FLETCHER, HEALD & HILDRETH

# Surviving the Spectrum Shortage

## National Spectrum Management Association

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**Mitchell Lazarus**
703-812-0440 | lazarus@fhhlaw.com


Serving the Telecommunications Industry since 1936

# Three Factors in Spectrum Shortage

1. Growth in demand
2. Limited supply
3. Past regulatory decisions lock in inefficient usage.

# Growth in Demand – Causes

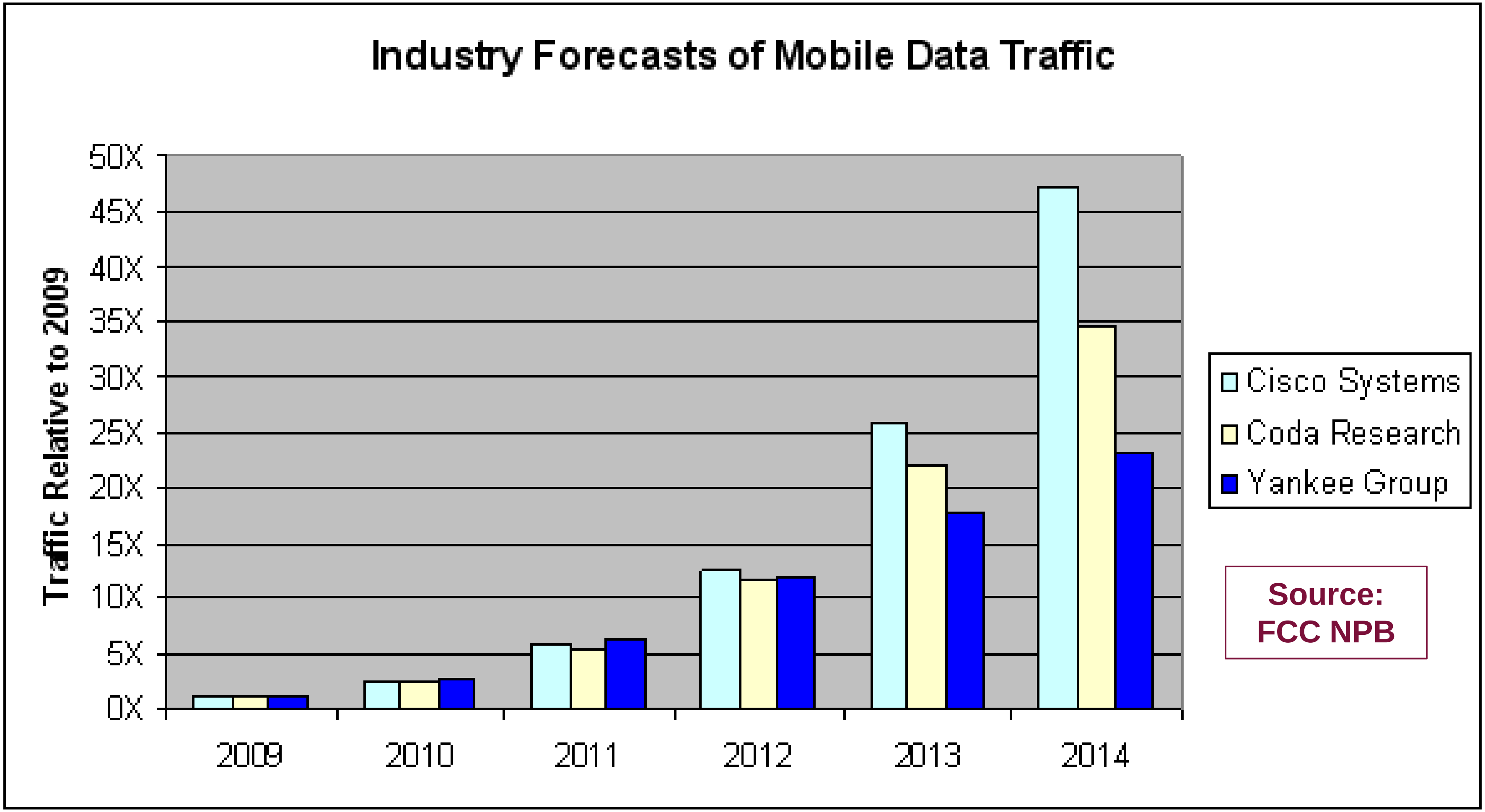
1. Shift from wired Internet to radio access
   - users leaving desktops for smartphones, laptops, tablets
     - iPhone, iPad, Android, Palm Pre, etc.
   - trend accelerating (1M iPads sold in first month)
2. Growth of Internet video
   - enormous popularity of YouTube, Hulu, Facebook videos, etc.
3. Devices in use more minutes per day
4. Users expect service everywhere, not just Wi-Fi hot spots.

# Growth in Demand – Data Points

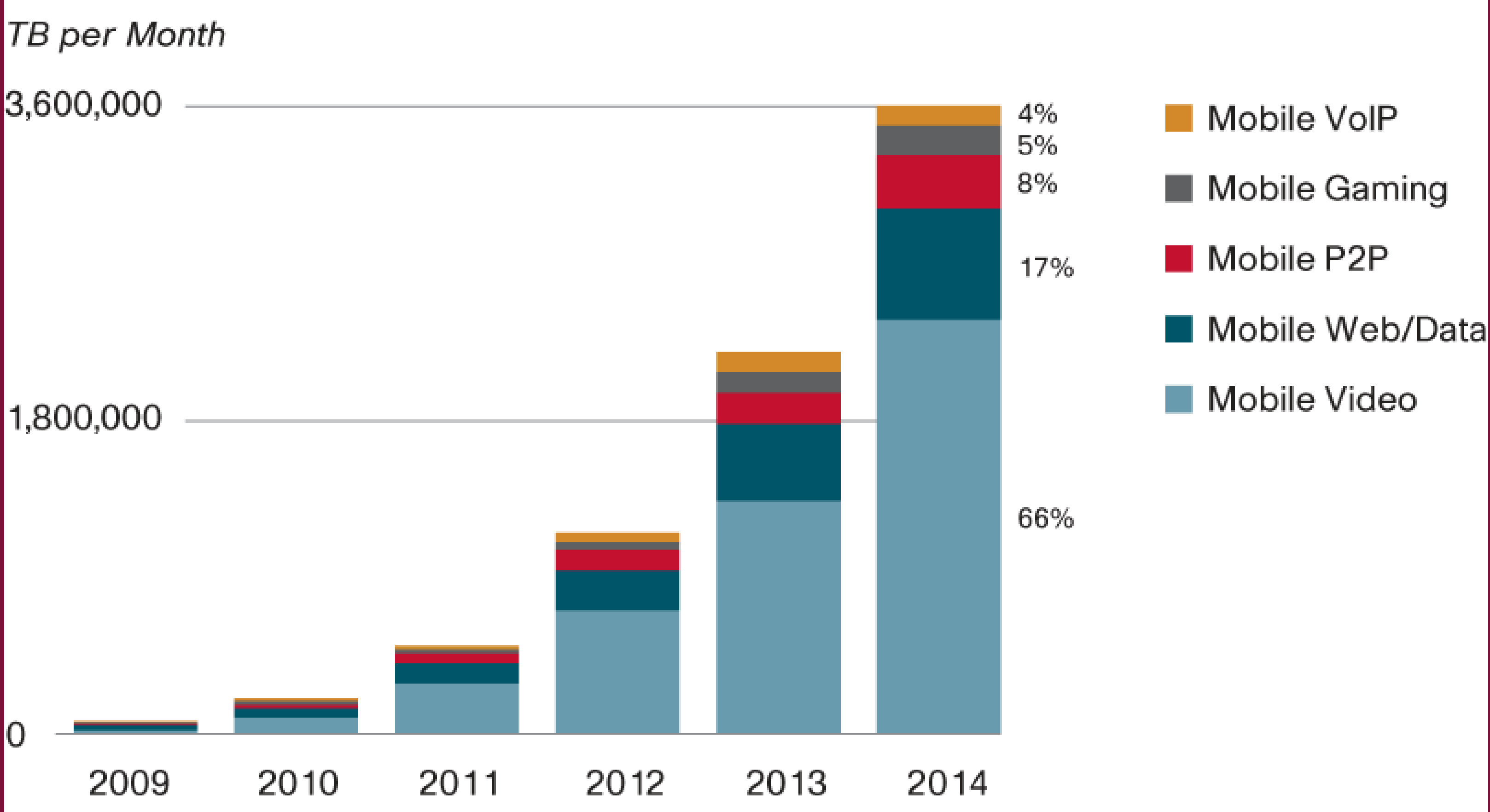
- Data traffic on AT&T's mobile network (think iPhones) over past three years has compound growth rate of ***268 percent*** per year
- Cisco says:
  - 2009: North American wireless networks carried 17 petabytes per month
    - 1,700 Libraries of Congress
  - by 2014, will carry 740 petabytes per month
    - 43-fold increase in four years.

Source: FCC National Broadband Plan

# Growth in Demand – Exponential



# Growth in Demand – Driven by Video




**Source: Cisco**

# Past Regulatory Decisions

- Many current rules arose in days of plentiful spectrum and primitive equipment
  - analog transmitters had inefficient spectrum usage
  - receivers had poor discrimination, needed widely spaced channels
- FCC allocated channel blocks to small groups of users
  - every industry wanted its own channels
  - (FCC later merged some categories)
- Result: uneven allocations; large embedded base of inefficient equipment.

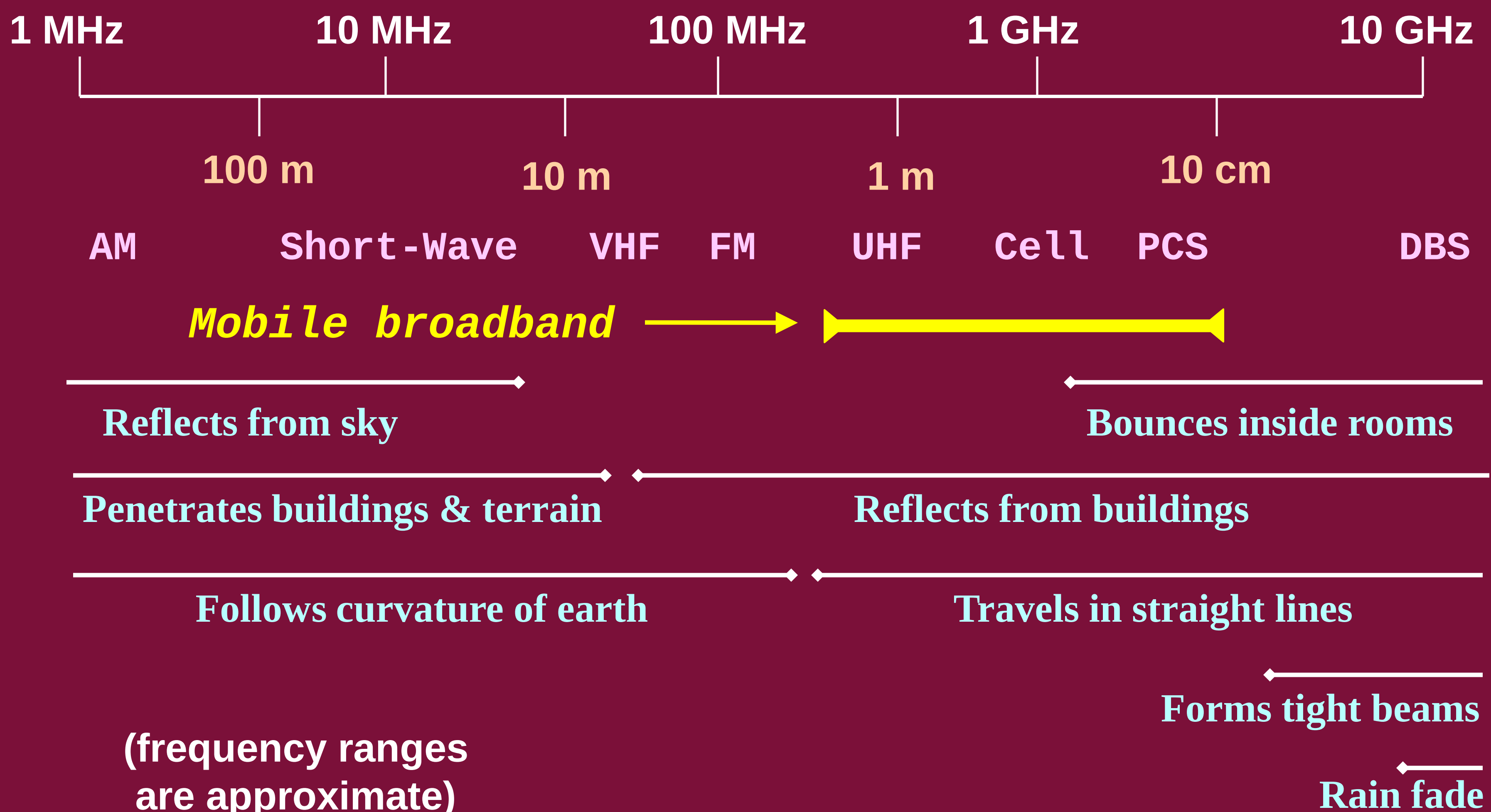
# Private Land Assignments (*circa* 1983)

- Local Government Radio Service
- Police Radio Service
- Fire Radio Service
- Highway Maintenance Radio Service
- Forestry-Conversation Radio Service
- Power Radio Service
- Petroleum Radio Service
- Forest Products Radio Service
- Motion Picture Radio Service
- Relay Press Radio Service
- Special Industrial Radio Service
- Business Radio Service
- Manufacturers Radio Service
- Telephone Maintenance Radio Service
- Motor Carrier Radio Service
- Railroad Radio Service
- Taxicab Radio Service
- Automobile Emergency Radio Service

# Methods for Addressing Congestion

1. Find more spectrum
2. Use spectrum more efficiently
3. Hope for magic breakthrough.

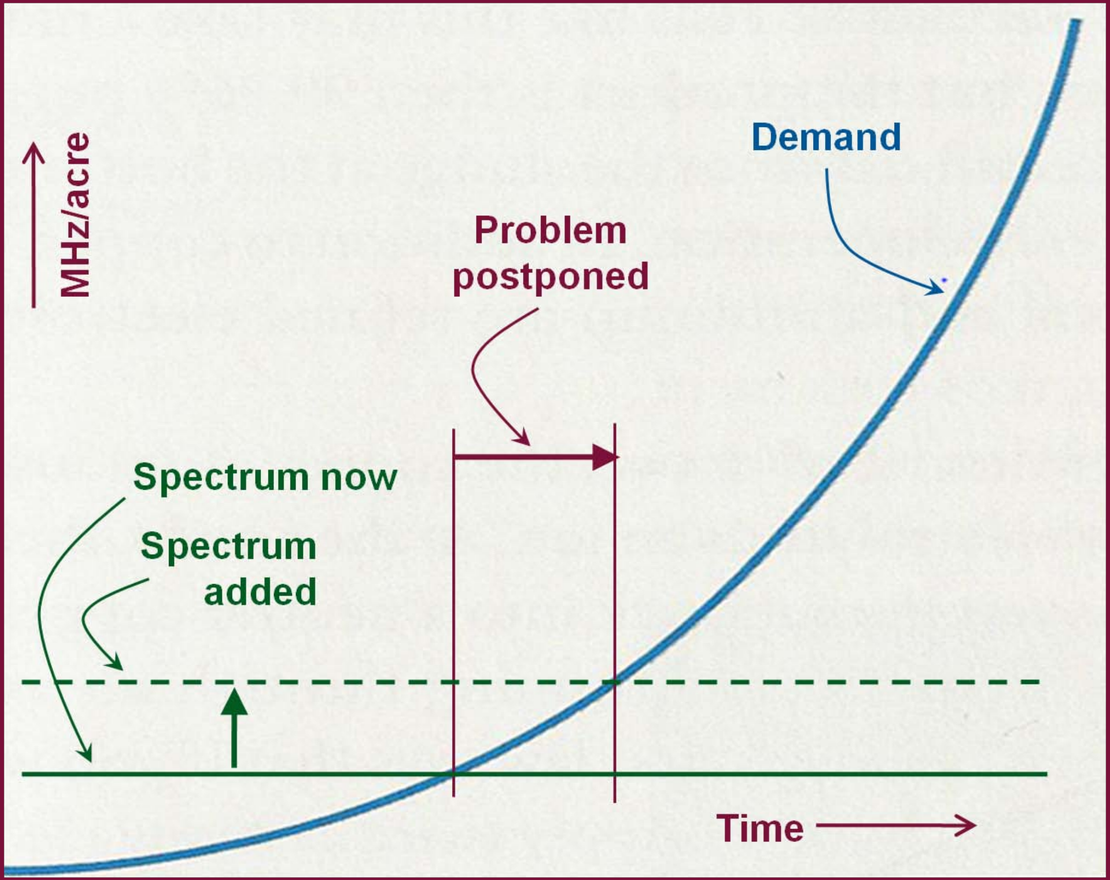
# Limited Spectrum for Mobile Broadband




(frequency ranges are approximate)

# More Spectrum Postpones Problem

- ❑ So long as demand is exponential, supply cannot keep up.



# Methods for Improving Efficiency

- trunking (sharing channels within small user group)
- narowbanding (less bandwidth per channel)
- geographic licensing; auction (gives incentive)
- mandated bits/second/Hz; high-order modulations
- directional antennas; smart antennas
- low power; automatic power control; adaptive modulation
- dynamic frequency selection
- multiplexing
- short-term spectrum leases
- underlay (use spectrum twice)
- receiver standards (not used in U.S.)

Two best methods not shown here.

# Theoretical Limitations

- System design trades off among these properties:
  - long range
  - high data speed
  - high reliability (low bit error rate)
  - long battery life (for portables)
  - low latency (limits use of compression)
  - efficient spectrum usage
- At design limits, can improve any of these (including efficiency) – but only at expense of one or more others.

# Practical Limitations

- ❑ Equipment in the field severely limits new options
  - ➢ users reluctant to replace working equipment
  - ➢ very long equipment life means replacement takes years
  - ➢ *e.g.*, FCC "refarming" for narrowband land mobile:
    - began in 1991
    - still a decade or more to completion
- ❑ New, spectrum-efficient equipment often must be compatible (or at least coexist) with older equipment
- ❑ Few chances to start over with clean spectrum.

# Economic Limitations

- Most techniques for improving efficiency require replacing or upgrading equipment
  - entails added costs for someone
  - improvements may not benefit party incurring costs
- FCC sometimes forces cost-shifting
  - *e.g.*, PCS needed clean spectrum for more efficient cell technology
  - FCC required PCS licensees to relocate incumbent Fixed Service users
    - led to many disputes.

# Case Study: Digital TV Transition

- Hard case for U.S. spectrum reform:
  - more receivers then people; used daily by most
  - main public source for news, disaster info, etc.
- Replaced studio and transmitter equipment, receivers
  - viewers could keep old sets with cable, satellite, converter boxes; many upgraded anyway
- Process took 22 years
  - 1987: first FCC Notice of Inquiry
  - 1996: FCC adopted digital TV technical standards
  - 2009: last full-power analog stations shut down
- Huge public education task.

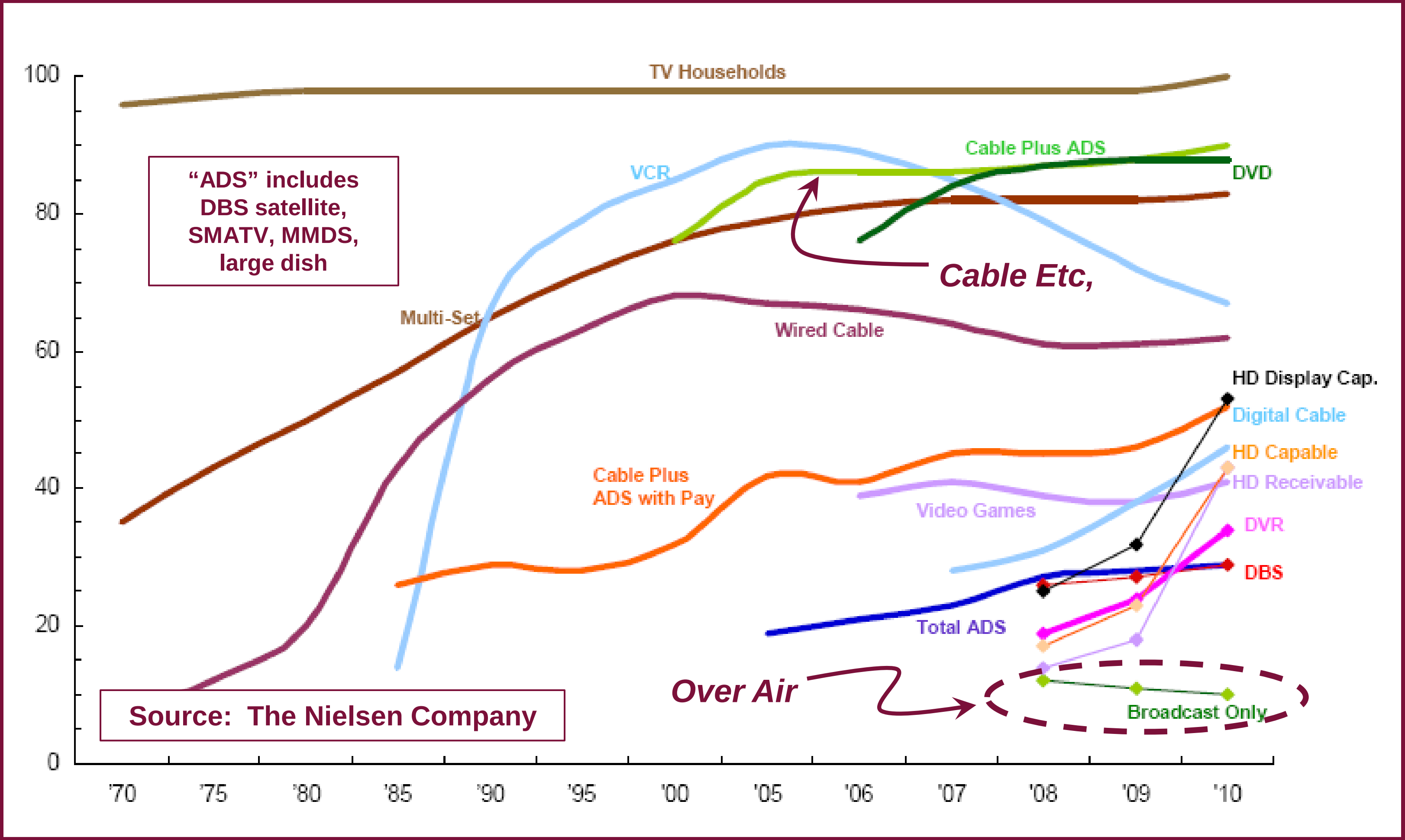
# Digital TV Transition – Benefits

- Freed up 108 MHz (698-806 MHz)
  - 27% of total TV spectrum
  - FCC auctioned 62 MHz for $19 *billion* dollars
- Quadrupled video capacity on remaining 49 channels
  - plus options for high definition, data services
- Most cost estimates well under auction revenues
- Improved TV spectrum efficiency 6-8 times over
- Big success . . .

# DTV Big Success, But . . .

- High efficiency serves few viewers
- Only 9% of U.S. households rely on over-the-air TV
  - (and some of those don't watch TV)
  - many took cable and satellite during DTV transition
  - now, TV stations are largely just feeds to cable systems
- Measure of spectrum efficiency not just bits/Hz, but also how bits are actually used.

# Few Households Rely on Broadcast



# Next TV Transition

- Households dropping cable to watch TV online
  - 800,000 canceled service by end of 2009 – under 1%
  - trend will rise as high-speed broadband spreads
- FCC proposes to reallocate another 120 MHz from TV to wireless
  - 41% of present TV spectrum
  - affects wireless microphones, TV “white space” devices
- Plan:  broadcasters consolidate on remaining channels and/or receive part of auction revenues
- Broadcasters are publicly opposed.

# Case Study: Wireless Voice – 1

- Arguably best improvement in spectrum efficiency
- MTS/IMTS (1950s-80s): one tower served entire city
  - max 32 VHF/UHF channels; most cities had far fewer
  - 100-250 Watts at base; 25 Watts at mobile
  - very expensive; long waits for calls
- First change: to analog cellular
  - each frequency multiply reused across city
  - 800 MHz; more channels; two providers per market
  - still expensive; geared to business users.

# Case Study: Wireless Voice – 2

- Second change: shift to digital cellular (and PCS)
- Misconception that digital signals are spectrum efficient
  - with other properties equal, digital uses roughly same bandwidth as analog
- Digital allows compression, high-order modulation, efficient multiplexing,
  - costs: compression causes delay, harms fidelity; high-order modulations more susceptible to noise
- Digital with compression improved cellular efficiency about tenfold over analog
  - changeover was transparent to end users (unlike DTV).

# Voluntary *vs.* Mandated Improvements

- Wireless voice: efficiency gains not imposed by FCC
  - carriers seeking to add users, increase profits
  - did analog-digital transition with little help from FCC
- DTV: government plan throughout
  - FCC chose standards, set deadlines, supervised public education – even fined stores for analog-only TVs
- One key difference: wireless carriers controlled handsets, while TV has open market
  - open market for wireless might hinder future efficiency improvements.

# A Possible Model

- Private land mobile (two-way) radio uses 12.5 kHz analog
  - inefficient even when used; many channels mostly silent
- One alternative:
  - non-profit group takes part of recovered TV spectrum
  - offers service at cost using high-compression digital
  - FCC pushes up license fees to drive traffic to group
  - later, FCC recovers and auctions old two-way spectrum
  - plan should free up far more spectrum than it requires.

# Conclusions

- Must find more spectrum for wireless broadband – but only buys time
- All suitable spectrum is occupied
- Solutions require squeezing incumbents into less bandwidth, *e.g.*:
  - DTV conversion kept all TV stations, freed up 108 MHz
  - PCS moved 2 GHz fixed service operators to other bands
- FCC recognizes problem, is open to solutions, but lacks workable specifics
- Technical innovations are welcome.

# Thank you!

Mitchell Lazarus | 703-812-0440 | lazarus@fhhlaw.com

**website**: www.fhhlaw.com

**blog**: www.commlawblog.com