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Modification Record

- August 2015 Version 1.0 Release
- October 2015 Version 1.2 Release
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University of New Hampshire

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University of New Hampshire

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University of New Hampshire

Michael Schoerner  
University of New Hampshire
Introduction

Overview
The University of New Hampshire’s InterOperability Laboratory (IOL) is an institution designed to improve the interoperability of standards based products by providing an environment where a product can be tested against other implementations of a standard.

Note: Successful completion of all tests contained in this suite does not guarantee that the tested device will operate with other compliant devices. However, combined with satisfactory operation in the IOL’s interoperability test bed, these tests provide a reasonable level of confidence that the Device Under Test (DUT) will function well in most environments.

Organization of Tests
The tests contained in this document are organized to simplify the identification of information related to a test and to facilitate in the actual testing process. Each test contains an identification section that describes the test and provides cross-reference information. The discussion section covers background information and specifies why the test is to be performed. Tests are grouped in order to reduce setup time in the lab environment. Each test contains the following information:

Test Number
The Test Number associated with each test follows a simple grouping structure. Listed first is the Test Group Number followed by the test’s number within the group. This allows for the addition of future tests to the appropriate groups of the test suite without requiring the renumbering of the subsequent tests.

Purpose
The purpose is a brief statement outlining what the test attempts to achieve. The test is written at the functional level.

References
The references section lists cross-references to the IEEE 802.11 standards and other documentation that might be helpful in understanding and evaluating the test results.

Resource Requirements
The requirements section specifies the test hardware and/or software needed to perform the test. This is generally expressed in terms of minimum requirements, however in some cases specific equipment manufacturer/model information may be provided.

Last Modification
This specifies the date of the last modification to this test.

Discussion
The discussion covers the assumptions made in the design or implementation of the test, as well as known limitations. Other items specific to the test are covered here.

Test Setup
The setup section describes the initial configuration of the test environment. Small changes in the configuration should be included in the test procedure.

Procedure
The procedure section of the test description contains the systematic instructions for carrying out the test. It provides a cookbook approach to testing, and may be interspersed with observable results.
Observable Results
This section lists the specific observables that can be examined by the tester in order to verify that the DUT is operating properly. When multiple values for an observable are possible, this section provides a short discussion on how to interpret them. The determination of a pass or fail outcome for a particular test is often based on the successful (or unsuccessful) detection of a certain observable.

Possible Problems
This section contains a description of known issues with the test procedure, which may affect test results in certain situations. It may also refer the reader to test suite appendices and/or whitepapers that may provide more detail regarding these issues.
Group 1: Evaluation of Wave-2 802.11ac Features

Scope: The following tests cover operations pertaining to Wave 2 of 802.11ac, including features such as MU-MIMO.

Overview: These tests were developed in collaboration with member companies.

This test suite requires the installation of Ixia Performance Endpoint onto all STAs.

The following tables specify the default settings for APUT:

<table>
<thead>
<tr>
<th><strong>Parameter</strong></th>
<th><strong>Value</strong></th>
<th><strong>Parameter</strong></th>
<th><strong>Value</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio</td>
<td>Enabled</td>
<td>Radio</td>
<td>Enabled</td>
</tr>
<tr>
<td>SSID</td>
<td>5GHzWave2</td>
<td>SSID</td>
<td>2.4GHzWave2</td>
</tr>
<tr>
<td>Security</td>
<td>WPA2-PSK</td>
<td>Security</td>
<td>WPA2-PSK</td>
</tr>
<tr>
<td>Encryption</td>
<td>AES-CCMP</td>
<td>Encryption</td>
<td>AES-CCMP</td>
</tr>
<tr>
<td>PSK</td>
<td>wireless</td>
<td>PSK</td>
<td>wireless</td>
</tr>
<tr>
<td>Number of Spatial Streams</td>
<td>Maximum Supported</td>
<td>Number of Spatial Streams</td>
<td>Maximum Supported</td>
</tr>
<tr>
<td>Channel</td>
<td>149</td>
<td>Channel</td>
<td>6</td>
</tr>
<tr>
<td>Channel Width</td>
<td>80 MHz</td>
<td>Channel Width</td>
<td>40 MHz</td>
</tr>
<tr>
<td>Hidden SSID</td>
<td>Off</td>
<td>Hidden SSID</td>
<td>Off</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Parameter</strong></th>
<th><strong>Value</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table – 5 GHz Default Settings</strong></td>
<td><strong>Table – 2.4 GHz Default Settings</strong></td>
</tr>
</tbody>
</table>

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InterOperability Laboratory
Test #1.1: Peak Throughput of 4x4 802.11ac Systems

Purpose: To verify peak throughput of a 4x4 dual-band wireless system.

References:
[1] IEEE Std. 802.11ac

Resource Requirements:
- Ethernet endpoint (EP1) running IxChariot Console and Performance Endpoint
- Two additional Ethernet endpoints (EP2, EP3) running Ixia Performance Endpoint
- Three Wave-2 11ac APs (APUT, AP2, AP3)

Last updated: October 6, 2015

Discussion: Given the lack of 4x4 client devices in the market, two bridge-mode APs acting as STAs connected to Ethernet endpoints will be used to emulate 4x4 clients (one in the 5 GHz band and one in the 2.4 GHz band).

Test Setup: Connect EP1 to APUT, EP2 to AP2, and EP3 to AP3 via Gigabit Ethernet. Place all APs and EPs in a wireless isolation chamber and within range of each other.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4 GHz Radio</td>
<td>Disabled</td>
</tr>
<tr>
<td>Wireless Bridge</td>
<td>Enabled</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 GHz Radio</td>
<td>Disabled</td>
</tr>
<tr>
<td>Wireless Bridge</td>
<td>Enabled</td>
</tr>
</tbody>
</table>

Procedure:
1. Allow all APs and STAs to Authenticate, Associate, and complete the 4-way Handshake.
2. Using IxChariot and a script to measure TCP throughput, simultaneously run eight pairs of TCP traffic from EP1 to EP2, EP3.

Observable Results: Ensure throughput is just under 1 Gbps (Maximum possible given the Ethernet link).

Possible Problems: None
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InterOperability Laboratory

Test #1.2: Capacity and Performance Gains of MU-MIMO

Purpose: To verify the performance gains for each device tested by comparing MU and SU modes.

References:
[1] IEEE Std. 802.11ac

Resource Requirements:
- Ethernet endpoint (ETH) running IxChariot Console and Performance Endpoint
- Three 11ac endpoints (EP1, EP2, EP3) running Ixia Performance Endpoint
- One Wave-2 11ac AP (APUT)

Last updated: October 6, 2015

Discussion: In MU-MIMO systems, a router can communicate simultaneously with multiple devices (as long as they are equipped with the MU-receive capability). This essentially multiplies the available wireless capacity and ensures a larger share of bandwidth (up to 3x) for each device. This test will expose the performance gains for each device by comparing MU and SU modes.

Test Setup: Connect ETH to APUT via Gigabit Ethernet. Place APUT, ETH, and all EPs within range of each other in an RF isolated environment.

1.2.1 MU-MIMO

Procedure:
1. Allow APUT and all EPs to Authenticate, Associate, and complete the 4-way Handshake.
2. Using IxChariot and a script to measure TCP throughput, simultaneously run TCP traffic from ETH to EP1, EP2, and EP3.

1.2.2 SU-MIMO

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MU-MIMO</td>
<td>Disabled</td>
</tr>
</tbody>
</table>

Procedure:
1. Allow APUT and all EPs to Authenticate, Associate, and complete the 4-way Handshake.
2. Using IxChariot and a script to measure TCP throughput, simultaneously run TCP traffic from ETH to EP1, EP2, and EP3.

Observable Results: Observe throughput of each client device. Throughput results in MU-MIMO mode should be significantly greater than in SU-MIMO mode.

Possible Problems: None
Purpose: To compare the rate vs. range impact in traditional SU and MU-MIMO environments.

References:  
[1] IEEE Std. 802.11ac

Resource Requirements:
- Ethernet endpoint (ETH) running IxChariot Console and Performance Endpoint
- Three 11ac endpoints (EP1, EP2, EP3) running Ixia Performance Endpoint
- One Wave-2 11ac AP (APUT)

Last updated: October 6, 2015

Discussion: Devices located far from a router must connect at lower MCS rates, which not only reduces throughput, but also consumes a greater proportion of the available capacity (or “airtime”). MU-MIMO helps overcome the capacity issues by serving groups of devices simultaneously and freeing up more airtime. The 802.11ac standard does not specify how groups are determined or adapted as devices move – which can have a significant impact in homes with many devices at varying distances.

Wave-2 11ac devices use sophisticated algorithms to intelligently group devices, based on the type of traffic they're using and how many spatial streams they support. To ensure that each device gets sufficient capacity, these algorithms can also dynamically adjust rates as clients move. This test will compare the rate vs. range impact in traditional SU and MU-MIMO environments.

Test Setup: Connect ETH to APUT via Gigabit Ethernet. Place APUT, ETH, and all EPs within range of each other.

1.3.1 MU-MIMO

Procedure:
1. Place EP1 3 ft. away and directly in front of APUT. Place EP2 20 ft. away and directly in front of APUT. Place EP3 20 ft. away and approximately 45° clockwise from the front of APUT.  
2. Allow APUT and all EPs to Authenticate, Associate, and complete the 4-way Handshake.  
4. Leaving EP1 and EP2 in their respective places, move EP3 so that it is 12 ft. away and approximately 45° clockwise from the front of APUT. Repeat steps 2-4.  
5. Leaving EP1 and EP2 in their respective places, move EP3 so that it is 12 ft. away and directly in front of APUT. Repeat steps 2-4.  
6. Leaving EP1 in its place, move EP2 so that it is 3 ft. away and approximately 120° clockwise from the front of APUT, and move EP3 so that it is 3 ft. away and approximately 240° clockwise from the front of APUT. Repeat steps 2-4.

1.3.2 SU-MIMO

Procedure:
1. Place EP1 3 ft. away and directly in front of APUT. Place EP2 20 ft. away and directly in front of APUT. Place EP3 20 ft. away and approximately 45° clockwise from the front of APUT.  
2. Allow APUT and all EPs to Authenticate, Associate, and complete the 4-way Handshake.  
4. Leaving EP1 and EP2 in their respective places, move EP3 so that it is 12 ft. away and approximately 45° clockwise from the front of APUT. Repeat steps 2-4.  
5. Leaving EP1 and EP2 in their respective places, move EP3 so that it is 12 ft. away and directly in front of APUT. Repeat steps 2-4.
6. Leaving EP1 in its place, move EP2 so that it is 3 ft. away and approximately 120° clockwise from the front of APUT, and move EP3 so that it is 3 ft. away and approximately 240° clockwise from the front of APUT. Repeat steps 2-4.

**Observable Results:** Observe throughput of each endpoint, noting that the devices at close range maintain performance, even as the other devices are consuming more airtime. When using SU mode, notice the farthest devices may actually bring down the performance of those at close range. In both cases, throughput in the MU mode should be greater than SU mode.

**Possible Problems:** None
Test #1.4: MU-MIMO Advantages for Mobile and Computing Devices

**Purpose:** To reveal how MU-MIMO can boost the performance of 1-stream devices to be comparable to previous 2-stream devices.

**References:**
[1] IEEE Std. 802.11ac

**Resource Requirements:**
- Ethernet endpoint (ETH) running IxChariot Console and Performance Endpoint
- Two 1x1 endpoints (EP1, EP2) running Ixia Performance Endpoint
- One 2x2 endpoint (EP3) running Ixia Performance Endpoint.
- One Wave-2 11ac AP (APUT)

**Last updated:** October 6, 2015

**Discussion:** A vast majority of today’s commercial smartphones, tablets, and laptops are 1-antenna wireless devices (also known as 1x1). As mobile content and applications require greater bandwidth, MU-MIMO can be a useful tool for multiplying the capabilities of mobile devices without adding to the cost and complexity of additional antennas. This test will reveal how MU-MIMO can boost the performance of 1-stream devices to be comparable to previous 2-stream devices.

**Test Setup:** Connect ETH to APUT via Gigabit Ethernet. Place APUT, ETH, and all STAs within range of each other

**Procedure:**
1. Allow APUT and all STAs to Authenticate, Associate, and complete the 4-way Handshake.
2. Using IxChariotThroughput.scr, simultaneously run TCP traffic from ETH to STA1, STA2, STA3

**Observable Results:** Observe the throughput of each device. Each endpoint should exhibit similar performance in throughput.

**Possible Problems:** None
Test #1.5: Range vs. Throughput

Purpose: To test throughput values between the APUT and a Wave-2 11ac AP over simulated range using the octoBox Multi-Path Emulator with quadAtten™ RF Attenuator Module.

References: Refer to the 802.11abgnac Range vs. Throughput Test Suite.