Real-Time Spectrum Management for Wireless Networks

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Outline

- Problem statement
- Disruptive idea
- Details: approach, issues, architecture
- Summary and conclusions

Problem Statement

- Increasing spectrum pressure on DoD
  - Commercial demand for wireless services
  - Network Centric Warfare needs more bandwidth
- Manual decision and approval process
  - Spectrum XXI (SXXI) support tools
  - Reassignments are infrequent – days, weeks
- Private property model
  - Exclusive use
  - Leads to inefficient frequency utilization
  - 2-15% depending on band

Disruptive Idea

- Dynamic (real time) spectrum allocation
- FCC vision for commercial systems
  - Abandon the private property model
  - Decision driven by economics, policy, technology
  - 10 year process
- What does this mean for DoD?
  - DoD needs more spectrum for network centric warfare
  - Could wait for FCC process
  - More freedom of action possible within DoD spectrum

Approach and Payoff

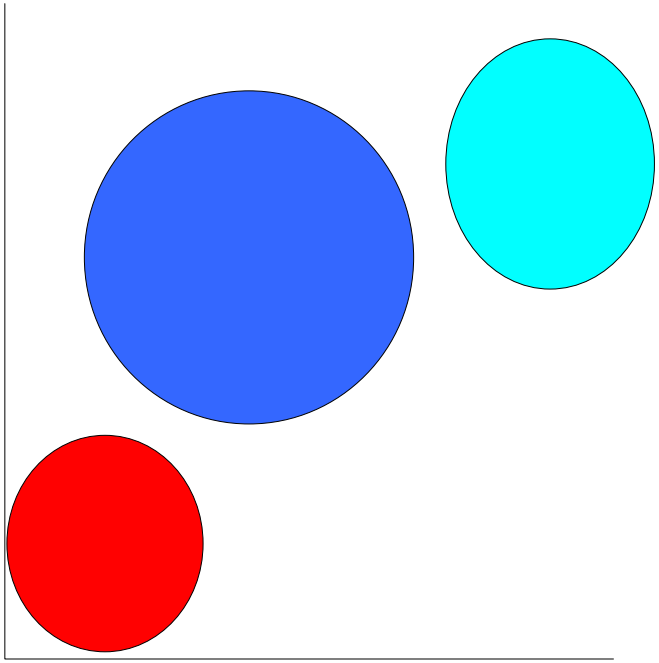
- Adapt FCC dynamic spectrum vision to DoD needs
  - Dynamic reassignment of frequencies within DoD bands
  - Use a private commons model
- Manual policy for bands of frequencies
  - Based on current practice, SXXI assignments, etc.
- Dynamic spectrum allocation potential
  - Assuming 50% spectrum utilization
  - 4 to 25 x more data passed in existing spectrum

DSA Requirements

- 1. Need to know what spectrum is available
  - Solved problem – DARPA xG: 10 μ sec
- 2. Need an infrastructure
  - Software defined radio is a mature technology
  - Reuse existing systems to extent possible
- 3. Need real time spectrum management
  - Existing adaptable solutions
  - Wired network algorithms for resource sharing

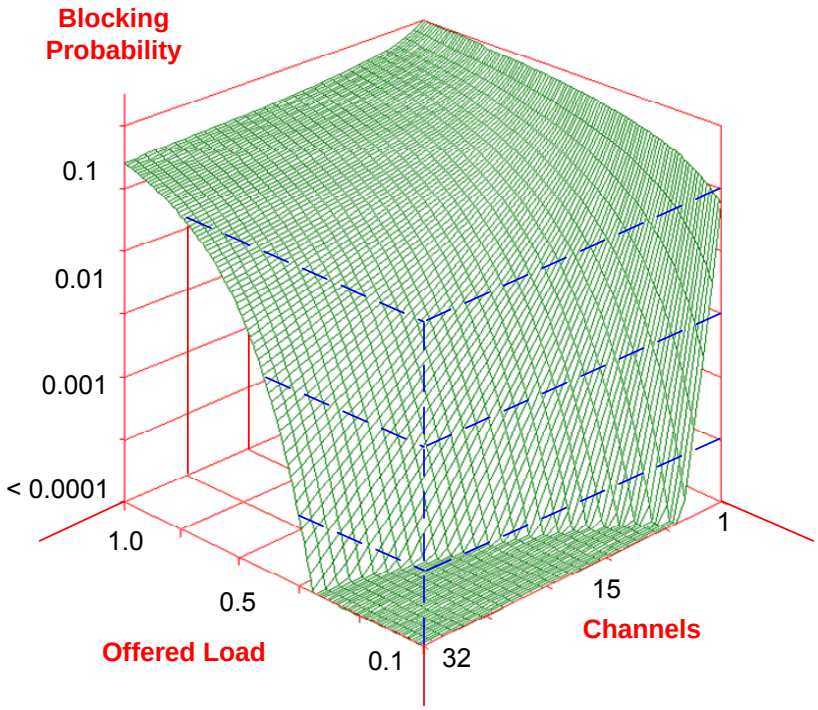
DSA Issues

- Wireless DSA requires sub-second provisioning
- DSA must also support longer term assignments
  - Tactical missions ~ hours
  - SXXI ~ days to weeks
- Priority & preemption support
- Fairness
- Application flexibility
  - Variable channel size & spacing



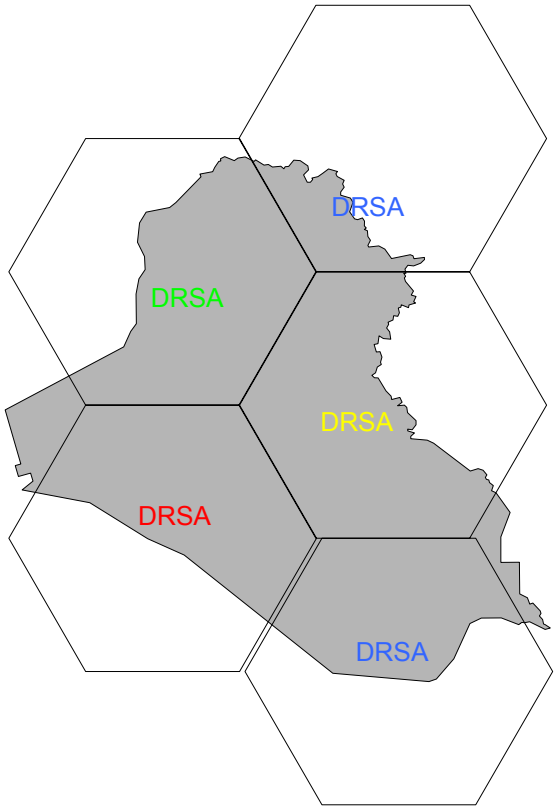
DSA Issues cont.

- Performance
  - Sub-second provisioning provides 2 – 10 x gain in efficiency
  - Negligible blocking
- Transparency
  - Real-time infrastructure sharing
  - Without manual intervention
- Must be difficult to misuse
  - Avoiding everyone is trusted pitfall



Possible DSA Architecture

- Structure bands as a private commons
  - Use SXXI for de-confliction planning
  - Spectrum divided into channels
  - Geography divided into cells
- Dynamic Real Time Spectrum Arbiter per cell
  - Multiple shared signaling channels
  - Arbitrate channels for end nodes
  - Keep local state – e.g., idle channels, usage
- Cell size varies, based on:
  - Frequency band, power level
  - Interference tolerance, policy
- Structure
  - Overlays
  - Sub-division



Signaling Channel Issues

- Multiple shared signaling channels
- Used for RF channel assignment & arbitration
- Existing solutions
  - SS7, GMPLS, SIP
    - Too slow, too complex
    - Missing key features: security, signal quality, variable allocation
- New methods proposed for commercial DSA are:
  - Complex
  - Based on research projects, most un-proven

Way Forward

- DoD “private commons” model
  - Potential to streamline process for military bands
  - All the technology pieces are here
    - 1. What spectrum is available – DARPA xG
    - 2. Infrastructure – frequency-agile SDR
    - 3. Real time spectrum management – existing adaptable solutions
    - 4. Complements SXXI
- Operational Implications
  - More bandwidth moved through available spectrum
  - Notch agile jamming

Conclusions

- Bad news: we aren't making any more spectrum
- Good news: we are wasting what we have
  - Today's DoD private property model → 2 – 15% average utilization
  - Commons model → potential for 4 – 25 times more traffic with same spectrum
  - We can recover much of what we're wasting
- FCC initiatives in commercial sector
  - Replace private property model with dynamic spectrum allocation
  - Increase utilization
  - Regulatory, economic, technical dimensions to solution
  - 10 – 15 year timeline – DoD can't wait

Backup

Just In Time

- Spectrum management control plane protocol
  - Physical layer agnostic
  - Pre-emption and priority support
- Existing implementation (TRL 7)
  - Field trialed (optical networks), documented
  - Open standard
- Signal quality monitoring
- Wicked fast (hardware implementation)
- Support for multiple administrative domains

IEEE Method

- Aloha like
  - Ok for commercial but
  - No planned notches for jammers for instance

http://www.orfm.noaa.gov/#Our%20Products1

- **The SXXI software was developed under the management and direction of the Department of Defense Joint Spectrum Center (JSC) and the National Telecommunications and Information Administration (NTIA). SXXI was developed to fulfill a need to automate many processes and to standardize the spectrum management processes throughout the Federal Government.**
- **The SXXI software enables users in any agency to:**
- **1. Maintain current frequency assignment records in a standardized database format with various selection and analysis capabilities.**
- **2. Maintain a database of communications-electronics equipment and associated technical characteristics in a standard format with various selection and analysis capabilities.**
- **3. Automatically select or nominate frequencies that are interference free.**
- **4. Automatically complete various frequency assignment and major system equipment certification application forms.**
- **5. Validate nominated frequencies via electromagnetic compatibility analyses with systems in the existing environment and perform hundreds of compliance checks on the accuracy of the nominated frequency assignments.**
- **6. Perform the NTIA-required five-year review of frequency assignments.**
- **7. Conduct engineering analyses and calculations to:**
- **a) convert coordinates from one form to another.**
  b) develop topographic charts of signal coverage.
  c) determine the necessary satellite look-angles of ground stations.
  d) perform HF skywave propagation analysis
  e) perform link analysis calculations.
  f) draw spectrum-occupancy graphs for frequency bands.
- **8. Perform interference analyses to:**
- **a) predict potential interference conflicts of new frequency assignment proposals.**
  b) identify potential sources to existing frequency assignments.
  c) nominate new frequencies.

Private Commons

- The FCC proposes that spectrum licensees be allowed to let others use their spectrum in a similar fashion to the unlicensed bands.
- The only types of devices allowed to operate in the “private commons” are peer-to-peer devices in a non-hierarchical network.
- Some current users of unlicensed spectrum would benefit by negotiating with spectrum owners to use their spectrum as a way to offer a service that is less crowded and thus potentially more valuable than services that operate in the unlicensed bands.
- Avoids the “tragedy of the commons,” where the shared item becomes so overused that it loses its value.