Response to Phase II/II Testing

Dr. Juan D. Deaton, Ph.D.

April 2012

1 Introduction

Wireless spectrum is becoming a vital and scarce resource due to the increase development and deployment of mobile device and their associated applications. Dynamic Spectrum Access (DSA) represents one of the few ways that our nation can be able cope with our anticipated spectrum crisis[1]. Wireless communications is a key tool in today's economy and efficient use of this spectrum is paramount. I commend the National Telecommunications and Information Administration (NTIA) and associated vendors for assuming the arduous task in testing these new devices and techniques, which are critical for the advancement of policy and technology of future DSA systems. Additionally, I am appreciative of the opportunity to provide feedback to the NTIA for phase II/III test plans. The overall purpose of this feedback is to provide insight to insure that these tests proceed efficiently and effectively as possible.

Before beginning my feedback, I would like introduce myself and my associated qualifications. I've spent my entire career working with wireless systems. After completing my undergraduate degree in EE at University of Idaho in 2001, I worked for Motorola's CDMA Networks division for 5 years where I wrote, developed, and executed system requirements, system tests, and beta deployments for commercial systems. In 2006, I took a cellular systems engineer position at the Idaho National Lab (INL)'s Next Generation Wireless Test Bed (NGWTB), where I did systems research on airborne wireless systems[2]. I've recently published research in DSA systems, specifically analyzing the effects of DSA in next generation networks[3], utility of spectrum access policies[4], and graduated with my Doctorate in Electrical and Computer Engineering

[1] Federal Communications Commission. "The Benefits Of Additional Spectrum". In: *U OBI Technical Paper* 6 (2010).

[2] J.D. Deaton. "High Altitude Platforms for Disaster Recovery: Capabilities, Strategies, and Techniques for Emergency Telecommunications". In: *EURASIP Journal on Wireless Communications and Networking* (2008).

[3] J.D. Deaton, R.E. Irwin, and L.A. DaSilva. "The Effects of a Dynamic Spectrum Access Overlay in LTE-Advanced Networks". In: *IEEE 6th International Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySPAN)* (2011).

[4] Juan D. Deaton, Christian Wernz, and Luiz A. DaSilva. "Decision Analysis of Dynamic Spectrum Access Rules ". In: *IEEE Conference on Global Communication (GLOBECOM)* (2011).

from Virginia Tech. I believe that my experience with testing in cellular networks in combination with my recent research provides me ability to provide valid feedback. Furthermore, I come to you as an independent researcher interested in only providing needed contributions to help the NTIA accomplish its mission. The comments I provide mine alone and do not reflect the view points of the my employer.

I use a *as if I was testing* methodology in reviewing the plan, i.e., as a rule I ask, "If I was given the test plan how well would I be able to execute the plan." I realize that some details of tests will be vendor specific and others covered by intellectual protections. However, I argue that the more specific and precise the test plan can be, the more efficient and effective will actually occur. In my comments, I addressed each section of the test plan with specific comments, which you have provided[5]. In these comments, I hope to provide more detail to the existing tests and propose questions which will add precision into further revisions of the plan.

After reviewing the test plan, I would like to summarize my general observations before continuing into specifics. In my experience with testing, testing was usually performed with respect to specific number requirements each defining a component of functionality. These requirements would provide the pass/fail criteria for the tests. In the following test plans, I do not see any *requirements* to speak of. As a result, the pass/fail criteria is vague and ambiguous. In many ways these *tests*, are perhaps more *experiments*. Thus, my main recommendation is for the NTIA is to either produce a requirements document to specify precise pass/fail criteria for all tests or produce an analytical/simulated scenarios for experiments and compare to measured results. Finally, I would like to emphasize how important precise procedures and results of these tests are for the DSA research community. I would also encourage the NTIA/vendors to consider publishing and discussing these results at the following ISART or IEEE International Symposium on Dynamic Spectrum Access Networks (DySPAN) conferences.

2 Phase II Comments

2.1 Channel Availability Check

In Phase II, I understand the objective to be to asses the Device Under Test (DUT) behavior in the presence of live Land Mobile Radio (LMR) systems, while not interfering with the existing systems. I also provide Figure 1 for reference in my discussion of this procedure. Figure 1, is my illustration of the channel availability check. In Figure 1, the DUT, at time t_sense begins to sense when the spectrum is available, after the sensing is completed t_calc is used to determine if the spectrum channels are free, and t_report to report these findings. In parallel, the Vector Signal Analyzer (VSA) will be taking samples of the set of spectrum channels that are being evaluated and report its own sensing data. Once both have completed sensing, comparing VSA at the specific times t_sense, t_calc, and t_report is done at some offline calculation that I name the *Metric Server* which produces the Receiver Operating Characteristics (ROC).

[5] National Telecommunications and Information Administration. “Phase II/III Test Plan”. In: *Spectrum Sharing Innovation Test-Bed Pilot Program* (2012).

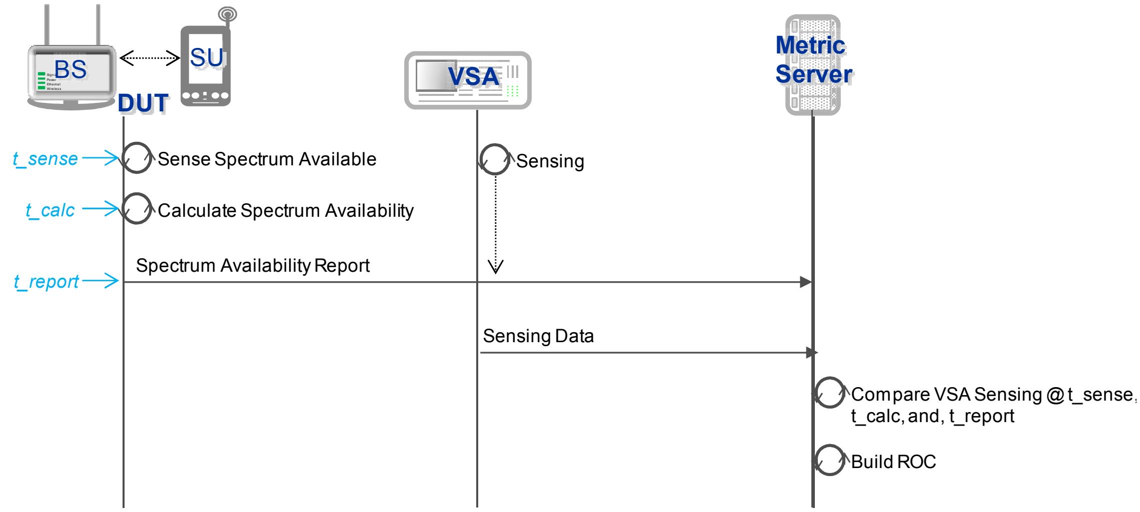

Figure 1: Illustration of Phase II channel availability check.

With in the scope of this illustration, there are several questions that I have to timing. First, how will the VSA be synchronized with the DUT, such that the appropriate measurements can be compared? Second, if these devices are synchronized how will the measured samples be taken for comparison to the output of the DUT, i.e., are they averaged, taken at an instantaneous moment? Third, if the samples indicate an available spectrum channel at t_report, what is the probability that spectrum availability has changed since t_sense? I think these questions are vitally important, since LMR activity may or may not be controlled. Further, if the LMR radios can be precisely controlled could the signal be produced say, mid-point between t_sense and t_calc?

There are several other questions with regard to spectrum channel availability, which are not obvious from the test plan. First, when is a channel declared available through the measurements from the VSA? I realize this question can diverge into an entire policy and technical discussion, but for the purposes of this test how do the DUT and VSA agree on channel availability? Of course, this question has roots into the previous questions with regards to timing, samples, and also thresholds. Finally, if the VSA is considered more accurate or providing higher fidelity samples or data, to what degree is it more accurate than the DUT? Should the VSA be more sensitive than an LMR for the test to be successfully executed?

2.2 In-service monitoring

For the discussion on in-service monitoring I've provided Figure 2, which illustrates this procedure. In this procedure, consider time t_pri_call as the time a primary user issues and call to its network. Additionally, consider the time t_adjust as the time the DUT stops using the frequency of the primary call. Clearly, during the time between t_pri_call and t_adjust the DUT is interfering with the LMR if close enough. Certainly, this time period should be one of the performance metrics. With regards to the LMR system, is it possible to obtain some type

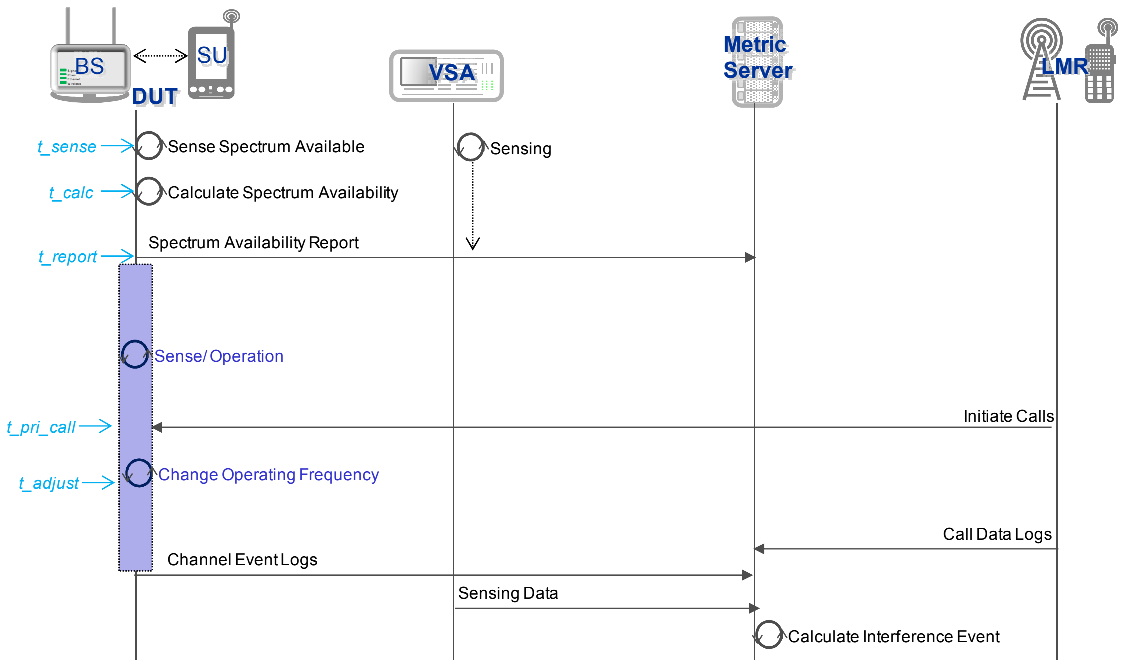

Figure 2: Illustration of Phase II in-service.

of call data logs, to verify that calls were made during specific time periods? This information may not show interference events, but may provide coarse information to the time close occurrence of real events recorded by the system. Additionally, it may be possible to configure the system performance pegs, to report information that may be useful during the testing phase. Finally, is it possible to have another automated device, possibly the metric server, to control the actual LMR transmissions and thus collect the needed metrics? In any case, I believe that these metrics will be important in calculating the interference events.

2.3 Automation

Assuming that most the questions I've posed have been answered. I end comments on Phase II with a discussion on automation. In this final comment, I opine that these tests will carry more weight if they done with sufficient statistical significance and thus repeatable. I've eluded to automation in my previous comments of the test by asking if it is possible to control LMR radios through some independent controller. If it is possible control all sub-systems highlighted in Figures 1 and 2 through automated scripts from a centralized controller, the chances of providing repeatable tests become much greater. Additionally, the test execution becomes more efficient. Has the NTIA considered engineering an automated test system for precise control? Furthermore, have the vendors been notified of what data their DUT is expected to provide in terms of data fidelity and formatting? These tests have a great opportunity for establishing metrics and techniques used for future testing. If these parameters are established early it will greatly assist in future research.

2.4 Summary of Phase II Comments

Precise definitions of success and failure are necessary throughout the Phase II test description. The timing of keys event also need to be considered and integrated into the test plan. Additionally, the conditions which define the measurement and reporting of an available spectrum channels needs to be precisely stated and agreed upon. Automation of the systems is highly recommended for repeatability of the tests. Creating an automated system and protocol to control such a system would be invaluable for testing of future DSA systems.

3 Phase III

3.1 Downlink Test

The effect of in-band emissions of DUTs onto the LMR systems can be analytically calculated. Has will the NTIA provide or calculate these measurements for the case without the DUT? I suggest the question should be to characterize rather to understand the effect. Clearly, the effect will be a lower Signal to Interference and Noise Ratio (SINR) for the LMR receivers, I think what needs to be understood is what is the probability of interference for these DUT with the associated primary system under the specific scenarios. Dr. Marshall performed some analysis on this subject that may be useful in this evaluation[6].

In Section 3.1.1., the prose of the section describes Figure 2: LMR base station as outside the detection range of the DUT. If the DUT is within the operating range of the LMR Base Station (BS), can it not receive signals from the LMR base station, and thus, detect the presence of the BS? Furthermore, if the LMR subscribers are within the detection range of the DUT are they not detected? From the figure and description, I can't understand how the BS or any subscribers are hidden from the DUT. Furthermore, usually when the hidden node problem is presented from a different perspective in literature. I recommend that you examine the work of Nekovee[7] and Yucek[8]. Figure 2 from Yucek, shows what is more depicted as the traditional hidden node problem. Additionally, the some of the same problems are also present in Figure 3. In the case of Figure 3, how can the DUT detect the LMR BS if it is out of the operating

[6] P.F. Marshall. "Dynamic Spectrum Access as a Mechanism for Transition to Interference Tolerant Systems". In: *2010 IEEE Symposium on New Frontiers in Dynamic Spectrum (DySPAN)* (2010).

[7] Maziar Nekovee. "Cognitive Radio Access to TV White Spaces: Spectrum Opportunities, Commercial Applications and Remaining Technology Challenges". In: *IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks, (DySPAN)* (2010).

[8] T. Yucek and H. Arslan. "A survey of spectrum sensing algorithms for cognitive radio applications". In: *IEEE Communications Surveys Tutorials* (2009).

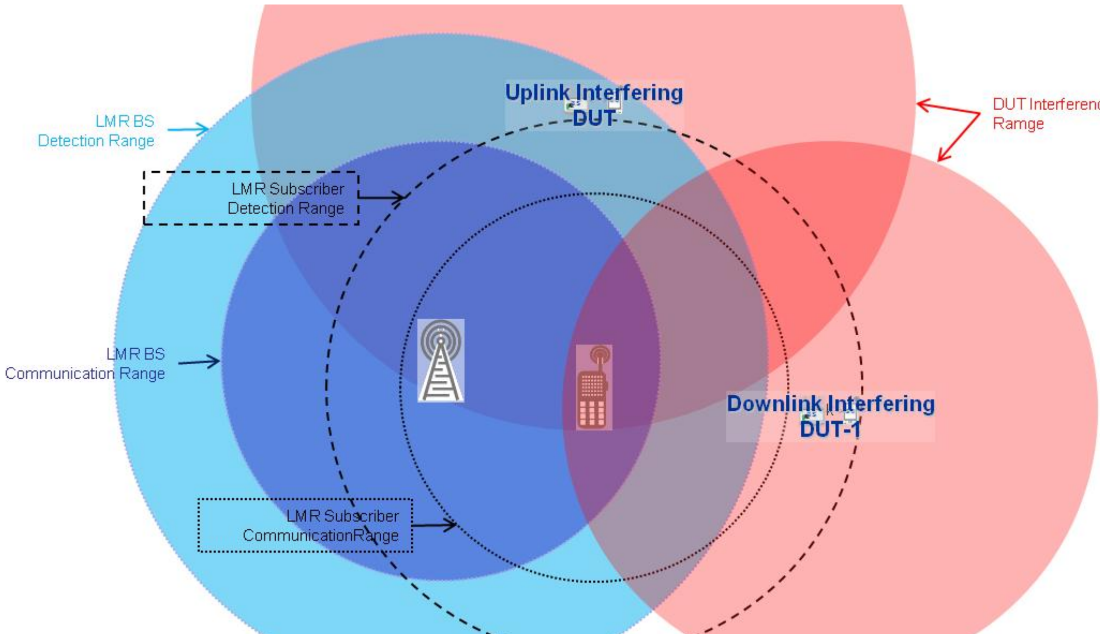

Figure 3: Illustration downlink and uplink hidden nodes.

range? I suggest these figures be redone by referring to the detection range with reference to the element that is being detected. For instance, the operating range of the LMR BS is less than the detection range. I've provided Figure 3 to illustrate what I believe is the intent the of Figures 2 and 3 from the test plan[9]. In Figure 3, the downlink interfering DUT, senses the LMR subscriber uplink since it is within the LMR subscriber detection range; however, the DUT is outside the LMR BS detection range. The uplink interfering DUT the converse is true of the subscriber and the BS.

Of course, these ranges are function of transmit powers of the LMR BS, subscribers, DUT, and the detection threshold of the DUT. For the downlink tests, has the NTIA plotted the hypothetical ranges and associated areas for proposed LMR BS and subscriber locations given the assumed values? Clearly, if DUT-1 has a very low transmit power and very low detection threshold, it may never interfere with the downlink, because the interference range of the DUT will become very small and detect range of the LMR BS will become very large. What detection threshold values have been proposed for this test? Under which conditions are they assumed to cause interference and not? This point also returns to the issue of whether this is a test or an experiment. If this is a test, the requirements or expected results should be know in advance. As opposed to an experiment, which I would assume compares the analytical values to the results of the experiment.

For synchronization of data, is one second time-stamp adequate for these tests? How will the VSA differentiate between signals from the DUT and LMR system? Does the DUT provide some type of logs that can be used to determine its behavior? Can the LMR system provide logs to show that the activity of LMR transmitters?

[9]Telecommunications and Administration, "Phase II/III Test Plan", op. cit.

Figure 5 from the test plan also introduces an alternative topology for testing the DUT by separating the DUT BS and subscriber by father distances. In Section 3.1.4., I don't know if topology in Figure 4 and Figure 5 are both tested or not. The procedure does not describe them. I suggest separating these into two procedures each describing each specific test according to the appropriate topology. The procedure refers to DUTs, which doesn't differentiate between the two topologies.

3.2 Summary of Phase III Comments

Regrettably, I was not able to completely review Phase III section of the document. As with the previous phase, many of the same comments apply such as increasing test case precision, control, and automation. Increasing precision in the tests/experiments will help with execution. An analysis should be performed in advance to predict the expected behavior of the DUT. These analytical results should be compared to the measured results.

4 Conclusion

In summary, increasing the precision of these test cases will help execution considerably. This recommendation applies throughout and I've provided many comments and questions as examples. Most importantly, pass/fail criteria or analytical expectations should be clearly stated with each test. NTIA should also consider automation of testing for repeatability when testing multiple different systems. Additionally, automation would require a system to control the transmission of the LMR radios. To improve the analysis of results, the DUTs should provide predefined logs or reports. These reports should be compared to the LMR system performance pegs and also the VSA readings. I appreciate the opportunity to provide feedback on these tests to the NTIA and I hope that my feedback is useful. In closing, I would like to reiterate how critical these tests are in shaping future DSA research and regulation and look forward to reviewing the final results. Thank you and good luck in your efforts.