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Request for Information on the National Spectrum Research and Development Plan

Idaho National Laboratory

INL Response to RFI on the National Spectrum Research and Development Plan

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Introduction

Idaho National Laboratory (INL) addresses research and development needs that cannot be met as effectively by the federal government or the private sector alone. INL accomplishes missions by operating between federal government and private sector to maintain long-term competency on issues of national importance to develop and transfer technology to the private sector. INL maintains a high level of competency in advanced spectrum study and use as supported by our uniquely capable wireless testbed, development of state-of-the-art spectrum efficient waveforms, center for studying wireless security, and broad governmental support for spectrum topics. As such, INL strongly supports the new direction for the advancement of spectrum laid out by the National Spectrum Strategy and are encouraged to see the rapid development of the National Spectrum Research and Development Plan (R&D Plan)[1]. Identified herein are suggestions that aim to continue the excellent progress on the later.

Successful spectrum R&D plans should address three core areas: (1) approaches to drive innovation, (2) tools to support collaboration, and (3) methods to increase understanding. Each of these areas interacts to develop a spectrum R&D ecosystem based on collaboration that effectively realizes practical advancements. Together, these areas provide a conceptual framework for the R&D plan at large. Additional specific responses to topics raised in the RFI are detailed in the subsequent sections below.

Approaches to drive innovation focus on directly enabling innovative spectrum solutions in practical situations. Within this area, five concepts have been identified to underpin innovation in spectrum R&D: (1) diversity, (2) consistent funding, (3) clear transition pipelines, (4) workforce development, and (5) operational connection. The foundation of innovation is

[1] https://www.federalregister.gov/documents/2024/02/20/2024-03400/request-for-information-on-the-national-spectrum-research-and-development-plan

fostering a diversity of ideas that cover the full range of spectrum R&D. Thus, enabling innovation in spectrum R&D requires investigation of diverse models for spectrum sharing, diverse waveforms, diverse testbeds, diverse tools or systems for spectrum monitoring, and diverse spectrum bands. Harvesting the benefits of this diversity, requires some consistency in the approach to funding to avoid the cost of context switching; this consistency can be achieved either by employing several different funding sources or by establishing large umbrella funding programs, such as the NTIA Innovation fund. For the results of this funding to have practical impact, there must be a clear transition pipeline. This pipeline must span from more basic research as captured by academic publications, through establishing maturity through established testing frameworks, to commercial or governmental use assessments with relevant stakeholder involvement and awareness of relevant policy mechanisms throughout. Much of this transition also depends on having a workforce with the necessary skills and knowledge to leverage the developed innovations. Developing a new workforce, training the existing workforce, and providing the necessary reach-back support are important enabling elements of practical innovation. Finally, realizing the impact of innovation through transitioning technology depends on R&D that is well connected to potential operational uses. A spectrum R&D plan should consider mechanisms to address each of these elements to support spectrum innovation.

The broad scope of activities necessary for innovation in spectrum R&D requires collaboration. Developing the tools necessary to support collaboration is a critical element of spectrum R&D plan. Four categories of tools that should be considered are: (1) metrics to communicate value, (2) platforms for sharing, (3) mechanisms for idea exchange, and (4) methods for harvesting knowledge. A set of commonly used metrics provide the foundation for communication of the value of different spectrum technologies and are thus important to facilitate meaningful collaboration. Similarly, fostering broad collaboration requires some means to share data, results, and methods. For example, the combination of websites to host open publications (e.g., arXiv), websites to host open-source code (e.g. GitHub), and websites that connect the two (e.g., papers with code) have helped to foster broad collaboration in the area of machine learning. Beyond platforms to support sharing, mechanisms for idea exchanges, such as inclusive field trial events or regularly scheduled symposia, are necessary to enable collaboration. Finally, the development of methods to harvest knowledge from experimentation and experience underpins the content exchanged at such events or on sharing platforms. Together these tools provide a foundation for the collaboration necessary to develop a spectrum R&D ecosystem.

Finally, a spectrum R&D plan should promote and manage diverse research perspectives, including fostering understanding of spectrum uses and properties. Promoting diverse scientific, data driven approaches to spectrum assessment and technology development facilitates both the innovation and collaboration envisioned by the National Spectrum Strategy. This includes developing approaches to directly facilitate spectrum innovation through the use of band studies assessing Federal Agencies' mission needs compared with commercial and other special purpose needs. While the spectrum R&D plan ought to encourage a broad diversity of technologies, it must also facilitate comprehensive reviews of such innovations. Policy makers, including regulators (NTIA & FCC) as well as Agencies, must benefit from the spectrum R&D plan to inform well-designed national policies. Comprehensive band studies ought to specifically include: "out of band" interference detection and potential human health effects. The spectrum R&D plan ought to propose a process to mitigate identified challenges, in order to create a beneficial loop for future spectrum R&D and collaborative, innovative solutions. Based upon well-defined, scientific-based methodologies, the spectrum R&D plan should enable a culture shift in the management and use of spectrum to promote understanding of critical spectrum issues and then facilitate innovative solutions.

Spectrum Research Strategies

The R&D Plan should focus on practical, collaborative efforts that realize the impact of diverse innovations. This is perhaps most significant with regard to enabling research through the use of testbeds that offer a diverse range of capabilities. To this end, INL suggests the following points:

- There are a diverse set of test facilities available that should be leveraged, per Strategic Objective 3.2:
    - INL's testbed, POWDER, COSMOS, & Hat Creek Range Observatory each represent outdoor wireless testbeds with different characteristics to enable real-world measurements and field-testing of Dynamic Access Methods[2].
        - INL provides 890 square miles with broad access to RF spectrum and low ambient noise throughout nearly all bands. This facility is well suited to explore new concepts and validate approaches with minimal risk of interfering with incumbents.

[2] Dynamic Access Method is a rule or control system for spectrum access that depends on external conditions. It is an "if-then" statement to be executed at runtime (not design time) to enable a spectrum sharing model. This term defined by Dr. John Chapin (NSF) during NRDZCOM3 public event.

        - POWDER is situated within downtown Salt Lake City and provides the means to examine 5G and beyond in the context of an active city RF background.
        - COSMOS offers several software defined radio nodes interfaced to mobile edge computing functional in the heart of Manhattan for the purpose of exploring high bandwidth, low latency communications in an urban setting.
        - Hat Creek Range Observatory focuses on radio astronomy and provides a clear case of an especially sensitive incumbent user.
    - NSF's Spectrum X consortium offers a good model for facilitate experimentation-based collaborations.
    - NSF's RDZ concept directly examines stitching together the benefits of diverse testbeds through some overarching management and commonly available tools.
- The NSS testbed may be best realized as a coordination of existing resources
    - The R&D plan would be well served to investigate and leverage tools, for example:
        - Monitoring and RF control system, similar to OpenZMS as developed by the POWDER testbed and explored within the NSF RDZ efforts.
        - Experiment Management service to schedule and report test results to stakeholders.
        - Spectrum Management services to control spectrum sharing and manage risk of interference to operational systems.
        - Ability to properly monitor and store results of classified and unclassified tests.
        - Infrastructure to perform network administration and cyber-security monitoring.
    - If a single NSS testbed is envisioned, then it will still need to develop advanced monitoring systems to improve remote monitoring by research stakeholders and to enable Dynamic Access Methods.
    - If the NSS testbed is envisioned to be distributed and to leverage existing spectrum resource and testing stakeholders, then collaboration could be fostered through periodic stakeholder working meetings. Existing forums (NRDZCOM or WSRD) could be modified to include NSS testbed break-outs, or a new collaboration forum proposed. NTIA could use such meetings to provide status updates on spectrum sharing capabilities and challenges, and stakeholders

could present ideas to mitigate/resolve challenges or explore alternate spectrum sharing models.

Beyond enabling collaborative, experimentation-based research, the R&D Plan should champion science-based assessment of spectrum risk to inform policy. This should include methodology for identifying and managing the risk of interference generated by spectrum sharing disrupting ongoing operations. Activities associated with the research and development of spectrum sharing techniques must directly fold into the overarching science-based approach and risk management scheme. This implies important responsibilities such as:

- NSS Testbed should remain aware of nearby licensees and coordinate spectrum sharing research where required
- NSS Testbed research should be informed by ongoing Academic studies, as well as commercial or Agency mission needs. Stakeholder working meetings may be helpful.

Priority Areas for Spectrum R&D

As mentioned above, developing a diversity of RF techniques is a critical enabling factor for realizing a health spectrum R&D ecosystem. This includes examining the following elements:

- Robust RF prediction modeling tools capable of predicting out of band interference.
- Robust spectrum monitoring tools to manage interference risk; for example improve sensitivity to a changing RF environment, such as detecting arriving point to point antennas.
- Investigation of new kinds of spectrum sharing models (includes differentiating spectrum sharing models from spectrum sharing methods).
- Toolkit of waveform adaptations that could be employed to respond when interference is detected.

Given the broad potential impact of RF, spectrum security is an important cross-cutting consideration that must develop in tandem with all other topics. Spectrum sharing, in particular, will shift the security landscape of communications by opening large new attack surfaces and security considerations. The R&D Plan must set forth a means of addressing emerging security concerns as a foundation for trust in emerging uses of spectrum.

Further, INL has captured the following questions as significant obstacles to the realization of spectrum sharing research and development:

- What automation capabilities are necessary to enable “safe” spectrum sharing tests?
    - What is a minimum coverage of RF monitors during spectrum sharing research to confidently be aware of interference potential?
        - Consider “out of band” effects upon non-participating emitters
    - What opportunities exist to automate detection of potential interferers for Spectrum Managers?
- Under what conditions should spectrum authorizations not be limited to geographic area?
    - Consider a dynamic access method which completely operates as a secondary signal on a “not to interfere” basis with primary signals.
- What defines spectrum saturation in a spectrum sharing paradigm?
    - Is there a threshold of spectral efficiency (usage) above which spectrum should be classified as saturated?
    - What are the human effects of spectrum saturation? Are human effects equally significant for some individuals – and in particular frequency bands – based on continual low-level exposure as compared to overall power received?
    - Does “OOB” (out of bound) power increase with saturation?
    - Do non-linearities (e.g. accumulation of OOB energy) affect spectrum sharing effectiveness?
- How does a researcher confirm “not interfering”?
    - Consider limitations of passive sensing at a single point, as with Spectrum Access System (SAS), to detect interference to a Point-to-Point communications link, especially due to OOB interference.
    - How close is “too close” between a spectrum sharing experiment and the nearest point on a Point-to-Point communications link?

Grand Challenge Problems for Spectrum

The diverse nature of spectrum research suggests that the need for a Grand Challenge series with regular scheduled events to facilitate large scale collaboration and development on key spectrum issues. Given the objectives of the National Spectrum Sharing, a first focus area for such a series should likely be field trials of spectrum sharing technologies suitable for use in the 7 GHz band identified in the Strategy. While there are several specific use cases that could be examined in the 7 GHz band, sharing with significantly disadvantaged incumbents (e.g. MILSATCOM users) and geo-fencing based sharing systems with automated enforcement mechanisms seem to be the most pressing two use cases.

Whatever Grand Challenge Problem is actually set, events in the challenge series should set ambitious, quantifiable goals. Such an ambitious, quantifiable goal might balance the performance achieved by secondary users with the impact experienced by Primary users. For example,

> Dynamic access methods during this Grand Challenge should demonstrate operation with >6-sigma availability as a Secondary user without creating >50 ms downtime for any Primary user.

An appropriate outcome for a Grand Challenge event could demonstrate the reliability of new dynamic access methods in a operational environment. However, unexpected results and even failures from a Grand Challenge might reveal insights that provide a basis for subsequent challenge events.

Spectrum R&D Accelerators

INL identifies the following R&D accelerators as being significant:

- Diverse open access to testbeds, especially as enabled through the development of distributed testbed management systems.
- Training events that contribute to workforce development
- Platforms for sharing ideas and data
    - Data sharing must enabled by identifying the data models that should be supported for spectrum data
- Collaboration forums for spectrum sharing researchers
- Collaboration forums for testbed managers
- Events to facilitate hands-on experience for decision makers

Near-Term Federal Activities

INL identifies the following potential near-term Federal activities:

- Spectrum collaboration/showcase events that provide hands-on experience/observation of spectrum and spectrum technologies for existing Federal decision makers.
- 7-8 GHz field trial of spectrum sharing with incumbents aligned with Federal band study

Process for Ongoing R&D Plan Refinement

INL identifies the following mechanisms for ongoing R&D Plan refinement:

- Focus on ensuring that knowledge is harvested and disseminated through activities such as:
  - Encouraging academic publications or open publications where possible.
  - Augmenting planned events with lessons learned reports.
  - Holding seminar series from practitioners.
- Develop idea exchange mechanisms to review R&D approach. Existing forums like WSRD or Spectrum X meetings could be a starting point.
- Establish spectrum collaboration/showcase events as strategy meetings for decision-makers.
- Fund R&D through consist vehicles that establish long-term visions while maintaining the ability to leverage lessons learned. The NTIA Innovation Fund is an example of large-scale, well aligned, long-term funding umbrella.

Spectrum Terminology and Definitions

INL proposes the following important definitions and terminology updates:

- Dynamic Access Method: A rule or control system for spectrum access that depends on external conditions.
- Dynamic Spectrum Sharing (DSS): Operation of independent systems close enough together (in frequency, space, and time) that dynamic access methods are required to prevent harmful interference.
- Spectrum Sharing Model: An operational framework that defines roles and responsibilities of entities involved in dynamic spectrum sharing.
- 7.11.1.1 could specifically state that dynamic spectrum sharing tests/research is "authorized under this section" and that it's distinct from electronic attack. Regardless of model.
- Discussion of interference should be refined to differentiate between acceptable (tolerable) and unacceptable (bad) interference.

Other Topics

The collaborative approach to research discussed above should extend beyond technology development and directly engage policy making. There are many emerging policy questions that would benefit from tighter collaboration with spectrum R&D activities. As examples of these questions, INL has identified the following:

- How often would regulators / policy-makers like to be informed of R&D results?
    - Continual monitoring from the Spectrum Monitoring system (or Zone Management System)?
    - Periodic briefings of major accomplishments, as at public idea exchange forums?
    - What metrics build regulators' trust that a dynamic access method is "safe" and "reliable"?
- Under what conditions should spectrum authorizations not be limited to geographic area?
    - Consider a dynamic access method which completely operates as a secondary signal on a "not to interfere" basis with primary signals.