PCAST Spectrum Report: Progress Towards Implementation, and What we are Learning

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Developed to solve real problems in 1912!

**Only Available Approach:**
- Isolate Users
- Isolate Usages
- Isolate Technologies

These people may have died due to lack of spectrum management.

But, Not that Different Today,
Despite new RF Technology, Tools, Models, Computing, etc.
Topics

1. Recap of Some of the Major PCAST Recommendations
2. Progress to Date on Implementation
4. Classical SM Problems that it Can Solve
5. Transition from Interference Avoidance to Coexistence Management
Some of the PCAST Study Recommendations

• Make Federal Spectrum Available for Sharing by Civil Users to the Maximum Extent Possible
• Provide a 3 Tier Framework to Enable Flexible Use
  1. Protected Federal Primary Users
  2. Secondary Protected Access (PA)
  3. General Access /no protection (similar to Unlicensed, with Registration)
• Manage Spectrum through Spectrum Access System (SAS) database
• Move to Protection without Exclusivity
• Flexible, Short-term Licenses
• Balance Civil and Federal Interests at the White House Level
  – OSTP CTO, CEA, NSC, OPM
Progress in the Last Two Years

- Dynamic Spectrum Technology Has Moved from Academia to Policy in 24 Months
  - PCAST Report Came out and Proposed Civil Sharing of Federal Spectrum be the Norm
  - Significant Initial Opposition
  - White House Issued a Presidential Memorandum Making this the Administration’s Policy
  - FCC has several cycles of NPRM to Provide Licensing Rules for Multi-Tier, Shared Spectrum; close to R&O
  - Even Initial Opponents Have Responded to the FCC with their Plans for Use
Open to a Continuum of Protection Methods to Tailor Protection to DoD Needs

- Unlicensed
- Local Sensing
  - Limits in Power Adequate
  - Strong, detectable signals (ex. DFS)
- Sensing Networks
  - More Complex Detection, and better siting
- Time Specific Exclusion
  - Database Driven (SAS)
- Fixed Exclusion
  - Only if Undetectable, or constantly on

- Fixed Rules in Devices
- Adjustable Rules in Database System
How the SAS Works

- **Devices/Networks Register with SAS to obtain Spectrum Access**
  - Deconflicted with Federal Users
  - Deconflicted with other Protected Secondary Devices/Networks

- **Higher Tier Users can Bump Lower Tier Users**
  - Federal Use forces relocation of all Secondary's
  - Priority Users force GAA users to other channels

- **Minimum Amount of GAA spectrum to ensure that no Devices are Pushed out**
  - Unless Feds reclaim entire band
Protection is an Economic Decision, not Technical

- Same Devices can be GAA (free) or PA (by auction)
- No Need to “Buy” spectrum in order to operate
- Decision to “Buy” driven by
  - Your Revenue from the Device/Location
  - Degree of Congestion
  - Interference Tolerance of Your Technology
  - Your Risk Tolerance
- Can Re-Evaluate Periodically and Enter Auction if Needed
Key Aspects of 3.5 FNPRM

- Shorter Licenses, with no long term assurance of renewability
- Licenses are for Spectrum Access, not a specific Frequency
- Full 3 Tiers of Operation
- No Exclusivity -- All Unused Spectrum is open to GAA access if not interfering with Protected users
- Same Operating Limits for Protected (Priority) users and Unprotected (GAA)
- Spectrum Access System “Hides” Complexity of Spectrum Sharing Regime
Prototype SAS:

- Protects federal incumbents from secondary users and protects for Priority Access (PA) from GAA interference.
- Uses the same technology to protect federal incumbents and PA users. (No additional technology challenges are presented by implementing third tier of access.)
- Accounts for aggregation effects.
- Protects from co-channel and adjacent channel interference.
- Accounts for in-channel and out-of-band emissions.
- Support technology-specific optimizations between spatially and spectrally adjacent users. (For example, ASA/LSA systems can be used within protection perimeters of PA licensees.)
SAS Behavior Examples

• SAS Relocating Nodes to Provide Higher Priority Users Protected Access to Spectrum
  – Spectrum Dynamically Repurposed

• Use of Actual Device Characteristics to Determine Exclusion Zones based on Different Device Out of Band Emissions
  – Creates Device Appropriate Physical and Spectrum Exclusion Zones

• Protection of Primary User from Aggregate Emissions
  – Avoid crippling all Devices for Projected, Worst Case Density
SAS Manages Multiple Tiers with “Use it, or Share it” Principles

- PA nodes have protected status in upper 50% (above 3.625)
- GAA nodes use entire 150 MHz band and are scattered randomly throughout
- All PA users provided an assignment
- PA Status determined through exclusivity-driven micro-auctions, if necessary

- 3 GAA nodes relocated to de-conflict with PA users
- Several GAA users can still use the full band without conflict with PA users
- 5 PA users not provided an assignment due to conflicts with other PA users
- Unassigned PA users can either use GAA spectrum or can adopt coexistence technologies
SAS Reflects and Incentivizes Improved Device Performance

**OOBE Limit:** -43 dBm + log(p)

**OOBE Limit:** WiMAX OOB E Mask

Exclusion area around C-Band dish with 5 degree elevation angle in 3.55 to 3.7 GHz

- Using actual out-of-band emissions shape reduces rejected nodes by factor of five
- Shaded area represents assignments that become possible when SAS uses actual WiMAX mask
- Maximum frequency is adjusted based on secondary users OOB E skirts
- Creates Dynamic Guard Band to Ensure Adequate Spectral Separation with Knowledge of OOB E Shape
SAS Enables Aggregation Protection

Without aggregation

- Using same C-band example, the out of band emissions from a single, individual node would be acceptable in any orange position.
- Only nodes in red positions would be precluded.

Accounting for aggregation

- A nodes would not have been valid, even singly.
- Node B consumed most of the incumbent out-of-band interference tolerance, so C Nodes are excluded, protecting the primary user.

Assumptions: 0.1 I/N threshold, 5 degrees elevation
Application of Protection Thresholds

Any Operation within the Harm/Claim Perimeter would obviously exceed limits and is precluded.

Any Operation close to the Harm/Claim Perimeter would also exceed limits and is precluded.

Limitations on Aggregate Energy would constrain the number of devices in the proximity of the perimeter.

Beyond a certain distance, there would be few limitations, but the SAS will check that there are no aggregation, or high altitude deployments.
A Not So Longer Term View
-- Achieving Coexistence

• To Maximize Spectrum Resources – Need to Move from Interference Avoidance to Co-Existence Management
  – Ex. LTE’s internal RRM an Example for Homogeneous, intra-domain
    • Incentives for Carriers through more dense operation in high cost spectrum
  – Wi-Fi provides user few advantages from Coexistence across access points – Little Attention

• The SAS Will Serve to Bridge Heterogeneous Technology and Users to Facilitate Coexistence
# Transition to Coexistence Management

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### Notes:
- **History**: Just about Everything
- **Today**: Cellular LTE
- **Future**: Not Yet
Future of Coexistence Management?

- Technology Neutral
  - Transition from Open Loop to Closed Loop Interference Management
    - Report, Rather than predict interference
    - Avoid Accounting for Massive Uncertainty in Prop Models which results in lost spectrum access
  - Power Management
  - Spectrum Measurements

- Technology Specific
  - Facilitate Exchange/Agreement on LTE Characteristics (ex. Interference Alignment)
  - Enterprise Wi-Fi Extensions
Summary

• Achieving Dense Spectrum Usage is Requiring Move to Dynamic, Real-Time Spectrum Management Systems
• Initial Efforts Underway for First Step in this Evolution
  – Open Loop, Interference Avoidance
• Building Block for Technology Neutral and Specific Extensions
  – Need to Be Integrated into the Design of Future Systems
  – Toolkit Being Created Needs Better Understanding within the SM Community