignments

SAS is right direction

- Technology, policy, and markets all co-evolving
- SAS is a tool for *Common Pool Resource* Governance (a la Ostrom)

Exclusion & Interference Protection rights separated

- Spectrum policy not just about interference protection
- Interference protection *always* an economic argument. Instead of arguing economics of exclusion via engineering models of Interference protection, make it explicit.
- License framework needs both explicit economic and engineering levers to incentivize sharing

References

Lehr, William (2015), "Spectrum License Design, Sharing, and Exclusion Rights," TPRC2015, Alexandria, VA, September 2015, available at SSRN: http://ssrn.com/abstract=2587877

Weiss, M., W. Lehr, A. Acker, and M. Gomez (2015), Socio-Technical Considerations for Spectrum Access System (SAS) Design, IEEE DySPAN 2015, available at http://d-scholarship.pitt.edu/25828/1/dyspan_revisions_4.pdf.

Lehr, W. (2014), "PALs as Options to Exclude GAA," Reply Comments submitted in the matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, GN Docket 12-354, August 15, 2014, available at http://apps.fcc.gov/ecfs/document/view?id=7521763142

CFP Spectrum Working Group

- https://people.csail.mit.edu/wlehr/SpectrumWG/SpectrumWG.htm
- Userid/passw: "cfplsa"

ADDITIONAL SLIDES

FCC 3.5GHz proceeding

- "More spectrum for Broadband!" BB Plan (2010), Pres Memo (2010), PCAST (2012)

- New *Citizens Band Radio Service* (CBRS) in 3.5GHz
  - FCC R&O (Apr2015)
  - Commercial Sharing with Government (Incumbent DoD Radar)
  - Small cells (low power, smaller exclusion zones, 70k Census Blocks)
  - Managed by Spectrum Access System (SAS) – time/location/license class

- Multi-Tiered model of usage:
  - (1) Incumbents: shared with Federal users (naval radar)
  - (2) Priority Access Licensee (PAL), protected users, like "licensed"
  - (3) General Authorized Access (GAA), like "unlicensed"

- How PALs (Licensed) and GAA (Unlicensed) should share?
  - Lehr (2014) Reply Comment "PALs as Options to Exclude"
  - R&O ➔ "GAA can use PAL spectrum, except when *in use*"

Spectrum Sharing: the value of exclusion

Q: Share spectrum among multiple tiers of users (rights holders)

-- call them "Licensed" (aka PAL) and "Unlicensed" (aka GAA)
-- #1: PAL is interference protected
-- #2: GAA can use if does not violate #1

How?

-- *Technical*: model/sense PAL usage, identify when GAA use non-interfering

-- *Economic*: assign right to PAL to determine when GAA should be excluded

A: Interpret PAL as *option* to exclude GAA (Lehr, Reply Comments, 2014)

-- PAL buys license, pays P1 at t0.
-- PAL pays P2 if it elects to exclude GAA users at time t1

Understanding "PALs as Options to Exclude"

Today.. *Arguing* about rules to enable sharing (in the future!)

- Interference based on models, not experience at scale
- Lots of stuff to decide and know we will need to adapt SAS
- Dueling business models: Licensed Cellular v. Unlicensed WiFi
- *What is the economic value of exclusion? Enhance the discourse.*

Tomorrow.. SAS and 3.5GHz sharing at scale

- Hybrid framework to determine "*in use.*" Engineering & explicit Economic levers to manage sharing. More flexible, adaptable control.
- Extensible: new license frameworks, business models, sharing options
- *What is best way to manage shared access? Let market decide.*

Future.. Spectrum resources are economically mobile

- i.e., Resources go to highest value use, minimal transaction costs. Spectrum resources increasingly fungible, commodity-like.
- Electrospace sharing model (time, space, frequency, context, etc.)
- *Securitization and derivative markets (e.g., options) to manage risk*

Benefits of "PAL as options to exclude"

Economic incentives to share spectrum
-- Better matching of sharing opportunities to local context
-- Exclusion only when efficient. Even more
-- More spectrum for GAA
-- *(Not alternative to technical interference protection, but "in addition to")*

Addresses asymmetric information challenge of regulators
-- Regulator assigns property right, market selects solution
-- Facilitates market learning (evolution of trust, best practices)
-- (Competition among PALs addresses hoarding risk)

Easy to implement & robust to other changes
-- just modify payment terms, update the SAS (dbase)
-- license duration, territory size, interference limits, etc. not impacted
-- if cannot exclude GAA on exercise option, then 3-tiered won't work

Consistent with Dynamic Spectrum Future
-- Enable more fine-grained ways to manage interference
-- Separate interference protection & right to exclude

Exclusion as a property right

What makes exclusive-spectrum rights more(+)/less(-) valuable?
  -- (+): scarcity (esp. of exclusive spectrum)
  -- (+): congestion/interference risk
  -- (-) : flexible, less co-specialized RAN assets (e.g., DSA tech, SDA, LTE)
  -- (-) : liquid spectrum markets
  -- (-) : small cell architectures

Exclusion as strategy for interference protection?
  -- Perfect Rx can separate signals
  -- Optimal interference protection mix technical, market, policy
  -- Evolves over time

Issues and Considerations

(1) Feasibility of GAA exclusion
    -- need to be able enforce protection in any case
    -- this is easiest form of exclusion

(2) PAL revenues?
    -- maybe higher, maybe lower
    -- max revenues wrong goal in any case

(3) Cheap way to foreclose GAA (via threat of exclusion)
    -- foreclosure risk seems over-stated in any case
    -- pricing of Exercise price (P2) is policy choice

(4) Optimal pricing of Option? Splitting is ad hoc, but simple.

(5) Nits and details
    -- Reversibility of exclusion
    -- Separate trading of option and exclusion rights: aka, derivatives…