The IEEE 1900.5.2 Standard for Modeling Spectrum Consumption

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Outline

- Introduction
- The IEEE 1900.5.2 Standard
  - Model constructs
  - System modeling
  - Assessing compatibility with spectrum consumption models (SCMs)
- Benefits
  - Robust tool development
  - Rapid decision making
  - Specialized algorithms
- SCM Builder and Analysis Tool (SCMBAT)
- Conclusions and Future Steps
Introduction and Background

- **Spectrum-sharing mechanisms are becoming more common**
  - Database-managed sharing and the National Spectrum Access System (SAS)
    - 3.5 GHz band (CBRS – Citizen’s Broadband Radio Service)
    - Other bands being considered

- **Dynamically sharing spectrum requires defining the boundaries of spectrum use**
  - Defining how systems emit EM radiation
  - Defining what is interference to a system
  - Defining how these qualities of systems are different in time and space
  - Identifying behaviors that allow sharing

- **SCMs define boundaries of spectrum use**
  - Defines the computation of compatibility among SCMs and removes the ambiguity of “what is harmful interference” before decisions are made
  - Can greatly support interactions in database-managed spectrum sharing
Model-Based Spectrum Management (MBSM)

- Spectrum management (SM) based on the creation and exchange of SCMs
  - SCMs capture the consumption of spectrum not the details of systems
  - SCMs have attendant computations for assessing compatibility among models (A common means across the entire SM system)
  - SCMs attempt to be loose couplers for the SM system
    - The minimal amount of data at the intersection of the activities of SM
    - Captures the intent of users and the judgment of spectrum managers
    - Conveys spectrum use policy
- Benefits
  - Greater resolution in spectrum management
  - More agile spectrum management (i.e., real time)
  - Enables devices and systems to collaborate in spectrum sharing
IEEE 1900.5.2: Standard Method for Modeling Spectrum Consumption

- Objectives of the standard
  - Define the data model constructs for SCMs
  - Define procedures to arbitrate compatibility among combinations of RF devices and/or systems that have expressed the boundaries of their spectrum use with SCMs
  - Provide the means to generate machine-readable SCMs: together with the standardized compatibility calculation mechanisms, these provide (among other benefits) the means to automate the identification of spectrum reuse opportunities and dynamically coordinate spectrum access.

- Final version of the standard was produced by the IEEE DYSPAN-SC workgroup 1900.5 in December 2017
- Official version published June 2018
SCM Constructs (IEEE 1900.5.2)

- **Reference power**: Captures the spectral content of the signal and the unique characteristics of spread spectrum systems.
- **Spectrum mask**: Captures a definition of interference.
- **Underlay mask**: Can capture antenna effects.
- **Power map**: Can capture environmental effects.
- **Propagation map**: Can capture behaviors that enable compatible reuse.
- **Intermodulation masks**: Captures susceptibility to intermodulation.
- **Platform**: Enable greater resolution in spectrum management.
- **Location**: Can capture behaviors that enable compatible reuse.
- **Schedule**: Enables greater resolution in spectrum management.
- **Minimum power spectral flux density**: Captures a definition of interference.
- **Protocol or policy**: Most constructs have probability data elements to declare confidence in parts that are variable or are uncertain.

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Combining Constructs into Models

- **Model and set functions**
  - **System Model**
    - Consists of transmitter and receiver models that are part of a system
  - **Collective Consumption Set**
    - Lists uses of spectrum by systems, transmitters, and receivers
    - Heading identifies the time, space, and frequencies over which the list is complete
  - **Spectrum Authorization Set**
    - List of system, transmitter, and receiver models identifying spectrum boundaries within which use is authorized
  - **Spectrum Constraint Set**
    - List of system, transmitter, and receiver models identifying existing uses of spectrum that have precedence and with which new uses must be compatible

Constructs are used to model transmitters and receivers.
Compatibility Computations

- **Constructs are a means to specify the factors that determine a link budget in all directions.**
- **Modelers build SCMs to identify the power spectral flux density of transmissions and allowed interference.**

**Transmitter**

- Reference Power +

**Receiver**

- Reference Power +

**SCMs are built to protect, not to predict!**

**Graphical Elements:**
- 2-ray model with vertical polarization, 1.7 meters high antennas
- Friis equation
- A piecewise linear model
- Interference threshold

**Diagram Notes:**
- One-meter pathloss
- Power Spectral Flux Density of a transmission
- Allowed Power Spectral Flux Density of interference

**Reference Text:**
- Construct is a means to specify the factors that determine a link budget in all directions.
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General Process for Computing Compatibility

- Determine if uses will overlap in time and spectrum
- Determine the constraining points (the point of primary operation and the point of secondary operation that most restrict the secondary user)
- Compute the allowed transmit power of the secondary

The variety of means to specify locations and the use of directional antennas makes the determination of constraining points the most challenging part of computing compatibility.
Architectural Differences in Tools

Key difference is in how and where the synthesis of the technical, operational, and environmental factors of spectrum use occurs.

Traditional

- SDS Data & Planned Use
- Terrain and propagation modeling occur here
- Computations for decision making occur here

UDOP

Using SCM

- SDS Data & Planned Use

MBE – Model Building Environment
SDS – Spectrum Dependent System
UDOP – User Defined Operational Picture

MBE – Model Building Environment
Arbitration and Decision Support based on SCMs
Visualization

The synthesis of technical, operational, and environmental factors of spectrum use exist in code that interprets the data.

A black box that obscures the decision making computations. The evolution of environmental models, and the changes in systems and system interactions and analysis implemented, result in accretion and systems too complex to maintain.
Algorithmic Spectrum Deconfliction

User Mobility, No Deconfliction

User Mobility, Algorithmically Deconflicted
Visualization – Understanding the Environment and Finding Whitespace

- Provides a view of spectrum use
  - Spectrally
  - Temporally
- Uses waterfall plot
  - Omnidirectional
  - Directional
The CBRS Use Case

- Channel assignment to CBSDs
  - Multiple priority levels
  - Initial assignment
  - N+1 assignment

- Find an alternative reaction to Dynamic Protection Areas (DPAs)
  - Current reaction is to turn off devices within exclusions zones surrounding the DPA
  - The alternative is to thin the set of CBSDs operating to meet the protection criteria
Large-Scale Channel Assignment

- Problem: Find solutions for 100,000+ system scenarios in under 10 minutes

- Solution: Maintain running estimate of scenario
  - Dynamic updating of interference adjacencies as scenario changes
  - Cut off insignificant interference adjacencies
  - Improve cache protection through insignificance detection
  - Parallel computation of interference
N+1 Channel Assignment and Reassignment

- Problem: Assign channel to new system in 100,000+ scenarios, targeting real time
- Solution: Dynamic scenario creation out of running estimate
  - Parameter controls
    - Time limit
    - Hop depth to consider
    - System ownership
    - Channels allowed to switch
  - Cut out unnecessary arbitration through adjacency list manipulation

System Models
- New
- Changeable
- Unchangeable
Alternative Responses to DPA Activation

- **Problem:** Keep customers on without interfering with system of unknown location and directionality

- **Solution:** Dynamic constraints

  - Branch and Relax method developed and implemented
    - Start with large area and wide directionality range
    - Divide and conquer with locations and directionality
    - Uses SCMs with transmitter densities to reduce arbitration computations
SCM Builder and Analysis Tool (Objectives)

- Open source software tool for elaborating/defining SCMs in conformance with the 1900.5.2 standard.
- Incorporates algorithms to compute the compatibility among SCMs
  - Several single Tx to single Rx receiver cases covered
  - Evolving to support more complex scenarios
- Identify limitations in the use of SCMs
- Code available from GitHub ([https://github.com/ccaicedo/SCMBAT](https://github.com/ccaicedo/SCMBAT))
Tabs to input information for a Tx Model
Compatibility calculation example. Multiple interferers vs. a bandwidth rated underlay mask (\([\text{BW Rating (MHz)}, \text{Power Adjust (dB)}]=[0.25, 30], [0.05, 20], [0.02, 10]\) )
Conclusions and Future Steps

- **Spectrum consumption modeling**
  - Is a supporting framework for current spectrum management initiatives
  - SCMs are standardized in IEEE 1900.5.2
    - Non-proprietary
    - Vendor independent
    - SCMs support rapid decision making and creation of innovative algorithms for better spectrum use

- **Spectrum sharing will drive the need for innovations in RF spectrum management**

- **Workgroup 1900.5 of the IEEE Dynamic Spectrum Access Networks Standards Committee (DySPAN-SC) continues work on:**
  - IEEE 1900.5.1: Standard Policy Language for Dynamic Spectrum Access Systems
  - IEEE 1900.5.2a: Adding Schemas to 1900.5.2
    - XML, JSON

  - Join us: [http://grouper.ieee.org/groups/dyspan/5/index.htm](http://grouper.ieee.org/groups/dyspan/5/index.htm)
Resources on 1900.5.2

  https://standards.ieee.org/standard/1900_5_2-2017.html
- The Spectrum Consumption Model Builder and Analysis Tool (SCMBAT)
  https://github.com/ccaicedo/SCMBAT