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International Symposium on Advanced Radio Communications

Boulder, CO

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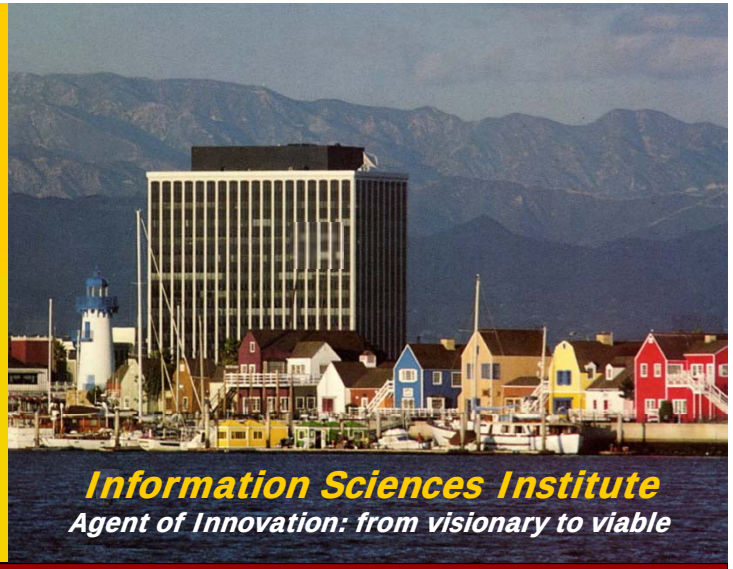

Spectrum Sharing, Interference Definition, and Interference Tolerance

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What is Next for Spectrum Sharing?

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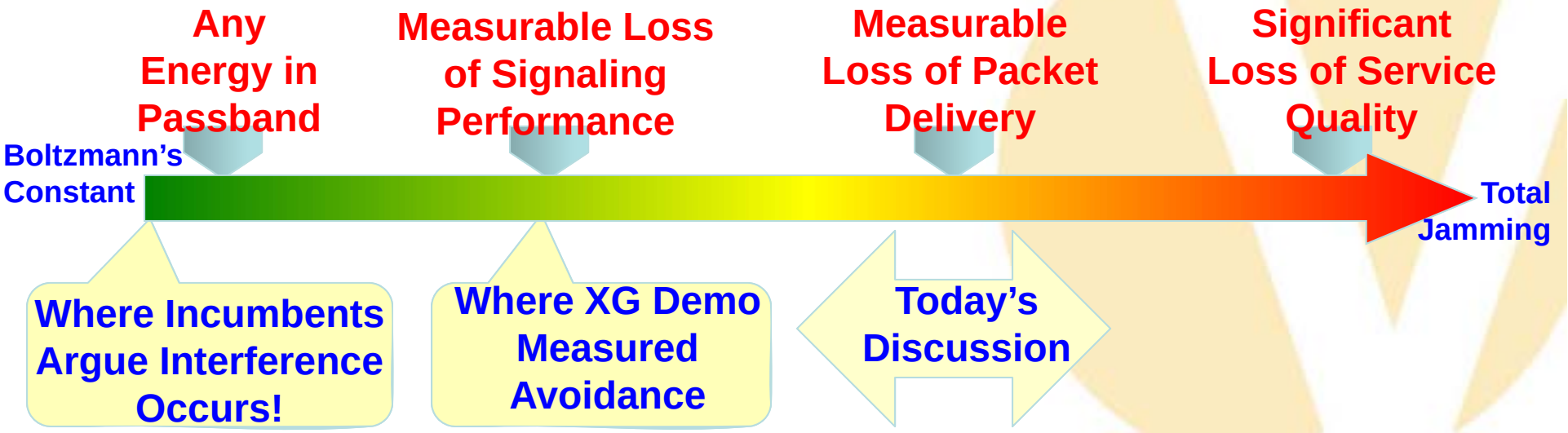
- **We Have Approached Spectrum Sharing and DSA from the Perspective of "Dumb" Primary's and "Smart" Secondary's**
  - Highly Stressing on Sensing
  - Fundamental Physics Constraints on Sensing
  - Impact -- Limits on DSA Power & Applications
- **This is an Ineffective/Defective Model for Maximizing 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



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It Does Not Have to Be So Hard

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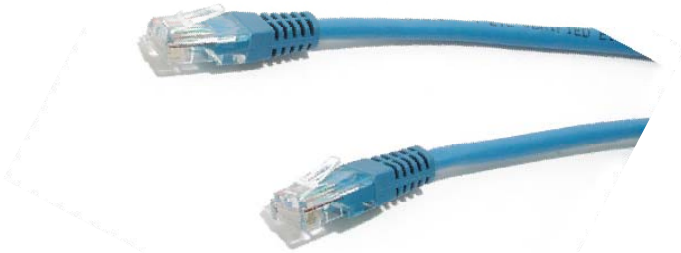
- **Interference Need Not Lead to Failure**
  - —Internet Shows Many Key Principles:
    - *Interference Management*
    - *Robustness to Occasional Disruption*
    - *Diversity of Methods to Deliver Information*
- **Example: Two Solutions Proposed to Connect Computer Workstations in the 70's and 80's**

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

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What Are Challenges for Interference Tolerance?

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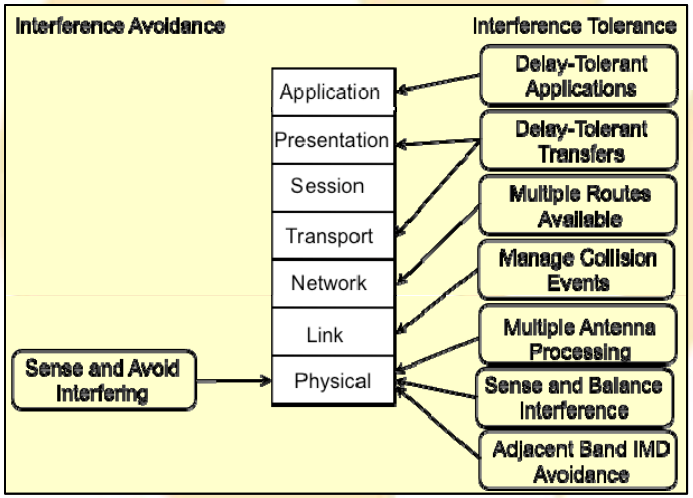
- **Upper Layer of Internet Based Systems are Inherently Tolerant of Significant Packet Loss**
  - Voice (VOIP), Cellular (LTE) Converging on IP
- **Spectrum Sharing Technology Should Include Making System Operation Resilient to Interference, ex.**
  - Avoid Cascading Failure (1 Lost/Delayed Packet should 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**



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What is the Right Objective for Spectrum Policy

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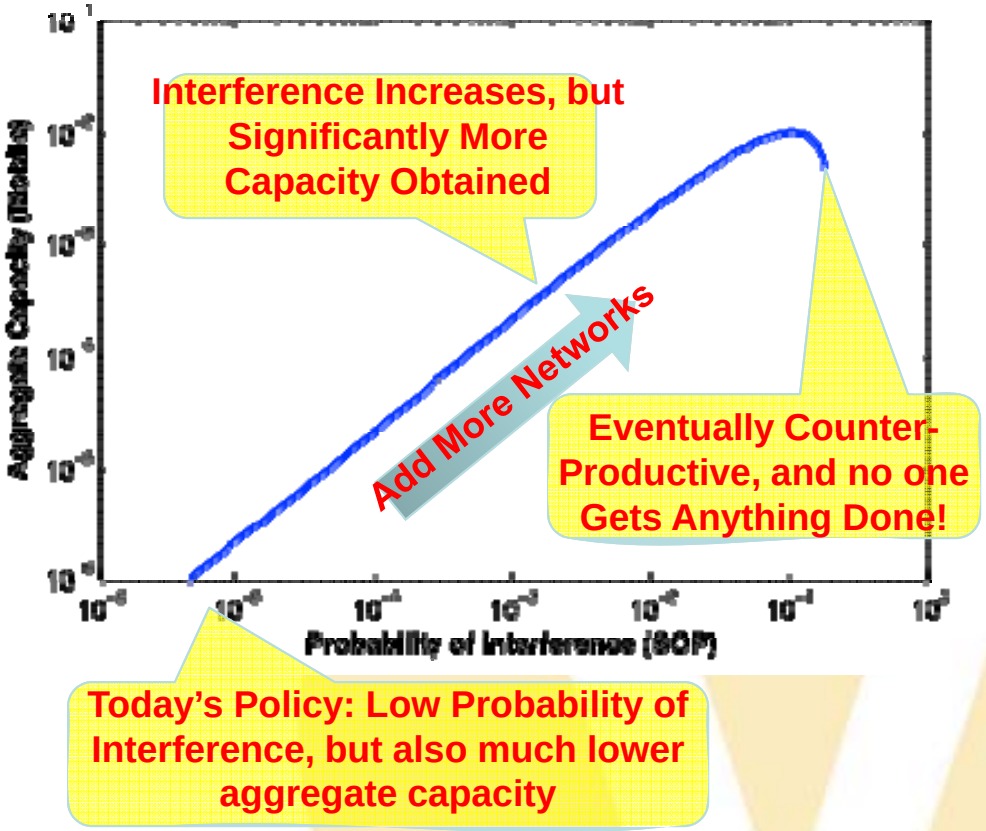
- **Example Using DSA to Resolve Interference by Relocation**
  - Uses XG Demo Performance for Sensing and Relocation
  - Mobile Nodes Using Packet Radios
- **Shows Accepting Some Interference Can Enable Major Increases in Capacity**
- **Optimal Interference-Tolerant Operating Point Orders of Magnitude More Aggregate Capacity than Interference-Free One**
- **Similar to Internet Strategy of Allowing Some Loss, but Obtaining Much More Capacity**



Example details provided in P. F. Marshall, *Quantitative Analysis of Cognitive Radio and Network Performance*. ARTech, Norwood, MA, 2010., or P. F. Marshall, "Dynamic Spectrum Access as a Mechanism for Transition to Interference Tolerant Systems," in *IEEE 4th International Symposium on New Frontiers in Dynamic Spectrum Access Networks*, (Singapore), April 2010.

These Are Policy Issues as Much as they are Technical

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Conclusions

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- **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 -- Its an Eco-System!**
- **Resilient Control Planes and Protocols are as Critical as Waveforms and Sensing to Spectrum Sharing**

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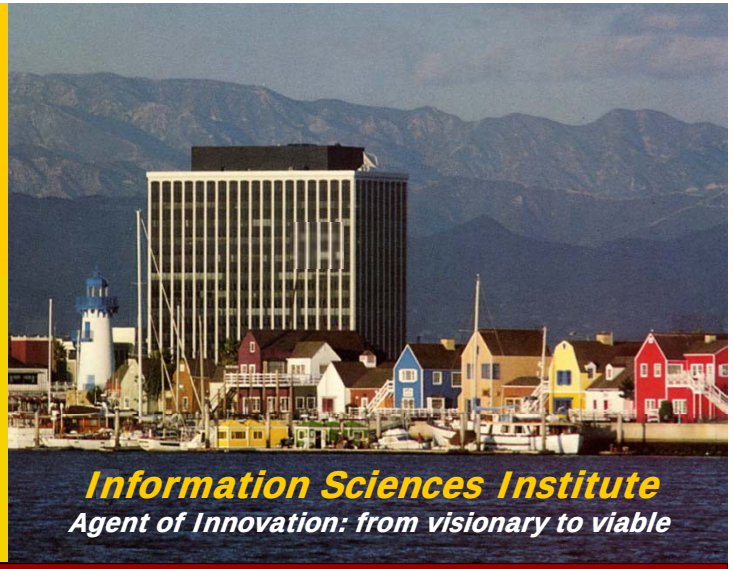

Thank You

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