SPECTRUM COLLABORATION CHALLENGE

The world's first collaborative machine-intelligence competition to overcome spectrum scarcity.

SC2 Phase 1 Collaboration Protocol

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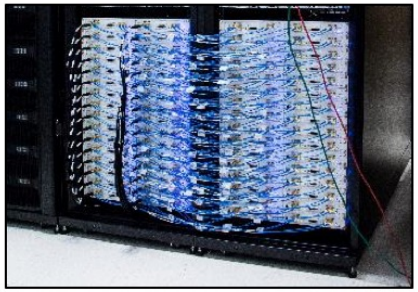
Where This Talk Fits in the Overall Workshop

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

too specific

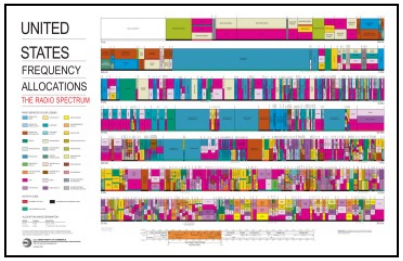
frame 15, slot 7

too general

A B C → D

Create a protocol that supports evolving new forms of collaboration

Evolve The Ecosystem



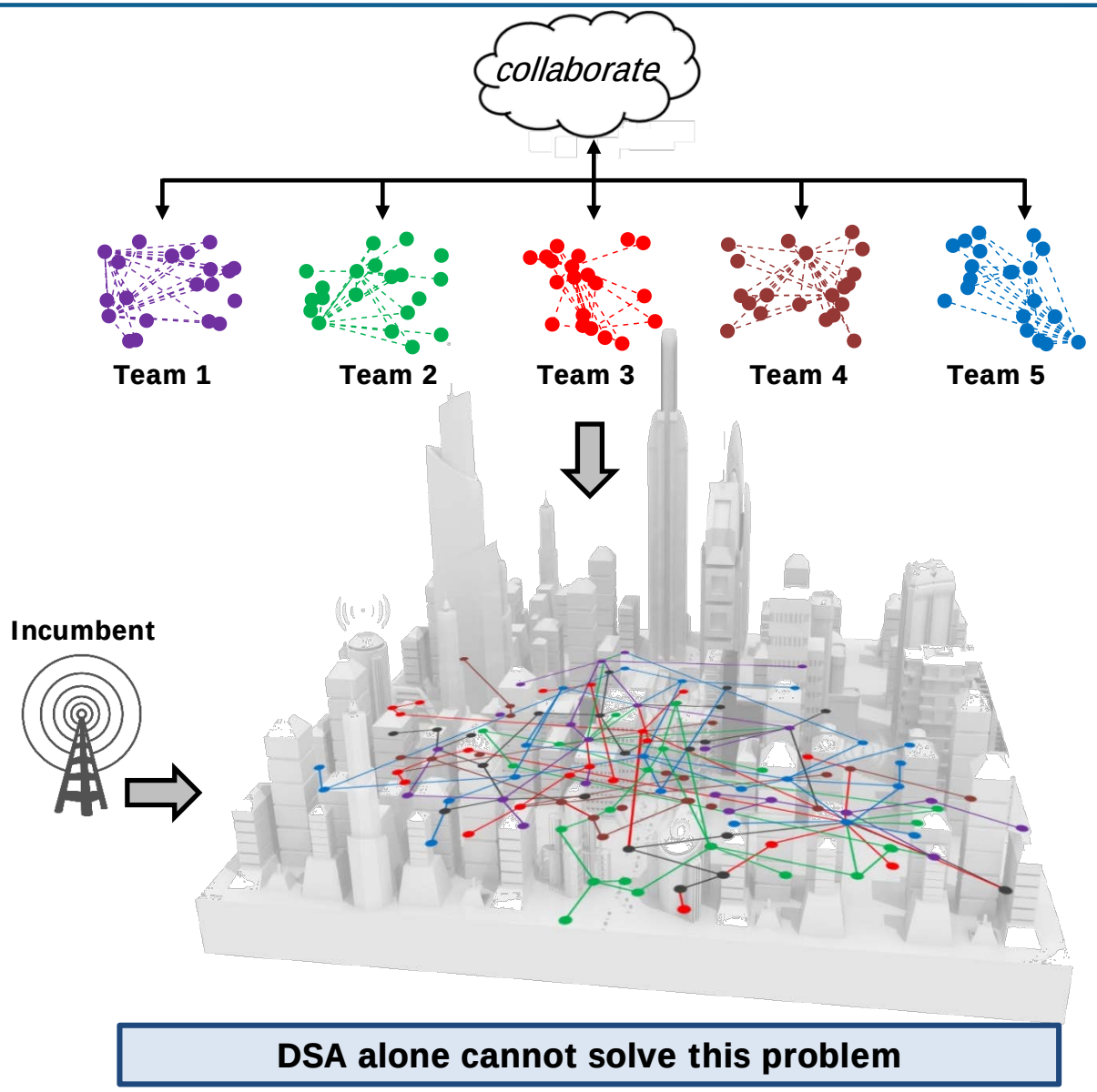
Change radio design, applications, and spectrum management to enable and leverage collaboration.

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

SC2 Collaborative Competition

THE GAME:

- Five teams need to move data through a spectrum obstacle course.
- The obstacle course can change over time.
- The teams themselves are obstacles.
- A team earns points by successfully navigating the course.
- A team earns more points by describing obstacles accurately so other teams can avoid them.
- The team that navigates the course and helps the most teams wins.

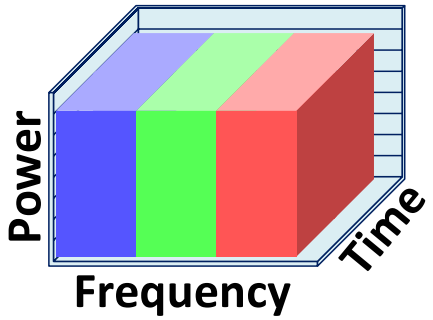


DSA alone cannot solve this problem

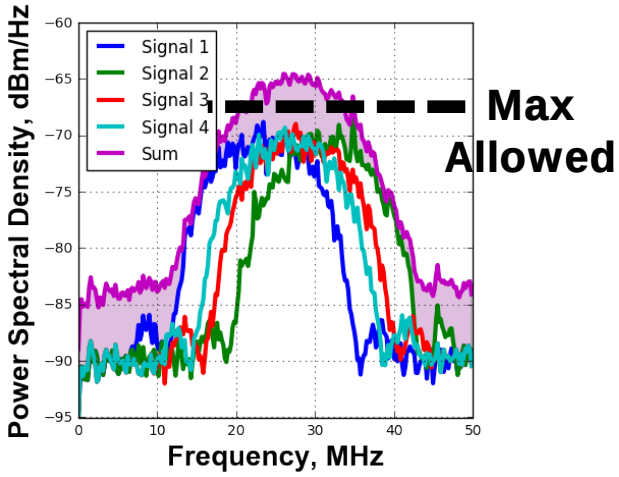
SC2 Desired Outcomes

- Heterogeneous system sharing
  - Bluetooth & WiFi, WiFi
  - Multiple DSA systems
- Management of aggregate interference
  - Prevent multiple independent users from collectively causing harmful interference
- Coexistence with incumbents and priority users
  - Networks must identify important uses of the spectrum even if no way to infer over the air
- Spectral Reuse
  - Indoor/Outdoor
  - Long haul/Short haul
  - Mixed radio types

Stable Multiple DSA Solution



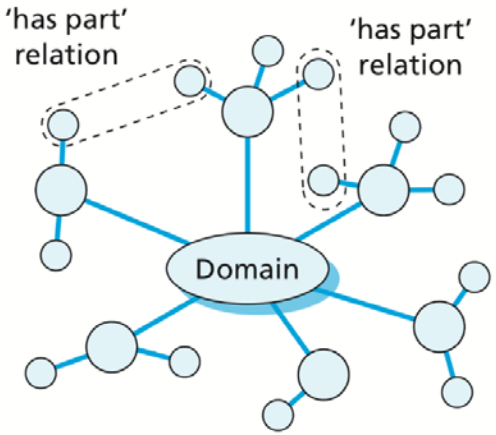
Aggregate Interference Management



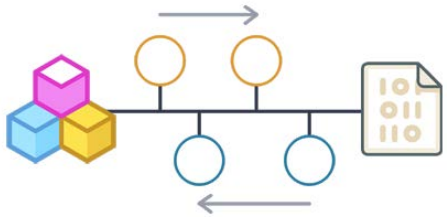
Collaboration Protocol Implementation

- Why use a Collaboration Protocol at all? Isn't machine learning with RF enough?
  - Closing the loop with information rich feedback improves convergence time
- Why implement as a separate back channel?
  - Independent radio designs are unable to communicate directly
- What should the Collaboration Protocol look like?
  - Pass free form JSON messages around?
  - Specify messages with structured language? (Protocol Buffers)
  - Formal Ontology?

Reasoning over Formal Ontology



Binary Serialization with Protocol Buffers

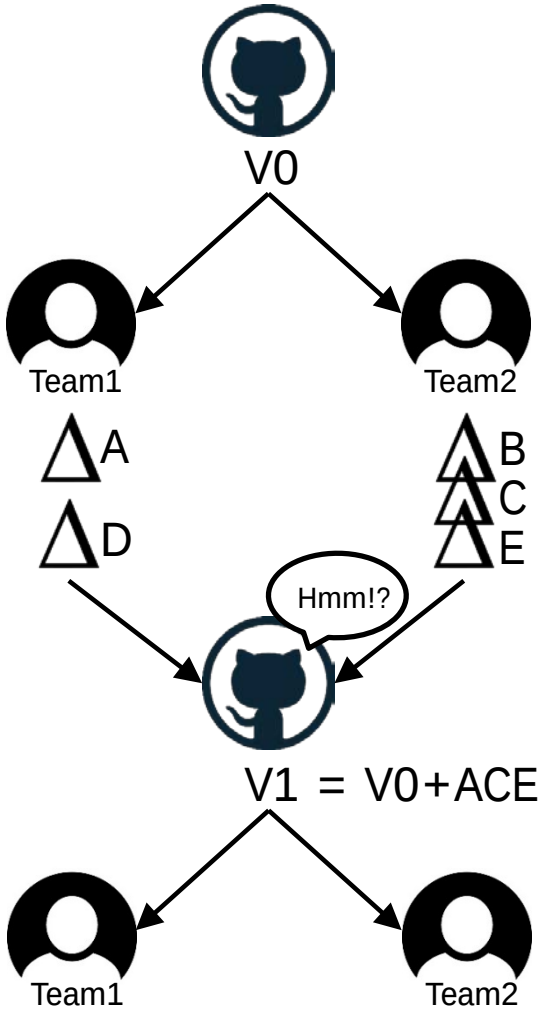


EVOCA: http://www.evocaproject.com/2016/06/15/ontology-vs-taxonomy/
Grijjy Blog: https://bloggrijjy.files.wordpress.com

Using a structured language reduces implementation complexity and permits learning over relevant time scales

Collaboration Protocol Evolution

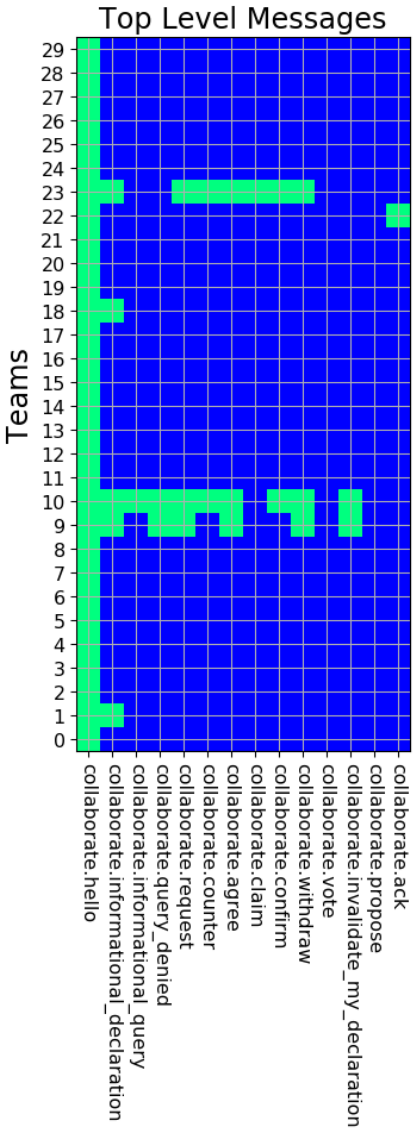
- How can one group design a protocol that suits the needs of many independently designed radios, sight unseen?
  - They can't
- Why not use a typical standards committee approach?
  - High risk of codesign
- Collaboration Protocol Evolution
  1. Competitors submit proposals to the architect
  2. Modify protocol specification in team's GitLab mirror
  3. Submit a patch
  4. Architect will accept/reject, integrate, & push out new versions



Government Team Architect owns the protocol content

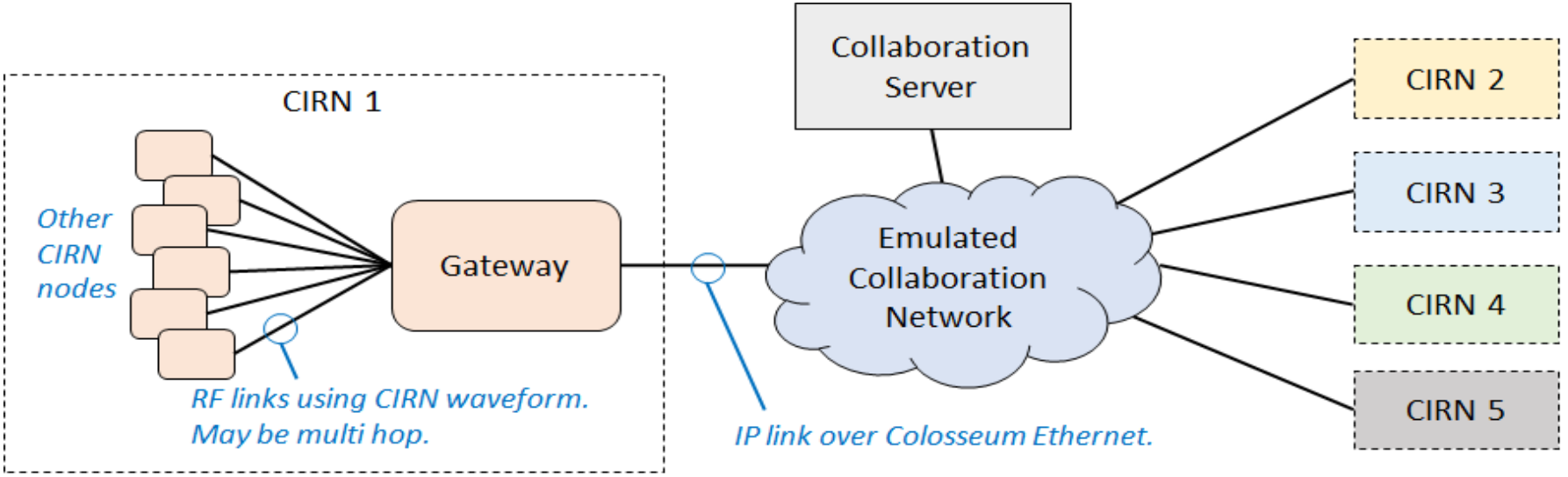
Conquering Babel

- How do teams know where to invest their development time if developers can't talk to each other?
- Continuously updated online dashboard shows teams what others implement
  - Current implementation status
  - Plan for next scrimmage/event



Massimo Marino:
http://www.massimomarinoauthor.com/just-knowing-your-nouns-and-verbs-makes-you-no-translator

Collaboration Protocol Messaging Architecture

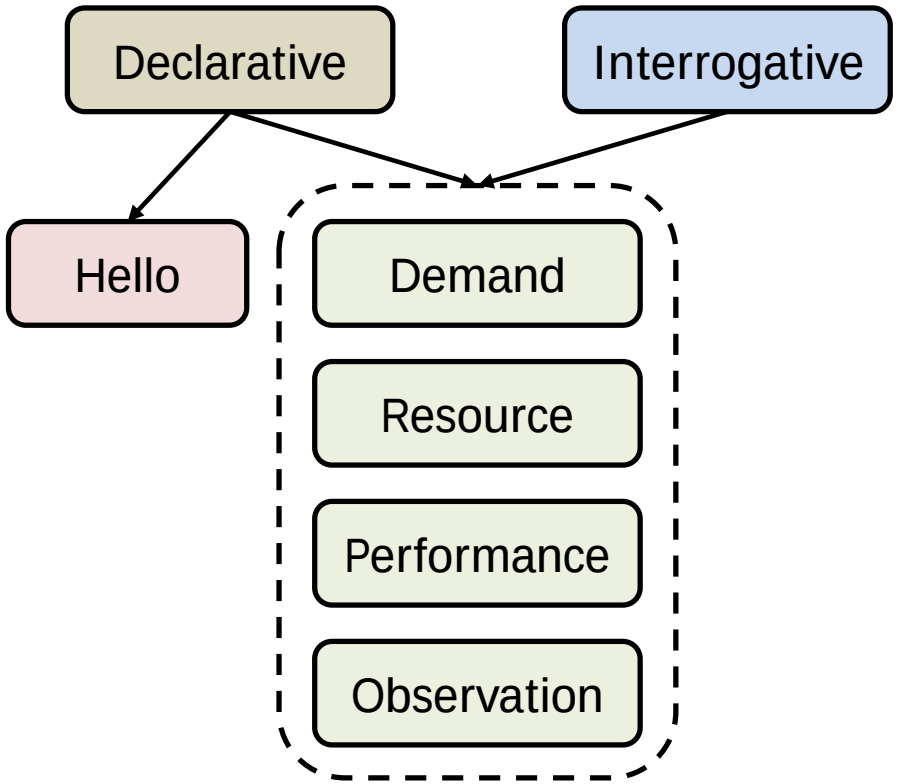


- Networks must communicate through gateways
- Gateways find each other using the Collaboration server
- Any gateway can message any other gateway directly
- Collaboration Channel emulates internet

Collaboration Protocol Content Hierarchy

Informational

Providing or seeking information without any formal arrangement between networks

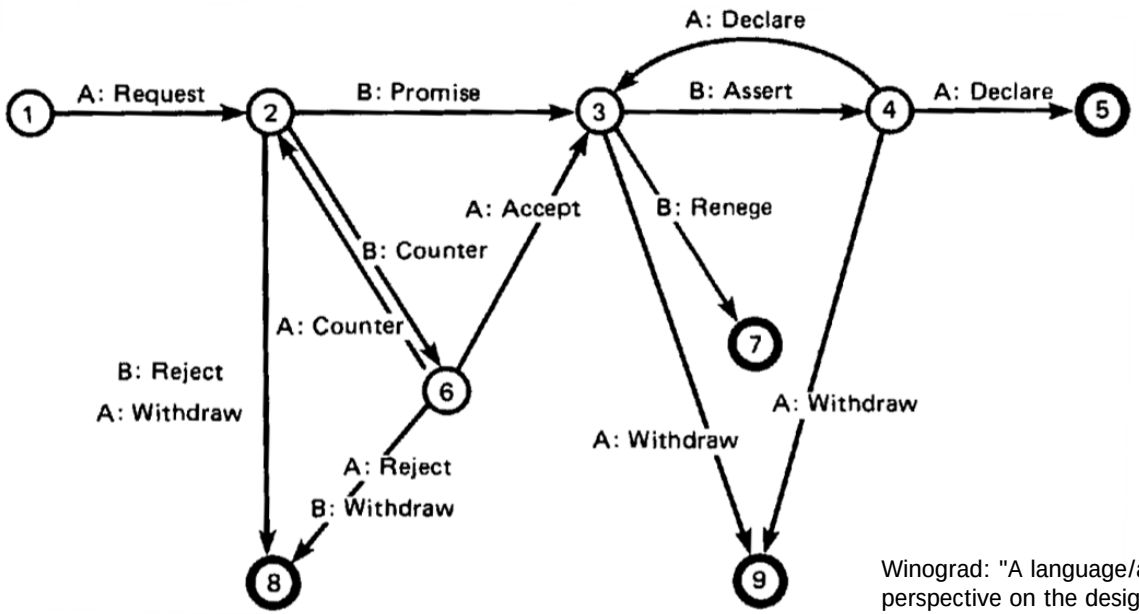


Time-frame (i.e. tense) asserts semantics
Classes are relational and extensible

- Hello: exchange of supported message types
- Demand: Something that drives the network
  - Latency, throughput, priority
  - Queue Length, supporting backpressure routing
- Resource: Anything that must be shared by networks
  - SpectrumVoxel
- Performance: metrics important to the network
  - Scalar performance
  - Bit error rate
  - Frame loss rate
- Observation: share information between networks
  - PSD
  - Spectrogram

Conversational Subprotocol

Enables processes for entering into an arrangement or seeking agreement



Winograd: "A language/action perspective on the design of cooperative work."

“Verb” classes:

- Request, Accept, Counter, Promise, Assert, Renege, Reject, Withdraw
- Each verb can encapsulate high-level informational classes... among others

Applications:

- Control Tones: Low latency signaling for local use of spectrum
- RF Relay: Mesh networking among dissimilar radios
- Voting: Autonomous resource contention resolution

Challenges and Future Work

- Trust between networks
  - Liars due to game theory
  - Liars due to inaccurate sensing
  - Not all radios are created equal

- Protocol is currently a collection of nouns and verbs without a codified set of Rules of Order
  - No current support for codifying specific message sequences
    - How do networks call for a vote?
    - How many votes are enough for the proposal to pass?
    - What happens if only two out of three networks agree?

- Future work:
  - Collaboration protocol will continue to evolve in Phase 2 and Phase 3
    - Current version is available online:
    - https://github.com/SpectrumCollaborationChallenge/phase2-hurdle
  - Plan is to evolve the protocol in such a way as to be a useful technological artifact of the competition

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DARPA