

Spectrum Policy Lecture #2:
Spectrum Management Reform

William Lehr

Massachusetts Institute of Technology

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Outline

- ❑ Why spectrum reform now: a recap..
- ❑ Models of spectrum regulation
- ❑ Property Rights v. Commons
 - Simplistic view
 - More complicated view

Why spectrum reform now?

- ❑ Lots of new technology and services that are being held back by legacy regulations...
 - Insufficient spectrum for commercial use
 - What is available, is not used efficiently
 - License rules limit market flexibility
- ❑ Problem: Artificial spectrum scarcity!
 - Sharing opportunities missed
 - Innovation blockaded: services, devices, and business models
 - High marginal cost for spectrum (auctions bankrupt providers)
- ❑ Solution: Spectrum Reform...

Goals for Spectrum Policy Reform

- ❑ Eliminate artificial scarcity: introduce market forces
 - Flexible use, secondary market trading
- ❑ Accelerate wireless broadband revolution
 - Convergence of Internet & wireless
 - Promote evolution from 2G to 3G
- ❑ Promote adoption of advanced technology
 - Refarm underused spectrum to high value uses
 - Enable new capabilities, promote investment (smart receivers)
- ❑ Last mile bottleneck: unleash 3rd mile competition
 - New, low cost infrastructure in developing world
- ❑ Enable new business models:
 - MVNOs and value-added service providers
 - Wireless grids and edge-based networks

Spectrum Management Models

- Three basic models:
 - Command & Control: (legacy model under attack)
 - Technology, provider, services specified by regulator
 - Exclusive license: “Property rights”
 - Flexible, transferable licenses to operate in area/band.
 - Licensee chooses technology, services
 - Secondary markets: licensee can trade rights to third parties
 - Unlicensed: “Commons”
 - Underlay: UWB, Part 15 devices (secondary use)
 - Opportunistic: interleaving, use white space (secondary use)
 - Dedicated: ISM 2.4 and 5 GHz bands used by WiFi
- Policy recommendation: increased reliance on exclusive licensed for scarce spectrum or commons otherwise
 - Especially for spectrum below 3GHz

Spectrum Management and Wireless Markets

- Broadcasting Spectrum (exclusive, inflexible licenses) – example of problem
 - Architecture for high power transmission for over-the-air broadcasters uses (low power) spectrum inefficiently
 - Move terrestrial TV to satellites or wires (cable)
 - Encourage development of smart receivers
 - Legacy of using “interference” threat to oppose competition (FM radio, UHF broadcasting) and slow to deploy new technology (digital TV conversion)
 - What about over-the-air digital TV?
- Mobile Telephone Services (exclusive, (semi)-flexible licenses) – success!
 - Poster child for competition success: consumer choice, declining prices, service innovation.
 - Use spectrum very efficiently. Lots of sharing.
 - Allocated via auctions (but what about 3G auctions and telecom meltdown in 2000?)
 - Benefits of mandating a single standard? 2G in Europe v. US
 - Further growth constrained by lack of access to available spectrum
- WiFi success (open access, unlicensed) – success!
 - Power limits on equipment. No exclusive right to interference protection.
 - Congestion emerging as problem.
 - Is this model generalizable?

Future is shared spectrum:

decoupling spectrum frequencies from
infrastructure investment & applications

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

Problem with Spectrum Mgmt: *Artificial Scarcity*

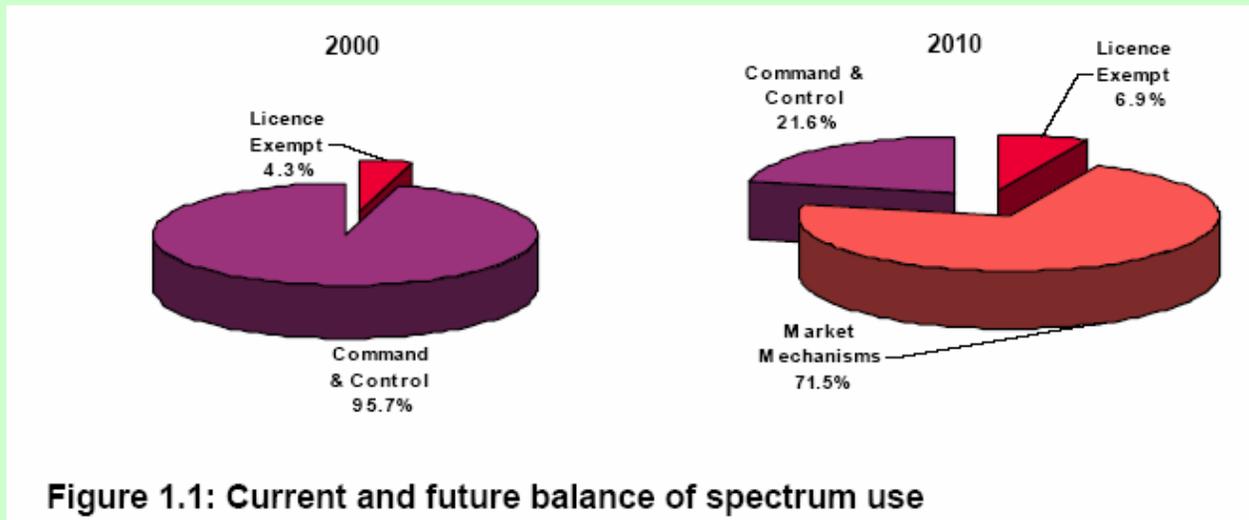
- ❑ Status Quo regulation => Command & Control
 - Blocks efficient reallocation of spectrum
 - Distorts opportunity costs => innovation, investment, competition
- ❑ Solution: Transition to market forces

Licensed (aka, “Market Mechanism,” “Exclusive Use,” or “Property Rights”)	Unlicensed (aka, “License-exempt,” “Open,” “Free,” or “Commons”)
<ul style="list-style-type: none">▪ Exclusive use: “right to exclude other transmitters”▪ Flexible: choice of technology & rules used to manage spectrum▪ Tradable: transferable right, secondary markets	<ul style="list-style-type: none">❑ Non-exclusive use: “right to transmit”❑ Flexible: choice of technology consistent with rules/etiquette❑ Collective choice of rules: standards/protocol (or government?)

Flavors of Unlicensed:

- Underlay: UWB, Part 15 devices (secondary use)
- Opportunistic: interleaving, use white space (secondary use)
- Dedicated: ISM 2.4 and 5 GHz bands used by WiFi (“Part 15”)

Current Trajectory for Reform



Source: Ofcom Spectrum Framework Review, Nov04.
Courtesy of Ofcom.

- From status quo C&C => flexible, tradable, exclusive licenses
- Unlicensed for low-power, low-range uses (<100m)
 - Limited allocation below 3Ghz
 - Underlays and Overlays (??), Dedicated @ 5GHz

#1: Need exclusive licenses (and secondary markets) to manage when scarce (if not scarce, then unlicensed best...)

#2: Unlicensed (decentralized, commons) suitable only for managing short distance, low cost of congestion

Property Rights v. Commons, part I (naïve view)

	Property Rights	Commons
View?	Transfer control to private sector via exclusive & flexible licenses defined over frequency blocks	Government-mandated communnal/"open access" use for large frequency blocks
Supporters?	Kwerel, Fahlhaber, Farber, Hazlett, Cave -- economists & regulators	Lessig, Noam, Reed, Benkler, Peha -- engineers and lawyers
Spectrum scarce?	Yes	No
Pay for spectrum?	Auctions	No, "free" to be shared
Markets or regulation?	Markets	Regulation
Network architecture	Network-centric, centralized control, service provider model	Edge-centric, distributed control, customer equipment model
What to do with incumbents?	Let them keep windfall. Cost of transition.	A detail. Buy them off if necessary.
Management? Use?	Centralized, single	Decentralized, communal

Licensed v. Unlicensed (simplistic view)

Markets	Government
Auctions	Free
Scarce	Abundant

- Spectrum scarce: use markets => exclusive licenses
 - Eliminate command & control. Transition to market forces. Allocate initially with auctions.
 - Define property rights that may be flexibly traded in secondary markets
- Spectrum abundant: conserve transaction costs => unlicensed
 - No need to incur overhead of property rights regime to allocate
 - Provide open access.
- Coordination costs
 - Small area (low power) (e.g., within home) => coordination costs without centralized enforcement are low => unlicensed fine
 - Large area (high power) (e.g., metro mobile) => coordination costs high, spectrum and network are co-specialized => use licensed
- Conclusion: (1) Flexible licensed for scarce (low-frequency) spectrum; and (2) Unlicensed access via secondary use (underlays, overlays)

Commons v. Property Rights, part II

- Some common themes, falsely dichotomized...
 - Markets v. Regulation
 - Auctions v. Free Use
- Real differences that may be relevant...
 - Spectrum scarcity
 - Frequency bias v. other ways to define “spectrum”
 - Network v. Edge/ Service v. Equipment

Markets vs. Regulation

- ❑ Simplistic: “Markets vs. Collective/Central Planning”
- ❑ Markets could adopt commons-sharing protocol if efficient
 - Fahlhaber’s “Public Parks”
- ❑ Spectrum Courts could replace administrative in either model
- ❑ Regulation in any case
 - By property rights or by administrator
 - Courts not cheaper than government necessarily
 - Government role does not disappear
 - Comm Act ‘34 → cannot alienate public ownership. Periodic review built in.
 - Realpolitik concerns associated with transition
 - On-going need to manage/enforce interference management
- ❑ And, what if “spectrum” is a *public good*?

Spectrum a public good?

- Public goods are (1) non-rival; (2) non-excludable

	Excludable	Non-excludable
Rival	Private Property	Common Pool Resource
Non-rival	Club Good	Public Good

- Technology: made more public-goods like?
 - Non-Rival: Ability to share ↑
 - Excludability: GPS ↑, Ubiquity of radios ↓
- Technology favors commons now?

Auctions vs. Free Use

- ❑ *If* scarcity, need to allocate and opportunity cost is borne. How financed/paid for is separable matter.
- ❑ Auctions achieve efficient assignment
 - Not necessarily if (1) market power; (2) capital market inefficiencies; (3) irreversible investments & uncertainty (lock-in).
 - Only for first assignment (also need efficient secondary markets)
- ❑ Could use fee mechanism to charge for access. Could have admission control for access to congested commons.
- ❑ If spectrum revenue collected, who gets it?
 - General fund or keep in sector (e.g., auctions as general tax mechanism)? Is a “spectrum tax” efficient?

Spectrum scarcity?

- ❑ What can technology do?
 - Smart receivers, MUD, etc. increase capacity
 - Need to maintain innovation and adoption incentives.
- ❑ No scarcity, then no need for property rights
 - Return to pre-1912 world for RF.
- ❑ Even if scarcity, commons may be more efficient
 - Open access/unlicensed instead of frequency-area licenses
- ❑ But, can we be certain?
 - How to protect sunk investment? (What is value of capital equipment?)
 - Cannot have free resource that is substitute for other costly resources (computation v. transport v. storage)
 - Is commons more easily reversible? (Interest group politics v. “Takings”)
 - Markets or regulation *redux*

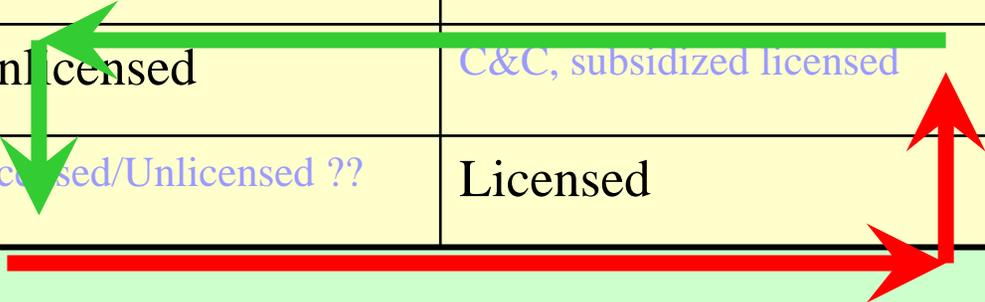
Spectrum scarcity is matter of perspective

User/Use ...

Interference Protection Needed

Transaction Costs
(relative to value)

	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

How to define interference?

- Who is causing the harm?
 - Legacy: Tx *cause* interference with Rx
 - New view: Dumb Rx *impose* externality on smart Rx
 - Ronald Coase: question of perspective, how you define property rights
- How to regulate?
 - Legacy: Restrict inputs (power limits) to limit outcomes (interference)
 - New view: Specify outcome limits (spectrum temp, receiver standards)
- How to implement?
 - Etiquettes (protocols) v. Prices v. Torts
 - Commons favors smart devices

Network/Service v. Edge/Equipment

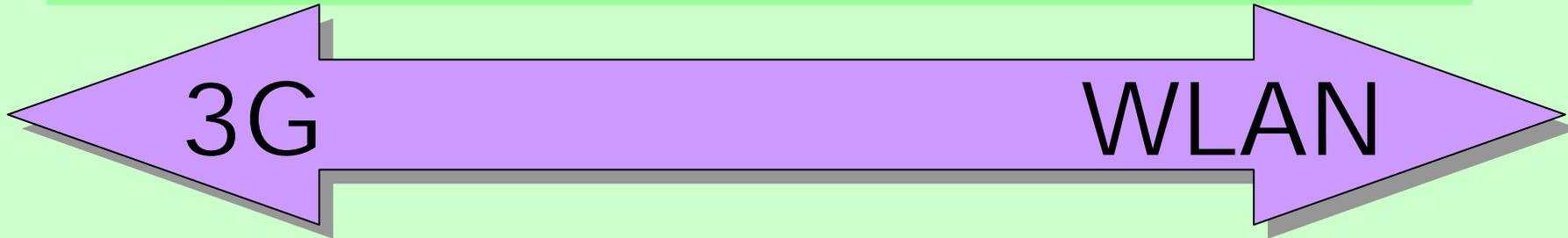
- Which industry structure better?
 - Licensed/Property rights favors service providers.
 - Unlicensed/Commons favors equipment makers and end-users
- Implications for:
 - Competition & Market Power (foreclosure)
 - Innovation & Lock-in
 - Investment in infrastructure
 - Regulatory approach (mechanism design)

How different...



Technology	UMTS, CDMA-2000, etc.	WiFi (802.11b), etc.
Bandwidth	Low (~100s Kbps)	High (~10s Mbps)
Coverage	Ubiquitous (Km)	Local (100m)
Deploy Cost	High (~\$50k)	Low (~\$1k)
Spectrum	Licensed	Unlicensed
Services	Voice adding data	Data adding voice
Retail infrastructure	Yes, service model in place	No, need to add

Wireless Industry structure?



- ❑ Traditional Carrier Model
- ❑ Top Down
- ❑ Vertically Integrated
- ❑ Centralized Control

- ❑ Accommodates Alternative Players
- ❑ Bottom Up
- ❑ Less Vertically Integrated
- ❑ Distributed Control

Service Provider Model
Network-centric
(Bell system redux?)

End-user Equipment Model
Edge-centric
(Internet vision)

Substitutes or Complements? WLANs Disruptive technology?



Example?	Telecom Services	Computer
Business model?	<i>Invest in capacity and lease access to consumers for monthly subscription service</i>	<i>Sell boxes to consumers who replace when become obsolete</i>
Where's network intelligence?	Network	Edge devices
Where's network CAPEX?	Service provider	End-user
Innovation adoption process?	Centralized	Decentralized
Who controls services?	Service provider	Customers
Regulatory?	Utility regulation	Unregulated, Certification, Industry Standards

— Different industry economics, institutional/regulatory history

Private Property v. Commons Debate

	Private Property	Commons
Resource is “scarce” (allocative efficiency)	+	
Transaction costs high (relative to value)		+
Compactness ↑: smaller community, reputation effects can work		+
Productivity ↑: value of economic activity ↑	+	
Complexity ↑: distance ↑, need network with co-specialized investments	+	
Innovation/investment incentives? (dynamic efficiency)	Network providers	Equipment vendors Smart receivers
Competition? (productive efficiency)	Incumbents	Entrants
Fairness?	Auctions?	Fees?

Licensed v. Unlicensed (more complicated)

Markets	Government
Auctions	Free
Scarce	Abundant

- Both consistent with markets, both still regulated
 - Unlicensed protocol can be chosen by SDO or markets
 - Enforcement via courts of license property rights is regulation by another means
- No free lunch, but spectrum reform lowers opportunity cost
 - Transition, congestion, transaction costs must be borne
 - Auctions may be used to effect transition, but not to extract rents
- Scarcity we observe is mostly “artificial”
 - Not driven by need to avoid “interference”
 - “Exclusive licenses” retain potential for *artificial* scarcity