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Request for Information on the National Spectrum Research and Development Plan

Jeffrey Reed (Virginia Tech), Nishith Tripathi (Virginia Tech), Vijay Shah (George Mason University), Vuk Marojevic (Mississippi State University)

Response to RFI on the National Spectrum Research and Development Plan[1]

Jeffrey H. Reed
Willis G. Worcester Professor
Founding Director, Wireless and Virginia Tech and CTO of Commonwealth Cyber Initiative
Bradley Dept. of ECE
Virginia Tech
[redacted]

Vijay Shah
Assistant Professor, George Mason University

Vuk Marojevic
Associate Professor
Mississippi State University

Nishith Tripathi
Research Associate Professor
Virginia Tech

Below are recommendations in the NSF RFI on the National Spectrum Research and Development Plan.

> *1. Recommendations on strategies for conducting spectrum research in a manner that minimizes unnecessary duplication, ensures that all essential spectrum research areas are sufficiently explored, and achieves measurable advancements in state-of-the-art spectrum science and engineering. This includes, but is not limited to, the following:*
>
> - *Methods/approaches to increase coordinated investment in R&D amongst government agencies, academia, civil society, and the private sector*
> - *Structural and process improvements in the organization and promotion of Federal and non-Federal spectrum R&D*

Indeed, several agencies have conducted research into the more efficient use of spectrum, spectrum sharing, and policy behind spectrum sharing, and DoD and NSF appear to be the two leading agencies behind this research. Frankly, there is a slight overlap. NSF research

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tends to be more fundamental, and DoD research focuses on more applied research to improve spectrum sharing with radar systems. Furthermore, sometimes DoD efforts have ITAR or classification restrictions that are unacceptable to NSF and many universities. Nevertheless, while the research scope and TRL level are different, ensuring that both research camps know each other's efforts is valuable and needed. Some possible approaches to make sure of this knowledge transfer include:

1. Request from one agency to participate in PI meetings of another agency. To some extent, the ISART Conference run by the Institute for Telecommunications Sciences (ITS) of NTIA has helped with this role. Still, this conference could be shaped better to accommodate that knowledge transfer. An alternative to ISART is to use SpectrumX or other university organizations as a convener for technology transfer from key DoD and NSF projects.
2. Create webpage descriptions of the projects in both agencies to discriminate that knowledge. Projects from both DoD and NSF should be required to set up these pages and link them to a central website.

2. Recommended priority areas for spectrum research and development, as well as productive directions for advancing the state-of-the-art in those areas. Areas of interest include, but are not limited to, the following:

- *Spectrum utilization efficiency*
- *Spectrum resilience and assured access for critical mission applications and passive scientific observation*
- *Dynamic spectrum access and management*
- *Spectrum situational awareness at scale*
- *Automatic and rapid mitigation of interference problems*
- *Modeling for coexistence analysis*

Topics relevant to each of the above include, but are not limited to, the following:

- *Technical methods, designs, and processes*
- *Economic-, market-, social-, and human-centric concerns*
- *Business and economic models*
- *Protection of citizen privacy, sensitive government missions, and business proprietary data*
- *Cost-effective hardware supporting more dynamic spectrum usage*
- *Use of artificial intelligence and machine learning techniques*
- *Testbed development*
- *Assessment and certification of advanced systems*

The key priority for research is described in recommendation 3. In addition, it is vital to remember that there are technologies, such as interference excision, that can significantly facilitate spectrum sharing. Understanding the theoretical capacity that intermit spectrum can provide (trunking gain) and the association of a value to that spectrum could increase the monetary value of this spectrum. Spectrum sharing, considering earth sensing, satellite-to-satellite communications, satellite-to-ground communications, and between space and non-space communications, will become a much bigger deal in the future with the proliferation of mega-satellite constellations. Optical links should be explored to support the necessary bandwidth for these systems and avoid interference with passive scientific uses of the spectrum.

3. Recommendations on grand challenge problems for spectrum R&D. Grand challenges are selected research problems that if attacked will help motivate and coalesce R&D efforts. Such problems have the following characteristics:

- *The goal can be concisely articulated to stakeholders outside the field*
- *Success or failure is clear*
- *Achieving success requires advancing the state-of-the-art in multiple areas*

The most important outcome from the R&D initiative would be a spectrum-sharing framework that becomes internationally recognized through standards organizations, is widely applicable across bands, and fits within wireless service providers' business models/practices. Having international consistency on how spectrum is managed is critical to the success of spectrum sharing, allowing mass-market costing and minimization of international boundary conflicts. There are also potential advantages for the DoD in having an international spectrum-sharing regime for when international operations are needed. We are at a unique time when this is possible, and this opportunity should be embraced! For example, 6G is beginning to be defined by the 3GPP standards bodies. The O-RAN Alliance has established a framework for potential sharing using Open RAN (O-RAN) that resides on top of the 3GPP architecture.

While O-RAN is not perfect for spectrum sharing, it has many merits and can be modified as it evolves to be even more spectrum-sharing capable. It has features such as disaggregated components, AI provisioning, slicing, edge computing, and real-time control of base station parameters, and it can host various special applications (e.g., xApps and rApps). Leveraging the RAN Intelligent Controller (RIC) of O-RAN could allow bi-directional spectrum sharing and interference excision techniques. Crowd-sourcing techniques for spectrum awareness could also fit within the O-RAN framework.

There is much momentum internationally, especially in the US, to adopt O-RAN to enable a more competitive RAN infrastructure environment. Spectrum sharing is potentially the "killer app" for O-RAN, and if the US pursues this initiative, it could provide a competitive advantage. The combination of spectrum sharing and network sharing that O-RAN enables can be a potent combination for improving spectrum availability. The US has a major funded O-RAN R&D initiative that can immediately be leveraged to help address spectrum sharing and provide incentives for adopting O-RAN.

4. Recommendations on spectrum R&D accelerators such as the following:

- *Shared public datasets*
- *Open-source software/projects*
- *Cost-effective flexible radio platforms*
- *Benchmarks and competitions*
- *Testbeds, research infrastructure, and collaboration support*

One of the significant impediments in spectrum research is the inability to perform experiments at scale with cellular networks. While simply collecting datasets has benefits, they are limited. They cannot reflect the dynamics that occur when spectrum decisions and actions cause other things in the environment to change; for instance, a radar system changes its modes to deal with interference. Access to this testing type is difficult since service providers' networks are there to serve customers. One approach may be to leverage private 5G systems to perform these experiments, such as those 5G networks deployed on college campuses for experimentation. This way, dynamic behavior can be observed, and sufficient users in the network can exercise spectrum-sharing approaches.

Another approach would be to perform these experiments during or immediately after the deployment and testing of a service provider's "greenfield deployment," establishing new infrastructure in a new band before it is turned over to become a production network.

Another approach is to extend the Minimization of 3GPP mechanisms such as Drive Tests (MDT) and Network Data Analytics Function (NWDAF) to facilitate data collection intelligently and with minimum power consumption.

5. Recommendations on near-term Federal activities to make progress towards anything identified in responses 1–4.

In response to question 3, we suggest that O-RAN is a crucial enabler for spectrum sharing and that funds allocated for R&D be used to perfect this critical application of O-RAN. This could be done quickly with funds that are already appropriated.

6. Recommendations on a process to refine and enhance the R&D plan on an ongoing basis.

A long-term plan is needed for how the spectrum will be transitioned and for researchers to have enough time to apply their creativity to the bands in question. Each band is unique due to its legacy users and propagation characteristics. Developing a long-term framework for implementing spectrum sharing, such as using the O-RAN framework, will also quicken the pace and provide a platform for researchers to evaluate their innovations.

7. Terminology and definitions relevant for spectrum R&D.

NTIA should consider creating and publicizing a glossary of terms that represents the consensus of the research community.

8. Other topics.

Workforce training is important to ensure that spectrum is used and managed effectively. Many spectrum managers are reaching retirement age, and a new contingent of spectrum managers is needed. There should be an overlap between the new and older generations to be effective. This means that workforce development activities must commence as soon as possible. Typically, workforce development is NSF's responsibility, and while it can lead to such an effort, other agencies must be highly involved in it.

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