NITRD Wireless Spectrum R&D Senior Steering Group Workshop II Report:

Federal Government and Private Sector Collaboration on Research Development, Experimentation, and Testing of Innovative Spectrum Sharing Technologies

Organized by the Wireless Spectrum Research and Development Senior Steering Group Under the NITRD Program

January 17-18, 2012

Berkeley Wireless Research Center
2108 Allston Way, 2nd Floor
Berkeley, CA 94704

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Executive Summary

On January 17th-18th, 2012, the WSRD SSG hosted a second workshop at the Berkeley Wireless Research Center in Berkeley, California, to further explore the options and challenges in establishing a national testing facility. The workshop provided an opportunity for technical experts and interested stakeholders from industry, government, and academia to collaboratively discuss the needs and requirements for a national-level spectrum research, development, experimentation, and demonstration environment. A preliminary inventory of existing test facilities was presented and representatives were available to answer questions regarding their facility and contribute to the discussion. The workshop considered spectrum sharing testing scenarios in a variety of sectors, such as public safety, military mobile command and control, Doppler weather radar, and maritime air traffic control, with a goal of identifying "high-risk high-reward" research and development opportunities that could benefit from a national level experimentation and demonstration capability.

The workshop used a series of four interactive discussion sessions to move the concept from hypothesis to the identification of concrete next steps. The following summarizes the findings of the four sessions:

- **Goal and Purpose:** The primary goal of a national testing environment for spectrum sharing is to accelerate the adoption of the next generation of wireless technology through experimentation aimed at validating performance and developing national and international standards, policies, and rulemaking. These facilities will reduce time and cost of development by providing realistic conditions in which to design, build, and test spectrum sharing technologies and thereby help build the business case for industry investors and entrepreneurs.
- **Current State:** Testing against an incumbent in a licensed scenario is currently not practical. This type of testing is extremely expensive due to difficulties in accessing suitable testing facilities, a lack of standards for testing, and the lack of a system for information exchange. Even knowing what facilities exist, are available for use, and contact information to do so, is cited as a problem.
- **Desired Characteristics:** In order to build trust among stakeholders and provide the technical validation necessary to drive widespread adoption of spectrum sharing technologies and practices, a national level testing environment should provide services and support in the following general areas: entrant network, entrant capacity, interference to incumbents, requisite equipment and sites (indoor, outdoor, simulation), and a suitable network architecture and organizational structure.
- **Next Steps:** It is premature to define technical specifications, but federal leadership could help with problems such as establishing standard testing scenarios, developing clear security procedures, and facilitating an information exchange.

Overall, this workshop confirmed the previous endorsement from both the public and private sectors that a proper testing environment for spectrum sharing technologies is critically important for achieving their full deployment, and, that these testing facilities will need to be comprehensive and robust to meet the scalability and complexity of the various spectral environments.

The participants also suggested a basic framework for developing such a resource. The outcomes contained in this report emphasize the value of, and establish the baseline characteristics for, a federated, national-level research and development testing environment. While the near-term goal will be to establish a pilot facility, the long-term goal is to build upon the pilot program to achieve a national test enterprise through which information, lessons-learned, and infrastructure can be shared and re-used to facilitate ongoing innovation.

Background and Workshop Description

In June, 2010, the President issued a memorandum, *Unleashing the Wireless Broadband Revolution,*[1] which identified the importance of providing adequate spectrum "to support the forthcoming myriad of wireless devices, networks, and applications that can drive the new economy." To help "wring abundance from scarcity," the memorandum called upon the Secretary of Commerce to "create and implement a plan to facilitate research, development, experimentation, and testing by researchers to explore innovative spectrum-sharing technologies…"

In response to this charge, the National Information Technology Research and Development (NITRD) program created the Wireless Spectrum Research and Development Senior Steering Group (WSRD SSG), to bring together representatives of all of the Federal agencies that conduct or support spectrum-related research and development. Upon its formation in November, 2010, and at the urging of the U.S. Chief Technology Officer, the WSRD SSG quickly recognized the importance of reaching out to private industry and academia as an avenue for supporting national-level wireless R&D investments.

Workshop II, held on January 17-18th in Berkeley, California provided an opportunity for technical experts and interested stakeholders to build on the outcomes of Workshop I[2] and focus on the concept of creating a national-level testing environment for spectrum research, development, experimentation, and demonstration that would be available to researchers from all sectors. The intent of the workshop was to identify "high-risk high-reward" opportunities that would warrant a national effort in this area.

The outcomes contained in this report include information on what the goal and purpose of such a testing environment would be, what the current state of our available testing facilities is, what the desired characteristics and capabilities are, and what steps can be taken by the federal government and the WSRD SSG to facilitate the development of such a testing resource.

- **Goal and Purpose:** The primary goal of a national testing environment for spectrum sharing is to accelerate the adoption of the next generation of wireless technology through experimentation aimed at validating performance and developing national and international standards, policies, and rulemaking. These facilities will reduce time and cost of development by providing realistic conditions in which to design, build, and test spectrum sharing technologies and thereby help build the business case for industry investors and entrepreneurs.
- **Current State:** Testing against an incumbent in a licensed scenario is currently not practical. This type of testing is extremely expensive due to difficulties in accessing suitable

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[1] http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution , June 10, 2010

[2] In July, 2011, the WSRD SSG held Workshop I to engage key representatives from the industrial and academic communities. The workshop was hosted at the U.S. Department of Commerce's facility in Boulder, Colorado, and was held in conjunction with the National Telecommunications and Information Administration's (NTIA's) International Symposium on Advanced Radio Technologies.. During the workshop, one of the many takeaways from wireless industry participants was the critical need for a national wireless testing capability for validating spectrum sharing technologies under realistic and controlled conditions. They emphasized the value proposition that such a facility would have on a diversity of users - such as testing spectrum sharing technologies among disparate systems - and cited this concept as being a key enabler to future wireless innovation.

testing facilities, a lack of standards for testing, and the lack of a system for information exchange. Even knowing what facilities exist, are available for use, and contact information to do so, is cited as a problem.

- **Desired Characteristics:** In order to build trust among stakeholders and provide the technical validation necessary to drive widespread adoption of spectrum sharing technologies and practices, a national level testing environment should provide services and support in the following general areas: entrant network, entrant capacity, interference to incumbents, requisite equipment and sites (indoor, outdoor, simulation), and a suitable network architecture and organizational structure.
- **Next Steps:** It is premature to define technical specifications, but federal leadership could help with problems such as establishing standard testing scenarios, developing clear security procedures, and facilitating an information exchange.

Goal and Purpose of a National Testing Environment

The primary goal of a national testing environment for spectrum sharing is to accelerate the adoption of the next generation of wireless technology through experimentation aimed at validating performance and developing national and international standards, policies, and rulemaking. Proper testing and demonstration facilities will establish trust among stakeholders by providing a repeatable and reliable testing environment to demonstrate activities such as ubiquitous sensing and dynamic access. These facilities will reduce time and cost of development by providing realistic environments in which to design, build, and test spectrum sharing technologies and thereby help develop the business case for industry investors and entrepreneurs.

Incentivizing spectrum sharing involves building trust, sharing experimentation costs, developing core technology in realistic testing environments, and providing support for economic business models. These critical needs can be satisfied by a national level facility that is shared by researchers from the private, academic, and government sectors. Trust can be built between stakeholders by demonstrating secure sharing scenarios that identify a system's design and configuration constraints and help reveal optimal solutions. Realistic outdoor environments that recreate the expected usage and interference of a variety of scenarios such as urban to suburban to rural, from rush hour to midnight, and from mundane activities to emergencies, are expensive and difficult to create. If designed correctly, they can accommodate an array of testing scenarios and provide consistent, recordable, and reproducible results that will allow for sound investment decisions across both the public and private sectors.

Key attributes and requirements that warrant a national level approach: It is understood that spectrum is a valuable national resource, and that it is vital to the functioning of federal, state, and local governments and of the private industry. However, to justify federal government involvement, there is a need to identify "high-risk high-reward" R&D opportunities that would benefit from a national level effort. Workshop participants agreed that *any one of the following characteristics* would justify this level of public-private collaboration:

- Testing that is too expensive for most researchers and developers to afford;
- Testing that engages classified or "close hold" government incumbent systems;
- Testing that requires specialized information, expertise and standardization in spectrum use, test plans, metrics, data analysis, etc. (information that facilitates development or makes results transparent, credible, and understandable by regulators); or
- Testing that addresses issues that are of national interest beyond the interest of an individual entity, organization, or industry.

This type of testing environment must insure the development of robust technologies through roaming, inter-working, and interoperability testing. Testing environments that are application or industry focused can help establish the constraints across the different communication layers and demonstrate the feasibility of spectrum sharing for specific applications. For example, participants from the automotive industry expressed interest in large-scale outdoor environments to test intelligent vehicle transportation technologies in a spectrum sharing environment. They suggested that large-scale national testing environments would be of great value to the transportation industry as a whole.

Conversely, small-scale testing environments that provide simulation, emulation, or small RF anechoic chambers remain important. The repeatability of the tests in controlled environments can provide greater fidelity for particular testing scenarios and can identify problems early in the development cycle when they are still economical to resolve.

A variety of testing environment types and sizes are necessary in the R&D lifecycle that starts with a great idea and ends with wide acceptance of a new technology; but not all of them need to be part of a national testing environment approach.

It should be noted that that there is disagreement as to whether a national level testing environment would be sufficiently justified if it were used only as a "sand box" (technical exploration) or for "decision making" (policy, regulatory and business decisions) without also having one of the characteristics described above.

Once the need for such a facility was established, the next step was to examine the current state of available testing environments.

Examining the Current State of Testing Environments

Despite significant research on innovative ways to share spectrum, testing environments that demonstrate the true efficacy of the resulting technologies don't currently exist in the United States[3]. To entice investors to invest, manufacturers to build, and carriers to deploy, new networks and devices must be used in realistic environments that present all the potential pitfalls and hazards of not enjoying exclusive spectrum rights.

Spectrum sharing is used successfully in areas such as unlicensed spectrum, within a given provider's network, and peripherally with agreements between partner networks. But testing against an incumbent in a licensed scenario remains economically unfeasible. Even with proven technology, the costs of transitioning business models from the single user lease model to the shared model are not trivial. Communication carriers need technology testing and analysis to prove that viable and trustworthy sharing is possible before committing to a new business model, and venture capitalists depend on advanced testing to help determine a technology's market readiness.

Previous studies including an inquiry at the White House Office of Science and Technology Policy in 2010-11[4], input received at the Federal Communications Commission during the writing of the National Broadband Plan in 2009-10[5], and a workshop conducted by the NSF in 2010[6], reveal important questions that can be addressed by testing environments at various stages in the research and development process. They also reveal two points along the pipeline where the lack of testing environments is particularly problematic. One is the transition from advanced research to development when the need to instill *confidence that sharing can benefit users of new technology without harming users of existing technology* is critical. The second waypoint is mid-way through the research process, when initial test results encourage researchers to ramp up activities, but doing so is too costly for individual labs to handle on their own.

Referring to the WSRD inventory of available federal testing environments7, representatives from Idaho National Labs (INL), the Institute for Telecommunication Sciences (ITS), Oak Ridge National Laboratory, the Aberdeen Proving Ground, and other facilities, contributed additional details on their respective capabilities. While the workshop concluded that it was premature to identify and address specific capability gaps, there was consensus in three general areas: the need to improve the accessibility to existing testing environments; the need to develop standards by which to judge the credibility of new technologies and systems; and the acknowledgment that multiple testing facilities will be necessary.

***Accessibility of testing environments*:** According to the testing environment inventory, ten federally operated testing environments are available to commercial companies, academic researchers, and

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[3] Industry stakeholders are quick to point out that large-scale next generation wireless testing environments currently exist in Europe and Asia and will likely impact technology development and the resulting economic prospects in those regions.

[4] Jon Peha organized and led an inquiry at the White House Office of Science and Technology Policy on Wireless Testbeds in 2010-2011 and contributed his findings at this workshop. For more information you may contact Jon at peha@stanfordalumni.org .

[5] National Broadband Plan, primarily Chapter 7. http://www.broadband.gov/plan

[6] For information on the 2010 NSF Workshop please go to http://www.kennesaw.edu/ogc/winteb/winteb.html.

[7] WSRD Testing environment inventory, http://www.nitrd.gov/Subcommittee/wsrd/WSRDTestBedInventory2012.pdf

other government agencies. Yet, no workshop participant, including those working for the government, had experience with a government testing environment that did not belong to his or her own organization. The reasons mentioned included:

- *Business model:* No clear business model exists today that provides incentives for developers or incumbents to utilize a testing environment other than their own, or provides a funding mechanism for participation in a "collaborative" testing environment.
- *Security:* Existing testing environment owners noted that access could be made available, but issues including privacy, intellectual property, security (and classified information) would need to be addressed. Some of the potential barriers include:
    - Whether non-government personnel (including foreign nationals) would be allowed onto government facilities,
    - Whether the testing environment could get sufficient information on government systems, including specific signals (or reasonable facsimiles) to enable useful testing, and
    - The ease with which one can travel to these sites, or run experiments remotely over a high-speed network.
- *Information Exchange*: interested parties lack information about what testing environments exist and what they have to offer. Specifically:
    - Although the testing environment inventory is a beginning it is incomplete; additional facilities need to be identified and included;
    - Information about current testing environments is fragmented with no overarching information, strategy, or procedures—even something as simple as a roster of points of contact for existing testing environments, would be helpful;
    - Information about current incumbent spectrum use is not available;
    - Information exchange between testing facilities is difficult or nonexistent (and as noted below, a standard set of data available at the beginning and end of a test would make such information flow more effective)

Standards: A major impediment to both leveraging existing resources and effectively utilizing any new capabilities is a lack of standardization. Standards that are needed include:

- Standardized scenarios,
- A standardized way to define tests and experiments and results (necessary to facilitate the comparison and assimilation of information derived from different test activities),
- A standard definition of harmful versus acceptable interference or a definition of success versus failure of a test (although it was noted that this issue can be resolved on a scenario-by-scenario basis).

Multiple Testing Facilities: Even for a single technology and a single form of spectrum sharing, a diverse set of testing environments and capabilities is necessary to meet the needs of various stages of research and development. Where academic labs exist, they are typically effective for early-stage research that does not require large-scale or costly equipment. Commercial labs are effective for some kinds of experimentation, such as testing equipment from a single vendor. Government laboratories such as the Idaho National Labs with large geographically and spectrally isolated areas can be useful for late stage outdoor testing. There is also the need to experiment with real systems where they exist today, for example, real airports and air traffic control systems could be used to support research with radar interference when the airport is closed. In this case, mobile testing equipment could be moved to the system of interest. Cities could be used for experiments involving broadcast TV if signals could be captured and replayed back at the lab. Oak Ridge uses this capability today, but new ways to capture signals and make them available to researchers in government, commercial, and academic laboratories are needed.

Desired Characteristics of a National Testing Environment

With the understanding that incumbent and new entrant systems will dictate requisite components of a proposed testing environment, workshop participants considered specific spectrum sharing scenarios (see Appendix A for notes on these scenarios) to discuss what types of desired characteristics are needed. Participants attempted to identify the infrastructure, tools, architecture, facilities, usage mode, etc. In order to build trust among stakeholders and provide the technical validation necessary to drive widespread adoption of spectrum sharing technologies and practices, the workshop concluded that a national level testing environment should offer the following services and support:

Entrant network support:

- Entrant Radio: Make it easier for researchers to introduce new technology into complex entrant systems like LTE. Provide items such as reference designs, open architecture and systems, improved programmable radios and research platforms, and a software support team.
- Entrant Scalability: Provide a large number of networked entrant systems to test scalability. Note that the need for national support (funding) depends on scale and market, and the group recognized that it is not clear how such support would be funded.

Entrant capacity test support:

- No Incumbent Environment: Provide an environment (bands without incumbent systems) where new spectrum rules and approaches can be explored for "Next Generation" system development. The focus can be on capacity, deployment cost, etc.
- Unified Capacity Testing: Provide a controlled environment to make it easier for stakeholders to understand and trust the results. This should include requirements, test plans, data collection plans, parameter definitions, unified propagation models, example data analysis, etc.
- Interference to incumbents test support
- Interference and Service Impact Models: Includes interference protection criteria (operational and user impacts).
- Instrumented Incumbents: Provide realistic and instrumented present day incumbent systems for interference susceptibility testing (both to entrants and incumbents).
- Instrumented Spectrum Band Incumbents: Provide a comprehensive set of incumbent systems within a spectrum band and that accounts for potential changes in incumbent use, background signals, and geographic and environmental factors.
- Spectrum Use Information: Provide information on incumbent systems, recorded spectrum occupancy, recorded incumbent waveforms, etc. Such information could be incorporated in a "toy model" of the incumbent system useful for analysis and simulations.
- Non-Interference Sharing Environment: Provide an environment where new spectrum rules and approaches can be explored with incumbent systems. The primary focus here would be on rights, enforcement, and sharing arrangements, in which the primary service may continue or has the right to continue to evolve. The focus is not on RF interference, which is addressed in other test environments.

- Unified Interference Testing: Provide a controlled environment to make it easier for regulators to understand and trust the results. Testing protocols would include documentation of requirements, test plans, data collection plans, parameter definitions, unified propagation models, example data analysis, etc.

Equipment and test site support:

- Simulation and Emulation: Provide a computer-based test environment where disparate algorithms, protocols, and transceiver software modules can be exposed to different radio environments, signals, and signal levels. Test bed support would include background spectrum measurement, traffic injection, data logging, and so on, and the staff to operate the simulation capabilities.
- Indoor Testing: Provide a conducted test environment which includes RF couplers, computer controlled attenuators, background spectrum measurement equipment, time/space/position instrumentation, traffic injection, data logging, etc., and the staff to operate the test equipment.
- Outdoor Testing: Provide a test environment that would require land, antennas, background spectrum measurement, time/space/position instrumentation, traffic injection, data logging, etc., and the staff to operate the test facility.
- Data Archiving and Dissemination

Network Architecture and Organizational Structure:

- A connected testing environment architecture that supports multiple verticals and allows people to move between and within the testing environment(s).
- A flexible architecture that allows experimentation across software layers, controlled testing between certain number of users, and some uncontrolled testing as well.
- An architecture and organizational structure that caters to the two key stakeholders: (1) those who currently participate in spectrum sharing, and (2) venture capitalists that are willing to invest in these technologies.
- An organizational structure that can be replicated easily at different locations to achieve repeatable results that can be generalized across multiple bands.
- An organizational structure that can be adapted to take a short-term, mid-term, or long-term perspective.

Next Steps

A national spectrum sharing testing and experimental environment is needed that allows flexibility, provides repeatability, standardizes requirements, and is economically sound. One single testing environment will not meet the requirements, but a federated testing environment approach could be effective and could leverage existing capabilities. The "federated" concept includes a set of testing locations with diverse but complimentary facilities in which assets and information could be shared as part of an overall coherent strategy.

It is premature to define technical specifications, but federal leadership could help with problems such as establishing standard testing scenarios, developing clear security procedures, and facilitating an information exchange. While the federal government may not lead standardization efforts, they can play a key role in such things as creating a standards setting process and identifying the key standards bodies[8]. To make progress toward improving experimental environments, the WSRD SSG should propose a budget to build and sustain such a facility and identify a manageable problem to focus on as a pilot project.[9]

Most of these "next steps" can be addressed immediately and in many cases, within existing budgets. The exception may be establishing standards, which can require a significant investment of time and money. However, the return on investment that can be realized by leveraging existing testing environment resources and building a sound foundation for efficient and effective testing environment construction in the future will be significant.

Conclusion

Overall, this workshop confirmed the previous endorsement from both the public and private sectors that a proper testing environment for spectrum sharing technologies is critically important for achieving their full deployment, and, that these testing facilities will need to be comprehensive and robust to meet the scalability and complexity of the various spectral environments.

The participants also suggested a basic framework for developing such a resource. The outcomes contained in this report emphasize the value of, and establish the baseline characteristics for, a federated, national-level research and development testing environment. While the near-term goal will be to establish a pilot facility, the long-term goal is to build upon the pilot program to achieve a national test enterprise through which information, lessons-learned, and infrastructure can be shared and re-used to facilitate ongoing innovation.

[8] For example: 3GPP www.3gpp.org or P1900 http://grouper.ieee.org/groups/emc/emc/ieee_emcs_-_sdcom/P1900-X_Stds/ieee_emcs_-_p1900-x_main.htm .
[9] Aneesh Chopra identified public safety as a possible near-term focus problem in his keynote address.

Appendix A: Spectrum Sharing Scenarios

The following scenarios were explored by dividing the workshop participants into separate working groups, having them explore the scenario, identify the test requirements, and report back to the larger group and field a question and answer session.

WG 1: Spectrum pooling for fixed public safety infrastructure in an urban environment and for sharing idle spectrum with the private sector

Description: The incumbent system is land mobile radio, where fixed base stations (approximately 10 for a large metropolitan area) communicate with handheld or vehicular subscriber units. Mobile units also communicate directly with each other. Public safety (PS) communications include safety of life and law enforcement and must not be compromised. PS users might occupy half of the available channels at any one time; however, average channel occupancy is on the order of 5%. Further, PS is a fragmented patchwork of segregated systems due to a legacy of PS entities compelled (for well-justified reasons) to build their own infrastructure. Spectrum pooling has been suggested as a means to consolidate PS systems, to improve interoperability, expand PS wireless capabilities, and to enable opportunistic access by commercial entities to unused PS channels. *WG1 focused on sharing scenarios involving different participants (e.g., PS entity 1 with PS entity 2 and PS entity 1 with a service provider or unlicensed end user) and different objects (spectrum, networks, services).*

Identified test requirements:

- Testing is needed for decision making, gaining consensus within the PS community, validating reliability to foster trust, and bridging the gap between blackboard and real world.
- Types of participants sharing and objects to be shared ultimately define the testing approach and requirements.
- Testing capabilities are needed to assess different stages of development ranging from simulation to at-scale demonstration.
- Technical questions that testing might address when sharing with commercial users: How fast can commercial users exit from spectrum if at all? Is there a viable business model for PS spectrum pooling?
- PS requires real-user tests in normal and emergency circumstances. Emergency tests could involve 100s of end-user units, and the public will be essential for extreme case testing.
- NextGen PS capabilities would involve testing new process/mission effectiveness (relevance of legacy), core (voice) versus new/additional (video) functionality, evolvability (extensibility, scalability), and capacity (to assess improved spectral and cost efficiency).
- Idea: Mobile testing infrastructure to perform tests in different cities.
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WG 2: Spectrum pooling for military mobile command-and-control operations (and training) that coordinates land-based, shipborne, and airborne units

Description: In a tactical military environment, system characteristics vary widely in terms of system types (mobile communications, radar, point-to-point backhaul), function (voice, data, target id/tracking, imaging), platform (ground-based, shipborne, airborne), and technical parameters (frequency, bandwidth, receiver sensitivity/vulnerability). System characteristics are sensitive. DOD is working toward pooling spectrum assignments of the different services and coordinating spectrum usage in space, time, and frequency to prevent different military operations from causing interference to one another. It is best to train the way you fight, so lifelike training missions are routinely performed at domestic military bases. Select military systems also occupy spectrum allocated to commercial uses, which must also be coordinated to prevent interference.

Identified test requirements:

- Testing is needed to prove to agency stakeholders that sharing is feasible without causing harmful interference to legacy systems (which will continue to exist for a long time).
- Preliminary testing via simulation and laboratory equipment can be used as a filter to weed out less viable ideas and save cost.
- Prototype testing in simplified environments can be used to gain confidence before moving to more expensive field tests.
- New military technologies must be demonstrated in a relevant operational environment, e.g., congested or contested environments. Pristine environments do not prove enough. Military test ranges are available for this purpose.
- Various use cases should be tested, e.g., urban w dense civilian population, rural w sparse civilian population, various scenarios with agency personnel and systems. To do this, DOD may need permission from regulators to use commercial spectrum.
- Monitoring capabilities would be required for field tests to help interpret results and establish confidence that commercial spectrum is not being used in an unexpected manner.

WG 3: Primary-secondary sharing of terminal Doppler weather radar spectrum

Description: The Federal Aviation Administration (FAA) manages 45 Terminal Doppler Weather Radar (TDWR) systems at large airports vulnerable to windshear. TDWR is a wind shear detection system used to increase the safety of the national airspace. It is capable of detecting hazardous weather up to 20 nautical miles. TDWR system performance must not be compromised by interference. TDWR systems operate continuously 24/7/365 with high gain antennas and sensitive receivers. Transmitters and receivers are fixed and co-located. Primary-secondary sharing has been suggested as a means to enable opportunistic access to TDWR spectrum in locations that would not cause interference to TDWR. *WG3 focused on a sensing DSA approach supplemented by spectrum sharing database (SSD).*

Identified test requirements:

- Testing is needed for concept development in a controlled environment until confidence is established.
- For concept development, tests are needed to measure (1) secondary sensing functionality at MAC layer, (2) what operational practices (e.g., channel-availability check) cause less interference, (3) how SSD might be used to reduce/eliminate interference, and (4) background scanning of wide spectrum range once secondary devices are turned on.
- Tests against operational TDWR are required to develop interference protection criteria based on operator experience of display strobes, i.e., blind spots where TDWR cannot see weather. TDWR systems are large/expensive, which makes it necessary to utilize existing assets when possible (e.g., at night when airports are closed or at available test facilities).
- At the prototype stage, there should be comprehensive testing around use cases – in-building fixed outdoor fixed, mobile, point-to-point, and point-to-multipoint.
- Integrated system testing might involve SSD with networked devices. Questions – Can SSD include "kill switch" to control legacy secondary devices? How would that work? What sensing capabilities are needed, if any? Could TV whitespace work be leveraged?

- System integration tests must address adjacent band issues, topology problems, scalability, and aggregate interference effects. Test facility should record node locations in real-time and in a centralized location. For repeatable results, it is not a good plan to set up and tear down test facility.
- Idea: Industry pays for testing through fee mechanism. Perhaps government subsidizes small innovators so they are not squeezed out.

WG 4: Primary-secondary sharing of maritime air traffic control radar spectrum

Description: Shipborne military air traffic control (ATC) radar installations on aircraft carriers can be located anywhere throughout U.S. littoral waters and navigable rivers. Radar characteristics are sensitive and the systems perform safety of life missions that must not be compromised. Operations are time-varying. These are pulsed radar systems with approximately 10 MHz bandwidths within a 100 MHz allocation. ATC radar systems are not typically operated until the ship is more than100 nautical miles offshore. Primary-secondary sharing has been suggested as a means to enable opportunistic access to military ATC spectrum in locations that would not cause interference to the radar systems. *WG4 focused on a spectrum sharing database (SSD) DSA approach.*

Identified test requirements:

- Testing is needed to help regulators (and incumbents) determine if maritime ATC bandsharing can work and support the development of rules/regulations/infrastructure (when practical).
- Testing should help regulations evolve to accommodate new technologies by supporting incremental change management and quality assurance in changes to architecture. Currently, the incumbent posture is to define exclusion zones along the coast to avoid jamming commercial systems. Testing could support development and validations of secondary technology (e.g., error correction coding) that mitigates pulsed interference as well as validation of exclusion zones.
- For prototype development, there was a need identified for testing to focus on and develop critical subsystems of the overall architecture. In this case study, testing is needed to explore security issues related to SSD that tracks all aircraft carrier locations. Hence, secure access mechanisms and schemes that somehow cloak locations should be investigated and thoroughly tested.
- For system integration, SSD could be developed to change/respond gracefully to increasing aggregate effects. Testing could be leveraged to assure that secondary devices operate according to policy updates from SSD. Also, testing is needed for regulators to understand limits set by aggregate interference.

WG 5: Commons: 100 MHz of unlicensed spectrum

Description: In a commons environment, spectrum is allocated/assigned on an unlicensed basis where users have equal opportunity to use the spectrum as long as certain technical limits are respected, e.g., low transmission power. Unlicensed spectrum is decentralized and barriers to entry are minimal, i.e., there are no license payments or central control for users. Traditional uses of unlicensed spectrum include cordless phones, baby monitors, garage door openers, Wi-Fi, and ultrawideband. It has been recommended that rules of etiquette are needed in unlicensed spectrum. *WG5 focused on testing devices that don't exist, for purposes not yet known, for performance requirements not yet defined.*

Identified test requirements:

- Testing is needed to support rulemaking by testing different constraints on devices.

- Testing can help validate proposed rules of etiquette and appropriate conformance tests.
- For technology development, experimental test facility could be used to emulate different environments and test device behavior and performance.
- Testing facility should offer indoor and outdoor environments, reprogrammable higher layers in the ISO stack, arbitrary waveforms, ability to plug-in existing devices (e.g., Bluetooth), and ability to capture results and replay later.
- To address scalability, testing facility should be able to accommodate 1000's of devices

Appendix B: Acknowledgements

NITRD and its WSRD SSG thank the workshop participants for their time and effort in providing valuable insight on such a worthy cause. This was the second in a planned series of workshops organized to engage federal and non-federal communities in furthering the goal of a nationwide environment of shared spectrum access. We look forward to your continued support on future workshops as we collectively endeavor to develop an environment that serves as a national venue to test and demonstrate innovative spectrum sharing technologies.

The WSRD SSG would also like to thank the following individuals who participated on the planning committee for the workshop, helped moderate the sessions, and/or contributed to this report.

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Strategic Spectrum Planning and Reform Division Chief
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Andrew Clegg
Program Manager,
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Michael Cotton
Electronics Engineer
Institute for Telecommunication Sciences
National Telecommunications and Information Administration

Lawrence Goldberg
Senior Engineering Advisor
Electrical, Communications and Cyber Systems Division
Directorate for Engineering
National Science Foundation

Joseph Heaps
Policy Advisor, Communications and Radio Frequency Spectrum issues
Manager, Communications Technology Portfolio
National Institute of Justice
Office of Justice Programs
U.S. Department of Justice

John Hunter
Telecommunications Specialist
Strategic Planning Division
Office of Spectrum Management
National Telecommunications and Information Administration
US Dept. of Commerce

Paul Kolodzy
Telecommunications Consultant
Kolodzy Consulting, LLC

Mark McHenry
President and CTO
Shared Spectrum Company

Nancy Merritt
Senior Policy Advisor
National Institute of Justice
U.S. Department of Justice

Eric Nelson
Supervisory Electronics Engineer
Institute for Telecommunication Sciences
National Telecommunications and Information Administration

Jon Peha
Professor, Carnegie Mellon University
Dept. of Electrical & Computer Engineering and Dept. of Engineering & Public Policy

Rangam Subramanian
Chief Wireless Technology & Business Strategy
National & Homeland Security Directorate
Idaho National Laboratory

Staff:
Wendy Wigen
WSRD Coordinator
National Coordination Office
Networking and Information Technology R&D