Technology Challenges for the Spectrum Collaboration Challenge

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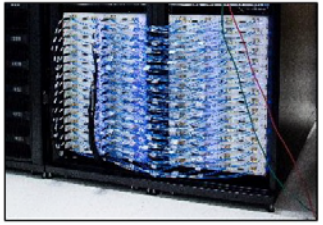
Where this talk fits in the overall workshop

DARPA Spectrum Collaboration Challenge – Challenges

Collaborate Without Co-Design

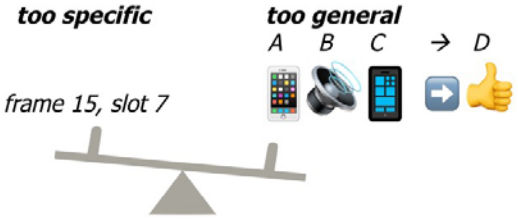
Create radio networks that work with others without knowing how they "think"

Engineer Emergent Effects



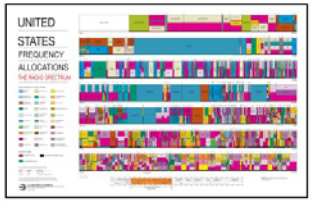
Discover and solve issues that only arise in large-scale realistic settings

Communicate Without Constraints



Create a protocol that supports evolving new forms of collaboration

Evolve The Ecosystem



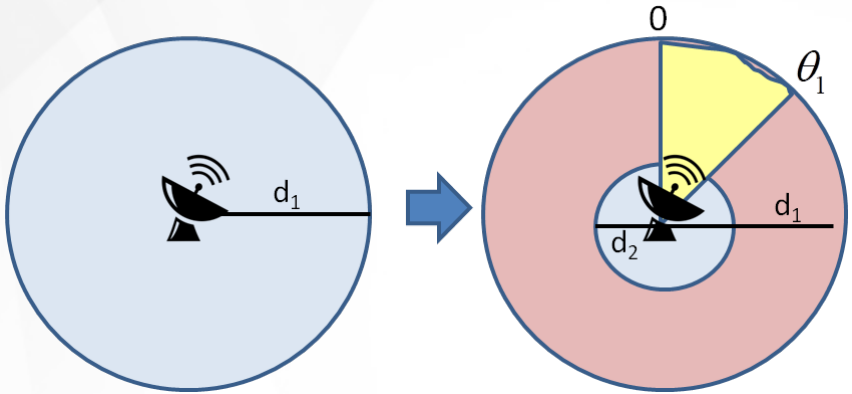
Change radio design, applications, and spectrum management to enable and leverage collaboration.

Thumbs-up image source: http://sr.photos3.fotosearch.com/bthumb/CSP/CSP880/k8803233.jpg
Pencil image source: http://www.pngall.com/wp-content/uploads/2016/03/Pencil-PNG.png

Radio Design

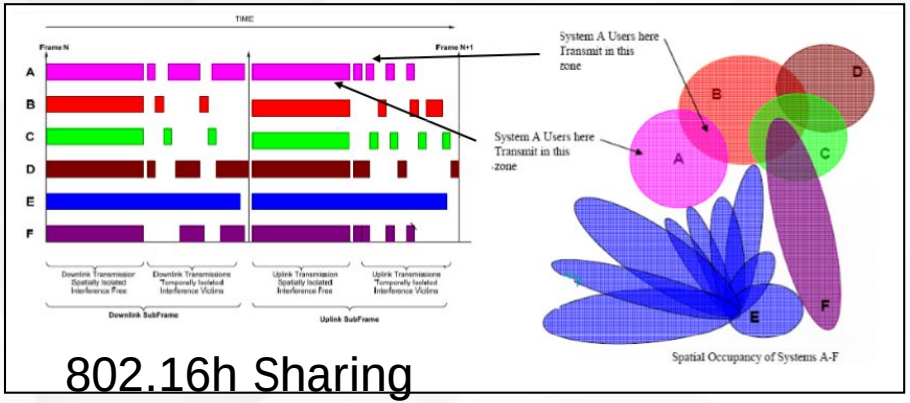
- Software Defined Radio (flexibility)
  - More knobs and meters
  - Cross-layer adaptation
- Interference Tolerance
  - Cancellation, Multi-User Detection
  - Receiver selectivity
- Receiver performance => Predictable interference effects
  - Documentation
  - Standards, e.g., WINNF-16-P-0020-V1.0.
- Tighter Transmit Filtering (reduce footprint)

Pic from: https://zenduder.com/do-it-yourself/



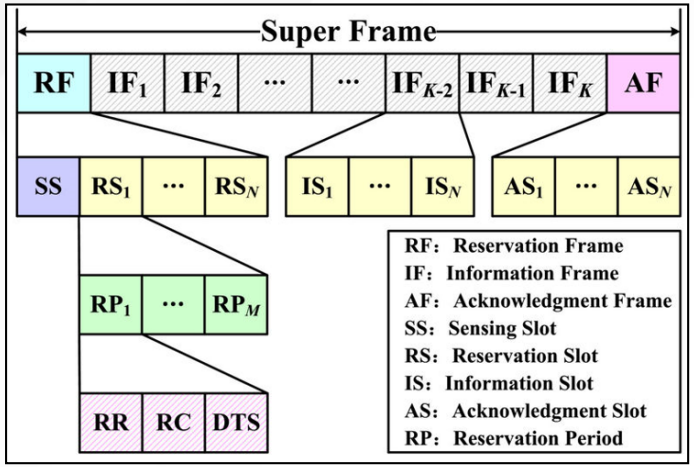
Protocols

- Reducing spectral footprint
  - More bps/Hz
  - Greater selectivity
- Protocol Flexibility
  - Optimal depends on context
- Accept Imperfection => Interruption Tolerance
  - Layer 1 -> Forward Error Correction, Interleave, spread
  - Layer 2-> Hybrid Automatic Repeat reQuest (HARQ)
  - Layer 3 -> Disruption Tolerant Networking
  - Application - Transport Layers -> Buffers
  - Control interruption; Collaboration interruption
- Support for information gathering
  - Sensing slots, SC2 Collaboration Protocol
  - Measurement reports



802.16h Sharing

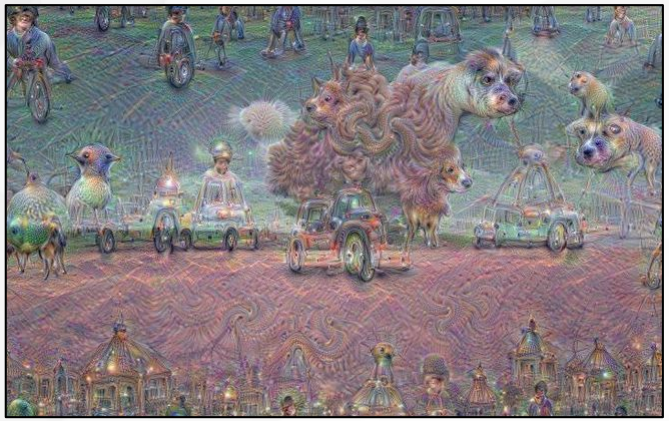
https://www.itu.int/dms_pub/itu-r/oth/0A/06/R0A060000400001PDFE.pdf



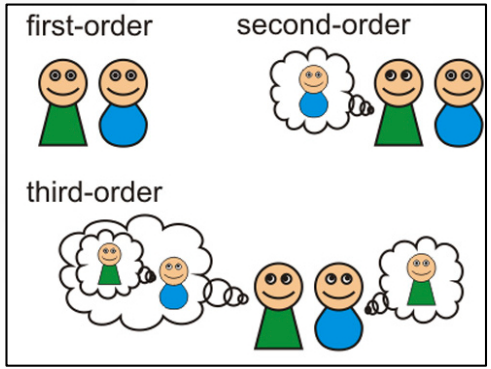
https://jwcn-eurasipjournals.springeropen.com/articles/10.1186/1687-1499-2012-60

Cognitive Radio

- Learning
  - Pattern recognition = > efficiency
  - Solution innovation => uncover opportunities
  - Gain information
- Understanding
  - Own needs / tradeoffs / context
  - Theory of Mind applied to other networks
- Cooperation
  - Selfish cooperation – interference avoidance
  - Altruism – sacrifice local performance for greater good



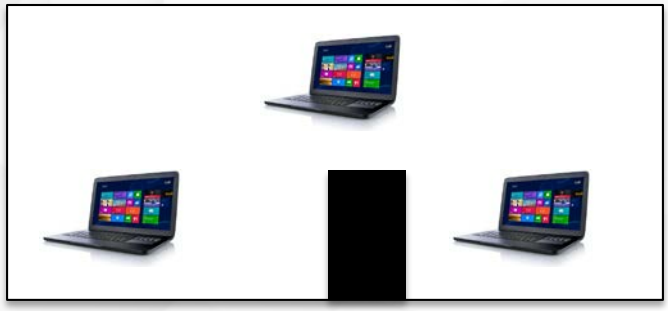
http://www.iflscience.com/technology/artificial-intelligence-dreams/

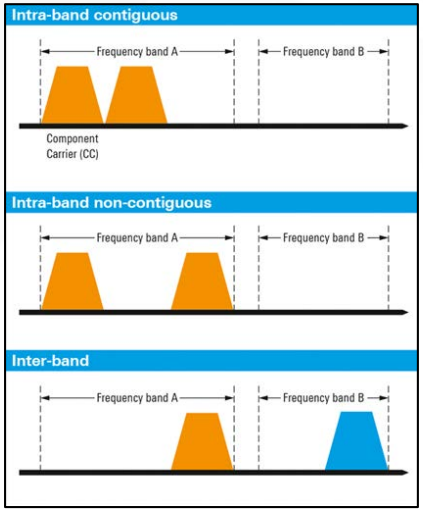


Pic from: http://integral-options.blogspot.com/2013/08/theory-of-mind-mechanisms-methods-and.html

Spectrum Sharing Infrastructure

- Mechanism to exchange information
  - Own RF / performance
  - Context
  - Third party information
  - With coordination, hidden nodes are sharing opportunities
- Mechanism to coordinate
  - Between sharing systems and others
- Extensible Protocol for heterogeneous systems
  - 1900.5, SC2 Collaboration Protocol
  - Share what you've learned
- Fall back channels (data and control)
  - E.g., LTE w/ Carrier Aggregation
  - Side channels





https://www.rohde-schwarz.com/us/solutions/wireless-communications/lte/in-focus/lte_advanced_carrier_aggregation_73018.html

Sharing-Specific Technologies

- Interference Prediction and / or Measurement
  - Increased accuracy reduces protection margin and increases transmission opportunities
- Enforcement: Detect, Identify, Rectify
  - Bad actors
  - Broken systems
  - Errors
- Inter-system synchronization
  - Time Division Multiple Access efficiency limited by synch
  - Coordination / adaptation “collisions”
  - GPS helps with timing and location

http://apr.org/post/operation-southern-shield-begins-today-0#stream/0

Spectrum Access System (SAS) and Technology Challenges

- Heterogeneity complicates all aspects of spectrum sharing, but heterogeneity is reality
  - SAS standardizes interactions among heterogeneous systems
    - Implement SAS to CBSD (Citizens Broadband Radio Service Device) Protocol (WINNF-TS-0016)
- Thin vs thick client debate applies to spectrum sharing
  - SAS enables thin client spectrum sharing and simplifies thick client spectrum sharing
  - Cloud-based SAS for dynamic scaling
- Infrastructure and information can simplify radio design and enable new opportunities
  - SAS for aggregate interference protections
  - SAS as Spectrum Situational Awareness Service
  - ESC (Environmental Sensing Capability) enables sensing without modifying radio design