Spectrum Sharing, Interference Definition, and Interference Tolerance

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• We Have Approached Spectrum Sharing and DSA from the Perspective of “Dumb” Primary’s and “Smart” Secondary's
  — Highly Stressing on Sensing
  — Fundamental Physics Constraints on Sensing
  — Impact -- Limits on DSA Power & Applications

• This is an Ineffective/ Defective Model for Maximizing Spectrum Utility and Achieving Spectrum Sharing

• Effective Spectrum Sharing Should Consider the Primary and Secondary’s as a Single System and Maximize the Aggregate Capability
A Defective Model of Interference and Spectrum Sharing

- DSA Has Inherited the Concept that Any Energy in a Receiver Passband is Interference, and Must Be Precluded
  - Shift from Continuous (Broadcast, AM, FM) to Time Domain Signaling Makes this Particularly Inapplicable
- A Commitment to Spectrum Sharing Will Also Require Consideration of Different Definitions of Required Protection

![Diagram](Diagram.png)
It Does Not Have to Be So Hard

- Interference Need Not Lead to Failure
  - Internet Shows Many Key Principles:
    - Interference Management
    - Robustness to Occasional Disruption
    - Diversity of Methods to Deliver Information
- Example: Two Solutions Proposed to Connect Computer Workstations in the 70’s and 80’s
  - Ever See This Cable?
  - IBM Token Ring: Complex, but Avoided Interference
  - But, This is the One that Took Over
  - Ethernet: Simple, But Allowed Interference, and Gave Higher Performance

Ethernet’s Big Advance: It Allowed, and Randomized Interference
What Are Challenges for Interference Tolerance?

• Upper Layer of Internet Based Systems are Inherently Tolerant of Significant Packet Loss
  — Voice (VOIP), Cellular (LTE) Converging on IP

• Spectrum Sharing Technology Should Include Making System Operation Resilient to Interference, ex.
  — Avoid Cascading Failure (1 Lost/Delayed Packet should not Cause a Blizzard of Traffic to Recover)
  — Loss/Delay Tolerant Control Planes, so Internal Network Operations Not Driver of Loss Tolerance
  — Use of DSA to Enable Networks to Relocate to Avoid Longer-Term Interference

• Change Focus to Protecting Services, not Links
• Example Using DSA to Resolve Interference by Relocation
  — Uses XG Demo Performance for Sensing and Relocation
  — Mobile Nodes Using Packet Radios
• Shows Accepting Some Interference Can Enable Major Increases in Capacity
• Optimal Interference-Tolerant Operating Point Orders of Magnitude More Aggregate Capacity than Interference-Free One
• Similar to Internet Strategy of Allowing Some Loss, but Obtaining Much More Capacity


These Are Policy Issues as Much as they are Technical
Conclusions

- Fundamental Changes in How Spectrum is Managed is Essential to Support Exponential Growth in Wireless
- DSA Alone Can Not Achieve Exponential Increases in Spectrum Sharing and Resulting Value, but ... 
- Adoption of New Principles of Interference, System Design (At all Layers) and Moving to the Stochastic Treatment of Interference Can
- Research, Engineering and Policy Needs to Look at All Spectrum Users as One “System”, Not Isolated and Independent -- It’s an Eco-System!
- Resilient Control Planes and Protocols are as Critical as Waveforms and Sensing to Spectrum Sharing
Thank You

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