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SPECTRUM REQUIREMENT PREDICTION METHODS

MICHAEL K. PAINTER
CHARLES H. JONES

AIR FORCE TEST CENTER
EDWARDS AFB, CA

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EDWARDS AIR FORCE BASE, CALIFORNIA
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Michael K. Painter, Charles H. Jones

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1408 University Dr. East
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14. ABSTRACT

In order to defend spectrum and to plan for future spectrum use, methods for aggregating and predicting spectrum requirements are needed. There does not appear to be a single repository for spectrum requirements. Every test program has their own approach to determining their requirements. Some projects may not plan long term. Test requirements, and the resulting spectrum requirements, can change for a variety of reasons including requirements from outside a project's direct purvue. Predicting requirements is always difficult and time consuming and spectrum prediction may not be a high priority.

There are several methods that can be used to predict future spectrum requirements. A commonly distributed graph showing exponential growth was produced in preparation for the 2007 World Radio Conference. The method used for that was to implement regression analysis on historic project requirements. This was a broad-brush approach: one data point for each project. More granular, and hopefully more accurate, analysis could be achieved given the tools and the data. Analysis can be done using historic daily usage data, using spectrum requests submitted to test resource scheduling systems, by aggregating yearly or monthly estimates from each project, or a combination of these data sources.

Methods to utilize different data sources and analytic techniques to better predict spectrum requirements will be presented.

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Test and Evaluation/Science and Technology Program

Spectrum Efficient Technology

Spectrum Efficiency Through Metrics (SETM)

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Spectrum Requirement Prediction Methods

Charles H. Jones, PHD
C. H. Jones Consulting, LLC

Michael K. Painter, P.E.
Knowledge Based Systems, Inc.

Background

- **Current spectrum demand prediction is inadequate**
- **Part of the Spectrum Efficiency Through Metrics (SETM)**
  - Developing software to aid spectrum loss impact
  - Developing models for demand, supply, and cost
  - Aided by spectrum management metrics software (RCC 707)
- **Capturing demand is first step towards meeting demand**
  - Current and predicted
  - Is demand going up the way everyone thinks it is? How much?
- **Need models and methods to predict effect of technology implementation on spectrum factors**

“Demand” Rather Than “Requirements”

- **Determining “requirements” vs. “nice-to-haves” is nontrivial**
- **Model is from perspective of spectrum suppliers**
- **How much spectrum do users want?**
- **Let users determine what they need**

Demand Aggregation Matrix

Program\Year	1	2	…	Total
Program 1			…	
Program 2			…	
…			…	
Program m			…	
Unknown Programs			…	
Overhead			…	
Total			…	

Bps vs. MHz vs. MH

- **The fundamental demand is for a rate of data, or bits per second (bps), for an amount of time.**
- **Bps translates into Megahertz (MHz)**
  - Transmitters transmit so many bits per Hertz
- **Megahertz Hours (MH) captures data rate and duration**
  - MH is the unit of spectrum demand
- **Analysis leading up to World Radio Conference (WRC) in 2007 (by MITRE) was based on MHz**
  - This captured a predicted max simultaneous spectrum demand

Multiple Methods

- **Program (user) Input**
  - Direct input into Demand Aggregation Matrix
  - Operational Pace
- **Analytic**
  - Use historic data and regression analysis for predictions
  - Individual programs or in aggregate
- **MITRE's method of Future and On Going (FOG) and Max User Programs (MUP)**
  - Used for WRC 07 support
  - MITRE used MHz. Can be applied to MH.

Program Input Methods

- **Provide estimates of MH for each month or year**
- **Define MH for operation types**
  - How many operations of each type per month or year
  - How many for each testing phase over program life cycle
- **Provide details and constraints**
  - Test ranges or test areas wanted or required
  - Time constraints
    - Specific months
    - Day or night
    - Weekday
  - Transmitter and receiver capabilities

MITRE FOG + MUP

- **Future and On Going (FOG) spectrum use**
  - **FOG = (mean number of users) * (median user bandwidth demand)**
  - Think of this as the “noise floor” of general use
  - Uses median user bandwidth because max users skew the average
  - MITRE estimated a doubling of FOG MHz demand every 13 years
- **Max User Programs (MUP)**
  - Think of this as a large “signal” on top of the FOG “noise floor”
  - One data point per program
  - Regression analysis to produce growth curve
  - MITRE estimated a new MUP arrives about every 4 years with a doubling of MHz demand from previous MUP

Unknown Future Programs

- **Determining the unknowns is never easy**
- **FOG + MUP does this via medians and growth curves as well as isolating MUPs**
- **Program inputs and regression analysis on historic data don't necessarily capture unknown programs**
  - A method similar to FOG can be used to estimate programs that will take the place of departing programs
  - Probably appropriate to use a version of MUP estimate as well
  - Might require expert input
- **Suggestions for other methods are welcome**

Spectrum Overhead

- **All telemetry methods require spectrum that does not carry test data**
- **Bit Overhead**
  - Sync bits, package headers, buffering bits, etc.
- **Spectrum scheduling limitations**
  - Algorithmic complexity (NP-hard)
  - MH requests don’t necessary pack spectrum exactly
  - Limitations in electronics and protocols
- **Non-spectrum scheduling limitations**
  - Spectrum is scheduled so it’s available when all resources are ready
  - Creates dead air between scheduled and actual start of test

Technology Affect on Demand

- **Adopting new technologies can affect how much spectrum is desired**
- **New modulation techniques have increased bits/Hertz therefore decreasing spectrum needs**
- **Modeling and Simulation can reduce overall testing**
- **Dynamic data specification**
  - Historically, a single PCM format is used through entire test
  - Network technology can allow transmitting only the data that is desired at the time it is desired
- **Plenty of other technologies also affect demand**

Applying Technology Adoption

- **Changes to demand from technology investments need to be included in demand prediction**
- **First establish a baseline demand (via presented methods)**
- **Estimate change in demand from specific technologies**
- **Estimate a rate of adoption (e.g., 10% per year)**
- **Combine demand changes and adoption rates (possibly for multiple technologies with overlapping adoption)**
- **Apply to baseline demand**

Supply and Cost Models

- **Spectrum loss impact requires all three components**
  - Supply, demand, and cost
- **Supply and cost models are in development**
- **Technology adoption effects supply and cost**
  - Adoption rate technique applicable

Concerns

- **Program input method requires full cooperation from everybody**
- **Analytic methods on historic data require complete data**
  - Spread across multiple databases or not fully captured
  - Many current databases don’t capture detailed info
- **FOG + MUP method lacks granularity**

Summary

- **Several spectrum demand methods are being implemented in software**
- **Having multiple methods increases robustness and helps identify a range of possible future demand**
- **Detailed input from every program is probably the most accurate**