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Powering the Mobile Revolution: Principles of Spectrum Allocation

Report Presentation on Capitol Hill

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The Panel

- Christopher Guttman-McCabe, Vice President
  Regulatory Affairs, CTIA
- John Leibovitz, Deputy Chief
  Wireless Telecommunications Bureau, FCC
- Preston F. Marshall, Deputy Director of the Information Sciences Institute, USC Viterbi School of Engineering
- Thomas C. Power, Deputy Chief Technology Officer, Telecommunications, White House OSTP
- David Redl, Counsel, U.S. House of Representatives Committee on Energy and Commerce
- Morgan Reed, Executive Director,
  Association for Competitive Technology

The World has Five Billion Cell Phones

Image credit: Olympic Broadcasting Service

The Mobile Revolution

- The Mobile Revolution marks a new era in computing:
  - Small mobile systems
  - Communication-driven
  - Social
  - Sensory extension
  - Dynamic
- Spectrum Management must support mobile usage:
  - Dynamically adapt to patterns of usage
  - Support emerging applications
  - Embrace new wireless technologies
  - Serve the needs of users
- Sound allocation principles can bring spectrum policy into alignment with user spectrum needs

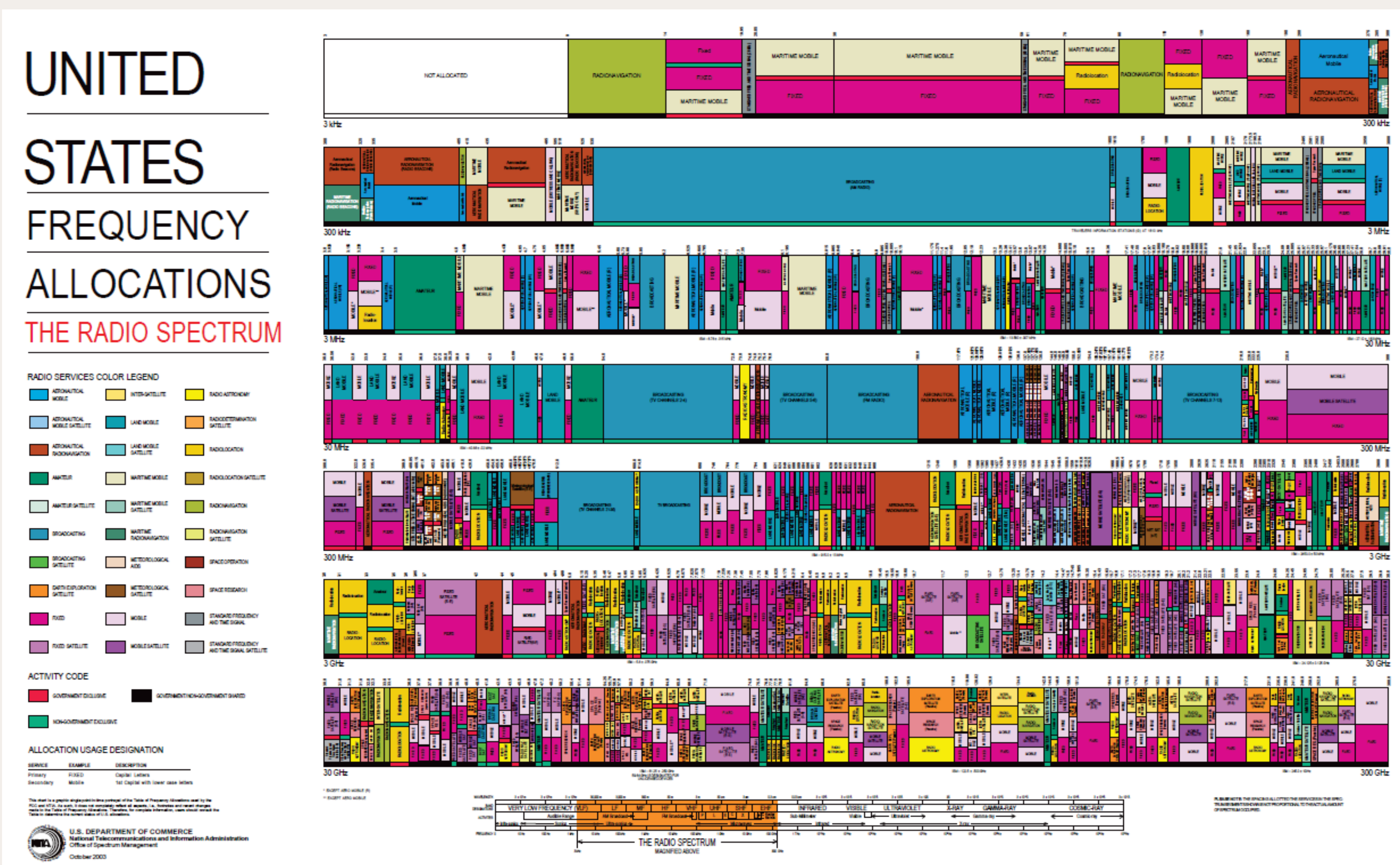
Spectrum

Image credit: Wikipedia

What is Spectrum?

- "Spectrum" is the range of Electromagnetic Radiation or Energy.
  - Radiation is charged particle energy moving in waves
  - These waves range in frequency from very small to very large
- Manipulating sine waves enables them to carry information
  - These modifications – distortions – have to be intelligible by a receiver
  - Intelligible distortions are signal, others are noise
- Noise comes from natural sources and from reflections of signals off natural surfaces
  - Frequency determines whether a signal passes through or bounces off a given obstacle
  - Antenna characteristics determine range.

How to Manage Spectrum Rights?



Spectrum Allocation Principles

1. Sharing
2. Application Flexibility
3. Dynamic Capacity Assignment
4. Technology Upgrade Flexibility
5. Aggregation Efficiency
6. Appropriate Facilities-Based Competition
7. High-Performance Receivers
8. Use All Relevant Dimensions
9. New Technologies
10. Maximize Redeployment Opportunities

Sharing

- The most desirable allocations are those that can be shared by large numbers of people.
- Commercial Mobile Networks (CMN) are one very good example of efficient spectrum sharing: The larger networks, operated by Verizon and AT&T in the United States, support approximately 100 million users with 100 MHz of spectrum, for a sharing factor of one hertz per user.
- Wi-Fi™ has similar efficiency, with some 300 million U.S. users on 300 MHz of spectrum.
- In contrast, broadcast television consumes 10 hertz per actual user.
- **Emphasize Effective Sharing**

Application Flexibility

- The most desirable allocations are those that can be shared by large numbers of applications.
- Both CMN and Wi-Fi™ networks host a variety of applications, allowing end users to make the ultimate choice of applications in real time.
- These networks support the whole range of applications permitted by the Internet Protocol and the roaming limitations of each technology.
- In contrast, most historical spectrum allocations have been made to single-purpose systems such as AM/FM radio, TV, satellite TV and radio, and taxi networks.
- **Emphasize Application Flexibility**

Dynamic Capacity Assignment

- The most desirable allocations bring supply and demand into balance.
- Modern networks allow for capacity assignments to follow demand by flexible definition of units of internal allocation (commonly called "channels.")
  - Wi-Fi™ channels can be units of 20MHz, 40 MHz (802.11n) or substantially more (802.11af)
  - LTE networks can work with channel bandwidths from 2.5 to 40 MHz or more
- **Permit Dynamic Re-Allocation.**

Technology Upgrade Flexibility

- The most desirable allocations are those that can easily be improved.
- In the old spectrum regime, regulators often stipulated technology choices for spectrum users by fiat, epitomized by the European requirement for carriers to use GSM for 2G phone service.
- This practice prevents the deployment of more advanced systems such as CDMA and LTE.
- Rational Allocation permits technology upgrade without permission, and indeed expects that all technologies will have limited lifespans as better technologies are developed that replace older ones.
- **Allocate Liberally, Flexibly, and Permissibly.**

Aggregation Efficiency

- The fundamental distinction among spectrum sharing technologies distinguishes the sharing done **within** a network from the sharing **between** networks.
- This can be conceptualized as the sharing of "cooked" spectrum in the first case and "raw" spectrum in the second case.
- The greater the pool of spectrum for a given network, the greater the potential for sharing.
- The smaller the typical allocation, the greater the guard band overhead to isolate networks from each other.
- Hence, large allocations have an efficiency advantage over small ones, as they can support large user populations and diverse applications.
- **Minimize Boundary Waste between Allocations**

Facilities-Based Competition

- The most desirable allocations are those that promote an efficient level of competition.
- A small number of networks leads to more efficient sharing (and to investment efficiency)
- A large number of networks produces competition advantageous to consumers, but only up to a point.
- This principle is in tension with the previous one.
- In industries in which a key input is limited, as is the case in mobile networking, the number of sustainable competitors is also limited.
- **Allocate to correct market power that demonstrably erodes innovation, investment, and distorts prices.**

High-Performance Receivers

- High-performance receivers tune into the signals intended for them and to reject or ignore all other signals.
- Every statement of transmission rights is implicitly a statement about the ability of receivers to reject noise.
- Every spectrum system is fundamentally analog and must be carefully engineered to work in a specific noise environment.
- Each generation of cellular technology has better noise immunity than the preceding one.
- **Develop Receiver Performance Standards and Make them More Stringent as Technology Develops.**

Use All Relevant Dimensions

- Traditional spectrum allocations don’t fully reflect the variety of ways that spectrum can be used.
- The traditional methods allocate by frequency, power level, and place.
- Spectrum can also be distinguished by direction of transmission, beam spread, modulation, coding, and time.
- As more advanced technologies are developed, allocation principles should come to recognize these dimensions.
- The TV White Spaces notion is a step in this direction, adding time to the factors that condition spectrum usage rights.
- **Develop Mechanisms to Allow Spectrum Rights to be Extended in into all Relevant Dimensions.**

Promotion of New Technologies

- The most desirable allocations are those that speed the path to new technologies.
- The FCC has created markets for satellite, cellular, Wi-Fi™ and UWB allocating spectrum for their use ahead of actual network deployment.
- Rules modification rather than exclusive allocation is the means of enabling the next generation of spectrum technologies.
- **Modify Rules When Necessary to Bring New Spectrum Technologies to Market, and to Retire Old Ones.**

Developing Redeployment Opportunities

- Today's spectrum policy problem is one of re-deployment and multiple use rather than new greenfield assignment.
- Incumbents resist rule changes for adjacent bands with the potential to interfere with legacy systems (e.g., LightSquared vs. GPS.)
- Incumbents also resist societally rational reallocations (e.g. DTV)
- Redeployment depends on upgrades to existing systems, which are generally good in and of themselves.
- **Use Every Generational Upgrade as an Opportunity to Adjust Historical Allocations.**

A Note on Spectrum Sharing

Image credit: The Telegraph

A Note on Spectrum Sharing

- Commercial networks share “cooked” spectrum by user and application:
  - Very efficient sharing that allows > 95% utilization
  - Scheduling, CDMA, SDMA, and MIMO
  - **Common Coordination Function** makes it happen
- Shared use of “raw” spectrum is much more difficult
  - Management functions in various networks have to coordinate with each other before doing what commercial networks do
  - Commercial model works in this space too: Sharing by Contract
- Research will simplify sharing:
  - Medium term: Time Sharing (LTE, Wi-Fi, White Spaces)
  - Long term: Simultaneous Sharing (SDMA, MU-MIMO, OAM and beyond)

Why These Principles?

- Spectrum policy has always been motivated by goals, either implicit or explicit:
  - Public Interest
  - Creating Markets
  - Growing the Economy
- Explicit goals must be consistent with technology development
  - Avoid policy/tech fads
  - Align timelines accurately
  - Bring as much certainty to wireless systems as practical
  - Support the mobile economy

Spectrum Controversies

- Channel 51
- 800 MHz Guard Bands
- Fixed Point-to-Point Microwave
- Military Tactical Radio Relay
- Air to Ground Systems
- Video Surveillance
- Initial PCAST Recommendations
- PCAST Spectrum Superhighway
- LightSquared and GPS
- Medical Body Area Networks
- Verizon/SpectrumCo Transaction

Leave Channel 51 on the Air

1. Sharing: Retarded
2. Application Flexibility: Retarded
3. Dynamic Capacity Assignment: Retarded
4. Technology Upgrade Flexibility: Retarded
5. Aggregation Efficiency: Retarded
6. Facilities-Based Competition: Retarded
7. High-Performance Receivers: Advanced
8. Use of all Relevant Dimensions: Retarded
9. Promotion of New Technologies: Retarded
10. Development of Redeployment Opportunities: Retarded

- Total Score: -8

Re-Assign Channel 51 to Mobile

1. Sharing: Advanced
2. Application Flexibility: Advanced
3. Dynamic Capacity Assignment: Advanced
4. Technology Upgrade Flexibility: Advanced
5. Aggregation Efficiency: Advanced
6. Facilities-Based Competition: Advanced
7. High-Performance Receivers: Advanced
8. Use of all Relevant Dimensions: Retarded
9. Promotion of New Technologies: Advanced
10. Development of Redeployment Opportunities: Advanced

- Total Score: +8

Remove 800 MHz Guard Bands

1. Sharing: Advanced
2. Application Flexibility: Advanced
3. Dynamic Capacity Assignment: Advanced
4. Technology Upgrade Flexibility: Advanced
5. Aggregation Efficiency: Advanced
6. Facilities-Based Competition: Advanced
7. High-Performance Receivers: Advanced
8. Use of all Relevant Dimensions: Advanced
9. Promotion of New Technologies: Advanced
10. Development of Redeployment Opportunities: Advanced

- Total Score: +10

Convert Military Microwave to Fiber

1. Sharing: Advanced
2. Application Flexibility: Advanced
3. Dynamic Capacity Assignment: Advanced
4. Technology Upgrade Flexibility: Advanced
5. Aggregation Efficiency: Advanced
6. Facilities-Based Competition: Advanced
7. High-Performance Receivers: Advanced
8. Use of all Relevant Dimensions: Advanced
9. Promotion of New Technologies: Advanced
10. Development of Redeployment Opportunities: Advanced

Total Score: +10

Convert Tactical Radio Relay to Fiber

1. Sharing: Advanced
2. Application Flexibility: Advanced
3. Dynamic Capacity Assignment: Advanced
4. Technology Upgrade Flexibility: Advanced
5. Aggregation Efficiency: Advanced
6. Facilities-Based Competition: Advanced
7. High-Performance Receivers: Advanced
8. Use of all Relevant Dimensions: Advanced
9. Promotion of New Technologies: Advanced
10. Development of Redeployment Opportunities: Advanced

- Total Score: +10

Convert Video Surveillance to Commercial

1. Sharing: Advanced
2. Application Flexibility: Advanced
3. Dynamic Capacity Assignment: Neutral
4. Technology Upgrade Flexibility: Advanced
5. Aggregation Efficiency: Neutral
6. Facilities-Based Competition: Advanced
7. High-Performance Receivers: Neutral
8. Use of all Relevant Dimensions: Neutral
9. Promotion of New Technologies: Advanced
10. Development of Redeployment Opportunities: Advanced

Total Score: +6

PCAST Update

1. Sharing: Advanced
2. Application Flexibility: Advanced
3. Dynamic Capacity Assignment: Neutral
4. Technology Upgrade Flexibility: Advanced
5. Aggregation Efficiency: Neutral
6. Facilities-Based Competition: Neutral
7. High-Performance Receivers: Neutral
8. Use of all Relevant Dimensions: Advanced
9. Promotion of New Technologies: Neutral
10. Development of Redeployment Opportunities: Advanced

- Total Score: +5

PCAST Spectrum Superhighway

1. Sharing: Advanced
2. Application Flexibility: Retarded
3. Dynamic Capacity Assignment: Advanced
4. Technology Upgrade Flexibility: Neutral
5. Aggregation Efficiency: Advanced
6. Facilities-Based Competition: Retarded
7. High-Performance Receivers: Advanced
8. Use of all Relevant Dimensions: Neutral
9. Promotion of New Technologies: Advanced
10. Development of Redeployment Opportunities: Retarded

- Total Score: +3

PCAST Self-Grading

- Could be as high as +9 with a different interpretation of the impacts
- Plausible, because it’s more a mechanism than a policy.

LightSquared vs. GPS

1. Sharing: Neutral
2. Application Flexibility: Retarded
3. Dynamic Capacity Assignment: Neutral
4. Technology Upgrade Flexibility: Retarded
5. Aggregation Efficiency: Neutral
6. Facilities-Based Competition: Neutral
7. High-Performance Receivers: Neutral
8. Use of all Relevant Dimensions: Neutral
9. Promotion of New Technologies: Neutral
10. Development of Redeployment Opportunities: Advanced

- Total Score: -1.

Medical Body Area Networks

1. Sharing: Advanced
2. Application Flexibility: Retarded
3. Dynamic Capacity Assignment: Neutral
4. Technology Upgrade Flexibility: Retarded
5. Aggregation Efficiency: Advanced
6. Facilities-Based Competition: Neutral
7. High-Performance Receivers: Neutral
8. Use of all Relevant Dimensions: Advanced
9. Promotion of New Technologies: Retarded
10. Development of Redeployment Opportunities: Neutral

- Total Score: 0

Verizon/SpectrumCo Transaction

1. Sharing: Advanced
2. Application Flexibility: Advanced
3. Dynamic Capacity Assignment: Advanced
4. Technology Upgrade Flexibility: Advanced
5. Aggregation Efficiency: Advanced
6. Facilities-Based Competition: Neutral
7. High-Performance Receivers: Neutral
8. Use of all Relevant Dimensions: Neutral
9. Promotion of New Technologies: Advanced
10. Development of Redeployment Opportunities: Advanced

Total Score: +7

Allocation Efficiency Research

- SDR/CR techniques allow easier access to unused or lightly-used patches of spectrum.
- These techniques are an alternative to traditional exclusive allocations that are not fully used (pauses in phone calls.)
- SDR/CR works best with an authorization database that provides go/no go information to prospective network operators.
- The decisions that this database implements flow from a spectrum allocation policy.
- SDR/CR actually aims to improve **allocation** efficiency, not **usage** efficiency.

Usage Efficiency Research

- Usage efficiency develops techniques that allow for greater bits/hertz density.
- This line of research concentrates on techniques that govern the ways that bits are represented on wireless networks, the nature of antennas, and the coding systems and scheduling systems that enable multiple users to share a given patch of spectrum in an orderly manner.
- Most of the practical advances in the use of RF spectrum by commercial and other public systems are the result of research on usage efficiency:
  - Packet radio
  - Modulation systems such as OFDM and QAM
  - Multiple-Input Multiple-Output (MIMO) antenna systems
  - Scheduling/coding systems such as CDMA and OAM.

Read the Report!

Go to http://itif.org. It's on the front page.

Responses to the Report

- "As Richard Bennett makes clear, the only way in which the spectrum crunch will be resolved in the public interest is with an enlightened spectrum policy that promotes the use of spectrum efficient technologies in concert with new principles of spectrum allocation.
- The goal is Dynamic Spectrum Access whereby users consume spectrum only for the minimum time, space, and bandwidth needed for each transaction.
- The ability of Spatial Division Multiple Access to achieve much of this goal has been demonstrated in the service of hundreds of millions of subscribers today.
- When cognitive radio technology matures and is added to SDMA, there is the potential for spectrum abundance in place of the looming scarcity." – Marty Cooper

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Thank You

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