



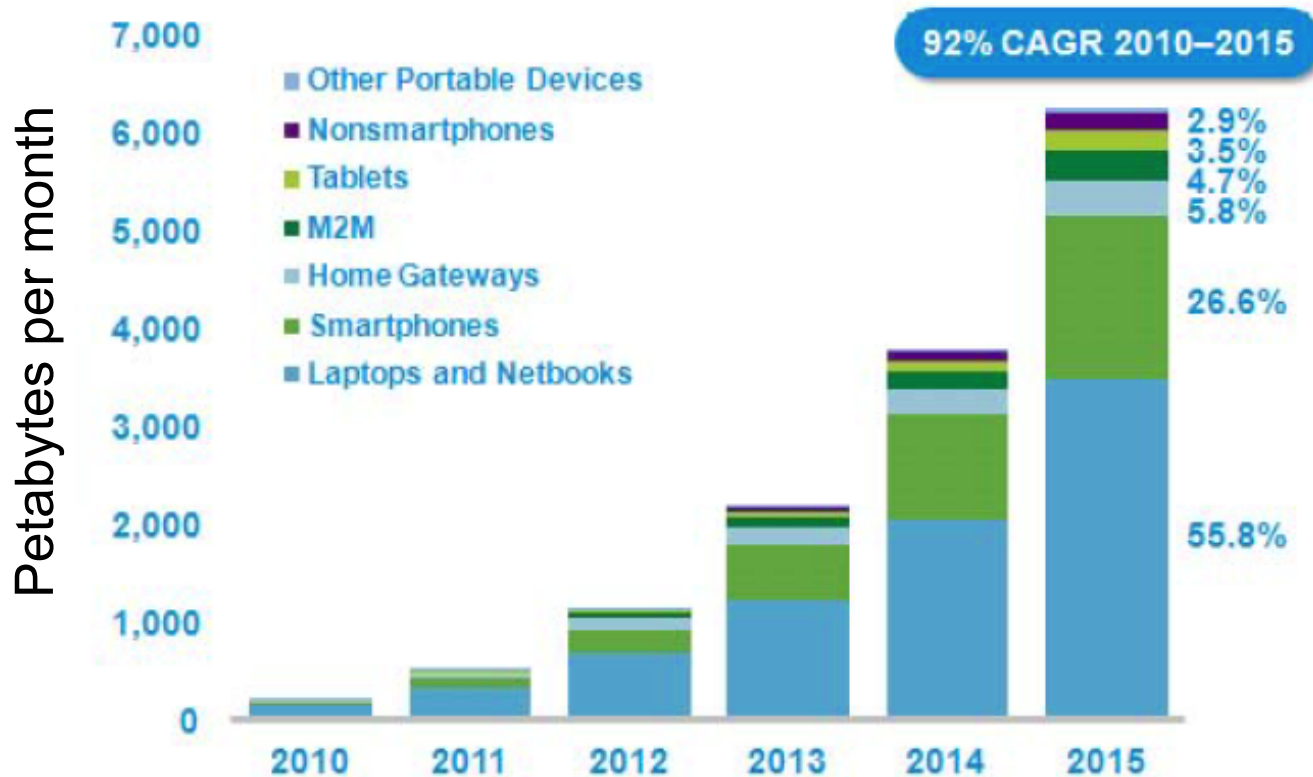
# VALUING SPECTRUM

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Based on a paper with Tom Hazlett.

# Spectrum “Crunch”

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Source: Cisco VNI Mobile, 2011

# Spectrum Policy is Important

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- Gross inefficiencies still exist with large opportunity costs.
- Spectrum assignments influence technology development
  - ▣ Licensed, unlicensed, secondary access, mmWave
- Re-allocations/assignments incur very large transaction costs.

# FCC Initiatives

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- Incentive auctions (repurposing TV spectrum)
- TV white space
- Millimeter wave bands
- 3.5 GHz band

Very high transaction costs.  
How can we reduce these?

How to define access rights?

# An Economist's Proposal

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R. Coase, "The federal communications commission,"  
*J. Law and Economics*, pp. 1–40, 1959.

Introduce spectrum property rights,  
sell to highest bidders, do not restrict use.

**Coase's "Theorem":** In the absence of transaction costs, spectrum owners will trade rights so that the outcome allocates spectrum to best use.

Ronald Coase,  
1991 Nobel Laureate in Economics

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**Role of government should be to minimize transaction costs.**

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Spectrum auctions finally introduced in the 1990s.  
Restrictions on use remain.

# Liberal License

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- Licensed for exclusive use
- Liberal use rules
  - ▣ Does not dictate technology (cellular, WiFi commons, satellite,...)
- Allows spectrum trading
  - ▣ Can re-allocate spectrum on large scales.
  - ▣ Can define/trade spectrum contracts on finer scales





# Unlicensed Spectrum (Commons)

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- ☐ Open access
- ☐ Requires etiquette rules for sharing



- ☐ Spectrum owned by government
- ☐ Etiquette rules part of industry standard (802.11)

# Licensed versus Unlicensed

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Cellular Service  
Providers



Software (apps)  
developers,  
Comcast, AT&T?

More licensed  
spectrum!

More unlicensed  
spectrum!

# More Licensed Spectrum

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- Encourages investment (cellular), efficient use
- Does not constrain technology,  
rules for spectrum sharing, business models
- Facilitates trading / Coasean bargaining

[Hazlett, 2010]

# More Unlicensed Spectrum

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- Reduces barriers to entry
- Encourages innovation (WiFi, Bluetooth, etc.)
- Has created as much value as licensed

[Thanki, 2009]

[Milgrom, Levin, Eilat, 2011]

[Benkler, 2012]

# Misconceptions

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- ❑ Open access requires unlicensed allocations.
- ❑ The value of spectrum can be estimated as the value of the services it supports.
- ❑ Free open access to scarce spectrum is economically efficient.

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# Licensed Open Access

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- Licensee sets rules, polices band
- Open access is a business model
  - ▣ Admission fee
  - ▣ Revenue from selling approved equipment
- Business model, technology can evolve without appeal to regulatory authority

# Misconceptions

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# Spectrum versus Services

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- The value of spectrum is **not** the same as the value of the services it supports.
- **Example:** the value of broadcast TV spectrum is not the same as the total sales of TV equipment.

# Valuing Broadcast TV Spectrum

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- **Opportunity cost:**

More value may be created by other services (e.g., cellular).

- **Substitution possibilities:**

Broadcast TV services can be provided by other means (cable, cellular, WiFi).

- **Marginal value:**

How much value is created by a marginal increase in spectrum?

# How to assess spectrum value?

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- The value of an increment of spectrum  $\Delta S$  is the sum of three components:
  - + Marginal value of services enabled by  $\Delta S$
  - Marginal value of services foreclosed by  $\Delta S$
  - Administrative costs associated with the allocation

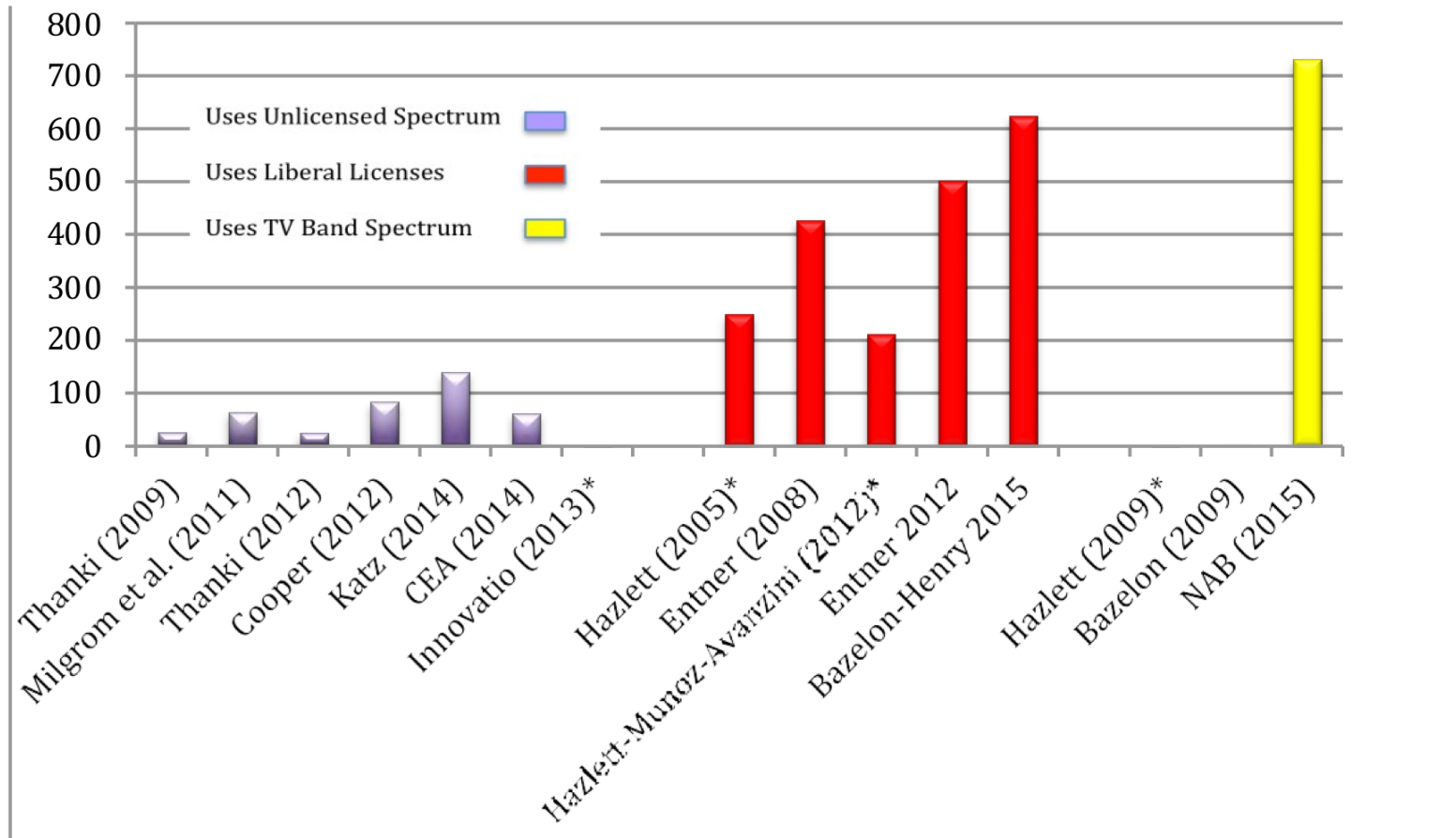
# The Regulator's Dilemma

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- How to compare social values of unlicensed versus licensed?
- Solicit estimates
- Issues:
  - ▣ Rent seeking
  - ▣ Focus on **total** value of **services**,  
ignoring opportunity/substitution/administrative costs

# Spectrum Value Estimates (\$B)

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# Transaction Costs

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- **Licensed:** normal market frictions  
(negotiations, imperfect information)
- **Unlicensed/open access:** restriction of access rights  
requires an appeal to regulatory authority

# Transaction Costs: Licensed Ex.

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- Licensed: normal market frictions  
(negotiations, imperfect information)
- Licenses for Media Flow bought by Qualcomm (2007), sold to AT&T (2011).

# Transaction Costs: TV White Spaces

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- FCC announced intentions in Dec. 2002
- Rules finalized in 2010
- Currently 735 fixed wireless radios registered
- Fragmented access rights blocks reconfiguration – needs regulatory appeal
- Another example: U-PCS (1915-20 MHz) allocated in 1993, remained idle for 20 years.



# Misconceptions

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# Free Open Access

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Free open access to **scarce** spectrum is economically inefficient.

Tragedy of the commons

Congestion in unlicensed bands → more unlicensed?



# Let Open Access Compete...

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Congestion in unlicensed bands → more unlicensed?

## Alternative uses:

- ▣ Cellular
- ▣ Satellite
- ▣ Government
- ▣ Backhaul
- ▣ ...



# Free Access and Congestion

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- Availability of unlicensed spectrum encourages use by wide-area providers (AT&T, Comcast).
- Can lead to excessive congestion, loss in total welfare.

T. Nguyen, H. Zhou, R. Berry, MH, R. Vohra, “The Cost of Free Spectrum”, to appear in *Operations Research*.

# Unlicensed Controversies

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- 5.9 GHz band:
  - ▣ Currently set aside for vehicular communications
  - ▣ Proposal to reallocate to WiFi
- LTE-U, License-Assisted Access
  - ▣ SPs will leverage licensed bands to make more efficient use of unlicensed bands



# The LAA Controversy

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Cellular Service  
Providers



WiFi Alliance

You have to share!

Leave us alone!

# Market Solution

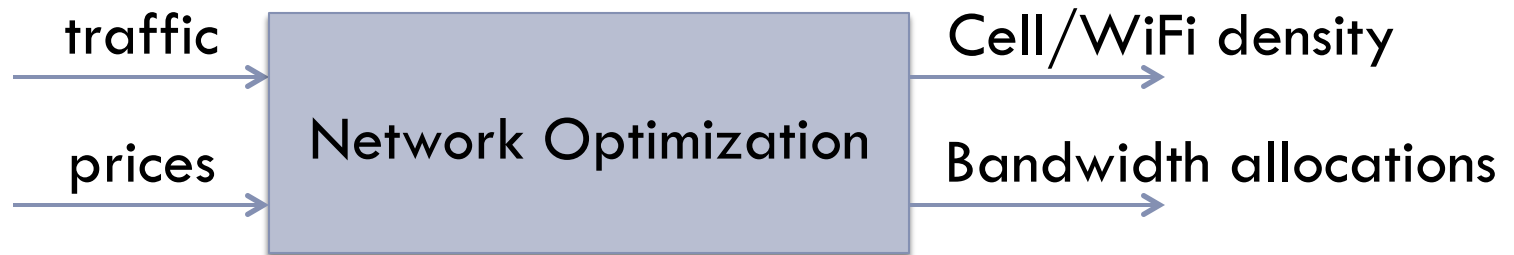
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- Assign rights, allow spectrum to be traded among providers (LTE, WiFi)
- Would eliminate need for LTE-U/LAA.
- Bids for licenses plus WiFi offloads suggest current allocations are lopsided towards unlicensed.

# Spectrum Allocation in 5G

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- Tradeoffs among:
  - ▣ Density of small cells
  - ▣ Density of WiFi access points
  - ▣ Bandwidth assignments





# Conclusions: Contention vs. Cooperation

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August 18, 2008

## FCC to Decide in Battle for TV Spectrum

As Google, Others  
Push for Sharing,  
Broadcasters Fret

By **AMY SCHATZ**

*August 18, 2008; Page B1*

Landover, Md. -- After eight months of testing, a plan to employ unused TV channels to provide cheap, high-speed wireless Internet networks still faces determined opposition and an uncertain future.