BLACK BOOK

Black Book

Edition 10

802.11ac Wi-Fi Benchmarking

Your feedback is welcome

Our goal in the preparation of this Black Book was to create high-value, high-quality content. Your feedback is an important ingredient that will help guide our future books.

If you have any comments regarding how we could improve the quality of this book, or suggestions for topics to be included in future Black Books, please contact us at ProductMgmtBooklets@ixiacom.com.

Your feedback is greatly appreciated!

Contents

How to Read this Book

The book is structured as several standalone sections that discuss test methodologies by type. Every section starts by introducing the reader to relevant information from a technology and testing perspective.

Each test case has the following organization structure:

Overview	Provides background information specific to the test case.
Objective	Describes the goal of the test.
Setup	An illustration of the test configuration highlighting the test ports, simulated elements and other details.
Step-by-Step Instructions	Detailed configuration procedures using Ixia test equipment and applications.
Test Variables	A summary of the key test parameters that affect the test's performance and scale. These can be modified to construct other tests.
Results Analysis	Provides the background useful for test result analysis, explaining the metrics and providing examples of expected results.
Troubleshooting and Diagnostics	Provides guidance on how to troubleshoot common issues.
Conclusions	Summarizes the result of the test.

Typographic Conventions

In this document, the following conventions are used to indicate items that are selected or typed by you:

- **Bold** items are those that you select or click on. It is also used to indicate text found on the current GUI screen.
- *Italicized* items are those that you type.

Dear Reader

Ixia's Black Books include a number of IP and wireless test methodologies that will help you become familiar with new technologies and the key testing issues associated with them.

The Black Books can be considered primers on technology and testing. They include test methodologies that can be used to verify device and system functionality and performance. The methodologies are universally applicable to any test equipment. Step-by-step instructions using Ixia's test platform and applications are used to demonstrate the test methodology.

This tenth edition of the black books includes twenty two volumes covering some key technologies and test methodologies:

Volume 1 – Higher Speed Ethernet

Volume 2 – QoS Validation

Volume 3 – Advanced MPLS

Volume 4 – LTE Evolved Packet Core

Volume 5 – Application Delivery

Volume 6 – Voice over IP

Volume 7 – Converged Data Center

Volume 8 – Test Automation

Volume 9 – Converged Network Adapters

Volume 10 – Carrier Ethernet

Volume 11 – Ethernet Synchronization

Volume 12 – IPv6 Transition Technologies

Volume 13 – Video over IP

Volume 14 – Network Security

Volume 15 – MPLS-TP

Volume 16 – Ultra Low Latency (ULL) Testing

Volume 17 – Impairments

Volume 18 – LTE Access

Volume 19 – 802.11ac Wi-Fi Benchmarking

Volume 20 – SDN/OpenFlow

Volume 21 – Network Convergence Testing

Volume 22 – Testing Contact Centers

A soft copy of each of the chapters of the books and the associated test configurations are available on Ixia's website.

At Ixia, we know that the networking industry is constantly moving; we aim to be your technology partner through these ebbs and flows. We hope this Black Book series provides valuable insight into the evolution of our industry as it applies to test and measurement. Keep testing hard.

Bethany Mayer, Ixia President and CEO

802.11ac Wi-Fi Benchmarking

Test Methodologies

This 802.11ac Wi-Fi benchmark testing booklet provides several examples with detailed steps showing an IxVeriWave user how to utilize Ixia IxVeriWave application to achieve comprehensive performance test analysis for 802.11ac access points.

Introduction to 802.11ac Performance Testing

Introduction

There are high expectations surrounding the newly introduced IEEE 802.11ac standard (still in the draft form as of the date of publishing this Black Book). The initial IEEE 802.11ac technology is based on the tried and tested 802.11n MAC and radio, but provides at least four times the bandwidth. Future chipset developments are expected to raise access point (AP) capacity to multi-gigabit levels. The subsequent generation of IEEE 802.11ac technologies plans to roll out multi-user multiple-input multiple-output (MU-MIMO) capabilities that can actually allow up to 4 clients to communicate simultaneously with an AP, without interfering with each other.

The IEEE 802.11ac Working Group has introduced an additional 350 pages of specifications into the already enormous IEEE 802.11 base standard. The task of the QA engineer is to figure out how well the IEEE 802.11ac AP performs, but this can be an overwhelming challenge. This document shows you how to figure out which IEEE 802.11ac capabilities and features matter most, and how you can quickly verify that your product delivers the capabilities/features conforming to these standards.

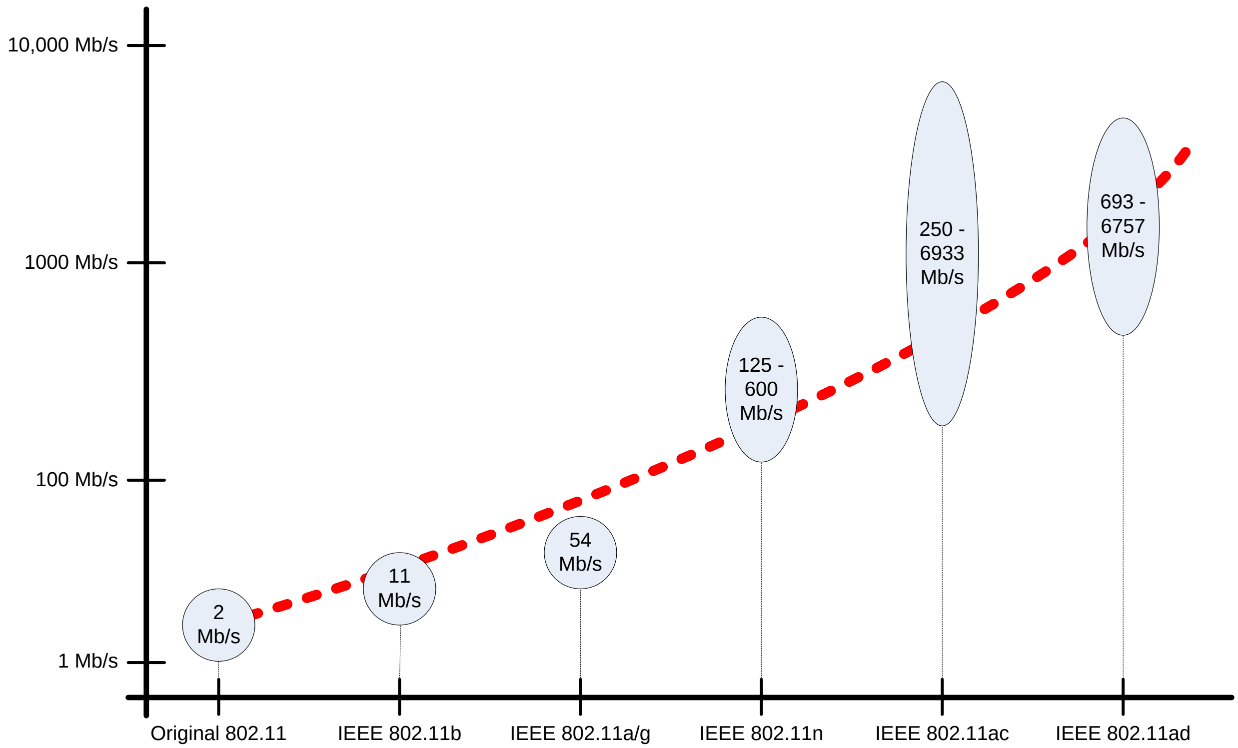
IEEE 802.11ac Technology and Benefits

In its initial form, IEEE 802.11ac is best described as a faster and more scalable version of IEEE 802.11n. It builds on existing IEEE 802.11a/g OFDM (orthogonal frequency-division multiplexing) modulation and IEEE 802.11n MIMO technology, adding new features to provide a new level of functionality and performance together with unprecedented wireless bandwidth. In particular, wireless LAN clients using streaming video will see significant gains in performance, as many more independent video streams can be supported by an IEEE 802.11ac AP. Even non-video clients will see substantial benefits in terms of application response times and reduced network congestion.

Significant new features added in IEEE 802.11ac are:

- 80 MHz channel bandwidth. This doubles the available bandwidth as compared to the IEEE 802.11n. Future chipsets support 160 MHz channel bandwidth, doubling the capacity yet again.
- MIMO support for up to 8 spatial streams using 8 antennas. This further doubles bandwidth compared to IEEE 802.11n.
- 256 QAM modulation capability, offering a 33% increase in bandwidth over the IEEE 802.11n.
- Standardized beam-forming, sounding, and feedback, which makes beam-forming practical by ensuring interoperability across vendors. This substantially improves range and interference resistance.

- Coexistence mechanisms to prevent interference with legacy devices due to the wider channels.



WLAN Capacity Progression

A key departure from IEEE 802.11n is that IEEE 802.11ac is defined to allow operation on only the 5 GHz band. Operation on 2.4 GHz is not permitted.

The following table outlines the primary differences between IEEE 802.11n and IEEE 802.11ac.

Attribute	IEEE 802.11n	IEEE 802.11ac
Channel Bandwidths	20/40 MHz	20/40/80/160 MHz
MIMO Support	Up to 4 streams	Up to 8 streams
Modulation	BPSK/QPSK/16-QAM/64-QAM	BPSK/QPSK/16-QAM/64-QAM/256-QAM
Max PHY Rate	600 Mb/s	6933 Mb/s
Operating Bands	2.4 GHz and 5 GHz	5 GHz only
Maximum MAC Frame Size	8000 bytes	11500 bytes
A-MPDUs	Optional	Mandatory
Maximum A-MPDU Size	65535 bytes	1048575 bytes
Beamforming	Supported but not standardized	Standardized
STBC	Many modes & options	Minimized in favor of beamforming

The clear benefit of IEEE 802.11ac over existing IEEE 802.11n is higher bandwidth at similar range. The first wave of IEEE 802.11ac, with fairly straightforward 2x2 MIMO systems (typical of a laptop connecting to an AP), supports peak PHY bandwidths of up to 867 Mb/s; in practice, 700 Mb/s might be usable. Even with devices supporting a single spatial stream at moderate ranges, 250 Mb/s transfer rates are not unreasonable. With improved beam-forming and sounding capabilities the APs with 4 or more antennas can considerably enhance the operating range.

The ultimate capacity of IEEE 802.11ac is a stratospheric peak PHY bandwidth of 6933 Mb/s, but this requires 8 antennas, enormous 160 MHz channel bandwidths, and excellent signal to noise ratios, thus very short ranges. This is unlikely to be the norm, at least for some years to come. A more realistic case is an AP with 4 antennas using a 160 MHz channel, which can practically support a peak PHY bandwidth of 3467 Mb/s, translating to a sustained usable data rate aggregated over all the clients of about 3 Gb/s.

The second generation of IEEE 802.11ac is expected to introduce multiuser MIMO (MU-MIMO) capabilities that are a significant step towards true "wireless switching," but this is unlikely to become feasible for some time, and in any case is not yet defined within the IEEE 802.11ac draft standard as of the date of publishing this black book.

Test Challenges of IEEE 802.11ac

Chipset and system designs around a new standard are prone to issues related to support of legacy standards for backwards compatibility, and implementation of the new standard. Performance and functionality cannot be assured by design only. To meet the demanding requirements of 802.11ac, the components and drivers have been substantially changed from earlier chipset designs. This means that the verification of all features, modes and functions set forth by the both 802.11a/b/g and 802.11n sections of the standard must be performed on the access point and associated WLAN controller.

The three most important questions to be answered about IEEE 802.11ac are:

- Are you actually getting the capacity increase that you expect from the new IEEE 802.11ac APs?
- Can your IEEE 802.11ac AP interwork with previous IEEE 802.11n and IEEE 802.11a/b/g/n clients?
- Can the theoretical data rate increase actually benefit client devices?

Clearly, the most significant reason to adopt IEEE 802.11ac is the substantial increase in AP bandwidth capacity. Therefore, it is essential to verify that the AP does in fact support the rated bandwidth, as close to the theoretical maximum as possible, under all expected circumstances. This can only be done by running exhaustive benchmark tests that measure the throughput and forwarding rate of the system (APs and WLAN controllers) under different conditions, such as frame sizes, and numbers of clients. Further, these tests should be performed with different types of traffic (like upstream, downstream, UDP, TCP).

To make the leap to the new technology, customers must be confident that current network performance will not be compromised, while still supporting a definite performance gain that is worth the cost and risk of changeover. Thus it is necessary to verify that IEEE 802.11ac APs work flawlessly in IEEE 802.11a/b/g/n legacy modes, without destroying the performance of either the legacy or new IEEE 802.11ac devices. The supersized channel bandwidths employed by IEEE 802.11ac (80 MHz and up) means that complex radio resource management (RRM) algorithms, dynamic channel assignment, and transmit power control have to be employed by the APs and WLAN controllers to prevent co-channel and adjacent channel interference with the legacy devices that are not aware of the IEEE 802.11ac system.

Verification of legacy interoperability is critical. This must be done by testing the APs against mixes of IEEE 802.11ac and IEEE 802.11b, IEEE 802.11a/b/g and IEEE 802.11n clients. For each mix, throughput tests need to be performed and the results checked to ensure that the legacy clients do not impact IEEE 802.11ac throughput and vice versa.

Assuring that the IEEE 802.11ac APs will live up to the promise of improved user experience makes the testing process complex. A properly functioning radio and MAC only ensures that the air interface works correctly; however, the user experience is determined by the end-to-end performance in multiple dimensions, such as, end-to-end latency, QoS, and multi-client support. These are determined by not just the air interface but also the internal AP and WLAN controller data paths and switching fabrics, in addition to the traffic management and prioritization firmware. The test strategy needs to take all these factors into account.

Tests should therefore be performed to quantify throughput, forwarding rate and latency with many clients (up to the rated capacity of the APs); often, AP throughput is found to be stellar with a single client but drops off rapidly when a large number of clients are associated with the APs. Finally, QoS testing is the key, particularly for VoIP and video traffic.

Test Approaches

Specific test approaches need to be taken during development and QA testing to verify that IEEE 802.11ac devices are "enterprise-ready." These tests are performed to verify that:

- The speed and range enhancements of IEEE 802.11ac are delivered by the APs
- The newly developed IEEE 802.11ac APs are robust and interwork correctly with WLAN controllers
- The IEEE 802.11ac APs work flawlessly in IEEE 802.11a/b/g/n legacy modes

Functional verification and performance benchmarking are critical test requirements for any IEEE 802.11ac equipment. The important elements that need to be tested and verified for optimum functioning and performance of IEEE 802.11ac equipment are:

- Connectivity with 802.11ac APs in both VHT (Very High Throughput) and legacy modes
- Quantifying performance gains from VHT modes under different channel models
- Verifying performance under legacy interworking and coexistence conditions

Once the basic operation is verified, the system under test should be subjected to benchmark testing. Industry-standard methods such as RFC 2544 provide a simple methodology for benchmarking performance of the network equipment. These test plans can start small but grow to encompass every combination of features desired. The usual progression is to establish baseline performance metrics in the areas of Frame Loss, Throughput, and Latency with different frame sizes (typically 64 bytes, 512 bytes and 1518 bytes) using one client. Then a Maximum Client Capacity test is performed using 64 byte frame lengths. The logs and configuration settings recorded during these tests can be used for duplicating and analyzing problems found.

More exhaustive benchmarking is typically pursued after establishing initial baselines. Such tests include testing for:

- Forwarding Rate and Frame Loss with one client at every frame length from 64 to 1518 bytes, inclusive
- Forwarding Rate and Frame Loss with one client at every PHY rate, using 64 byte frame lengths
- Forwarding Rate and Frame Loss with multiple clients using each security/encryption type
- Latency with multiple clients, measured with different frame lengths and security modes

- Throughput with one client at every frame length from 64 to 1518 bytes, inclusive
- Throughput with one client at every PHY rate, using 64 byte frame lengths
- Throughput with multiple clients using each security/encryption type
- TCP Goodput with multiple clients at different frame lengths and security modes

Test Case: Packet Loss Benchmark Test

Overview

The packet loss test measures the rate at which frames are dropped, as well as the rate at which they are forwarded by the system under test (SUT) when presented with specific traffic loads and frame sizes. See Figure 1 below for details on the test setup used for the following tests.

The results of this test can be used to characterize the SUT behavior over a wide range of traffic, rather than obtain a single performance number. This test can be performed using frame size and intended load sweeps to fully exercise the SUT with all combinations of traffic loads.

Objective

The objective of this test is to determine the count of frame / packet loss and the percentage of maximum theoretical traffic load the DUT can forward under a variety of conditions. This test quickly identifies the performance weakness in the frame processing engine of the DUT with a wide variety of features.

This test is the most robust benchmark test that can be performed and is therefore performed first. It is important to perform this test before performing a throughput test. It is not uncommon to have an AP have relatively high measured forwarding rates, but throughput measurements of zero. This condition commonly occurs when there is a consistent, but low percentage of packet loss. This situation is particularly common with early generations of hardware that often lose the first few packets of every test.

Setup

As shown in Figure 1 below, the test consists of a DUT, acting as an access point, and two Ixia test ports.

The 802.11 Ixia test port emulates up to 500 stateful Wi-Fi clients sending and receiving traffic from the wireless interface on the DUT. The other Ixia port emulates servers on the Ethernet network that source and sink the traffic from the Wi-Fi clients.

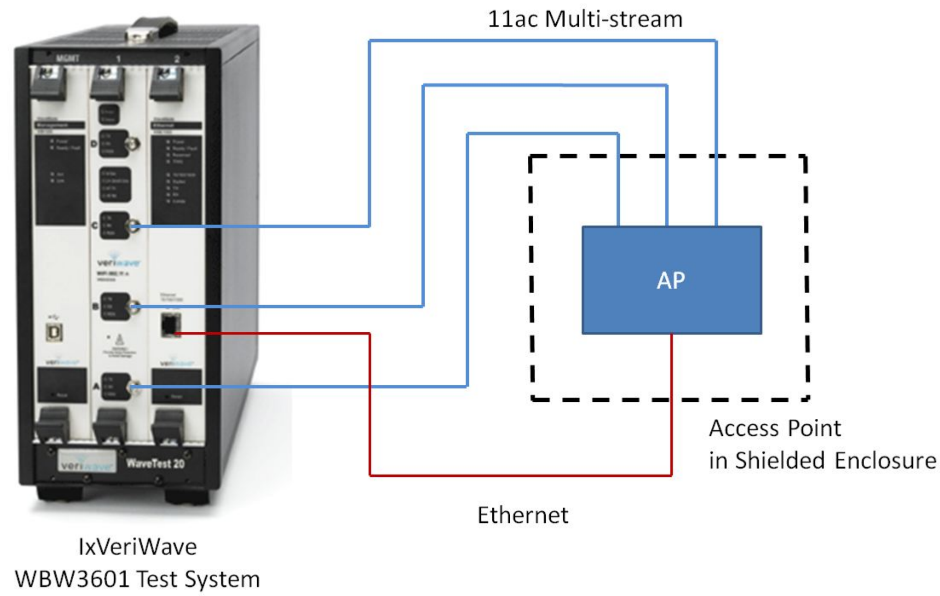


Figure 1. Test Setup

In the test setup above the DUT is placed in an isolation chamber to ensure that external signals do not affect test results. By connecting the AP to the test chassis with RF cables and enclosing the AP in an RF isolation chamber, you can be sure that other devices using the same frequencies do not affect the test results.

Benchmark Tests

All of the following tests are performed using the Benchmark Test Suite of the IxVeriWave WaveApps test application. This test suite contains all the test methodologies to baseline an access point performance.

Step-by-step Instructions – Forwarding Rate and Packet Loss Test

Follow the step-by-step instructions to create a forwarding rate and packet loss benchmark test. In addition, you can use the steps below as a guide for building many other layer 2/3 WLAN benchmark tests scenarios.

Select Packet Loss Test Suite and start test configuration.

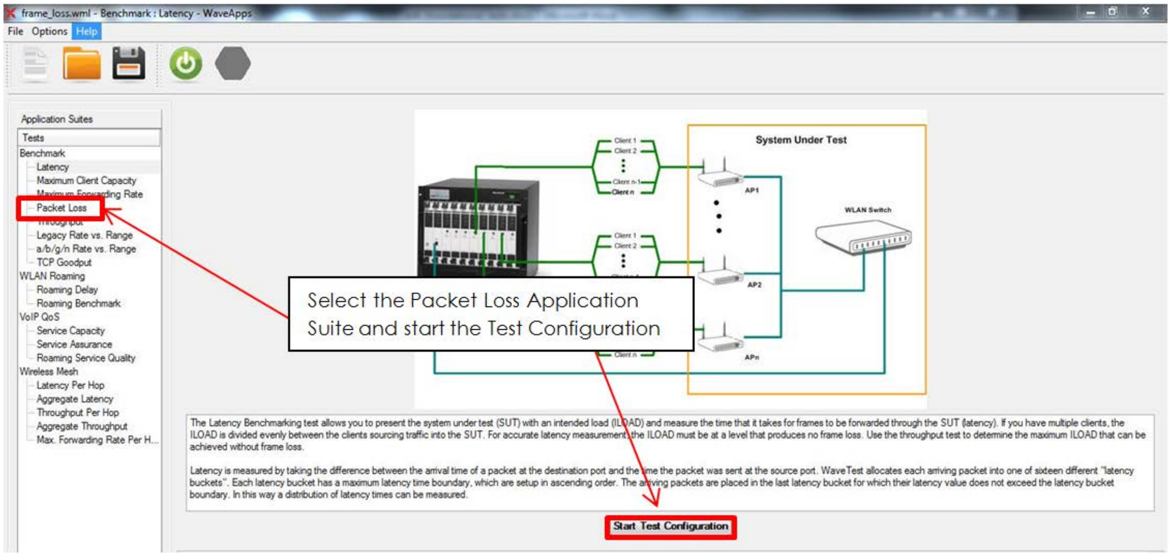


Figure 2. Application Suite Selection

Figure 3. Connect to the test chassis and select the port to use for following tests.

Note: When scanning for channels the scan stops at the lowest channel that has an active signal on it. If the channel detected is not the channel desired for the test enter the band and channel using the drop down menus at the right, then click the Scan BSSISs button to obtain the desired BSSID/SSID.

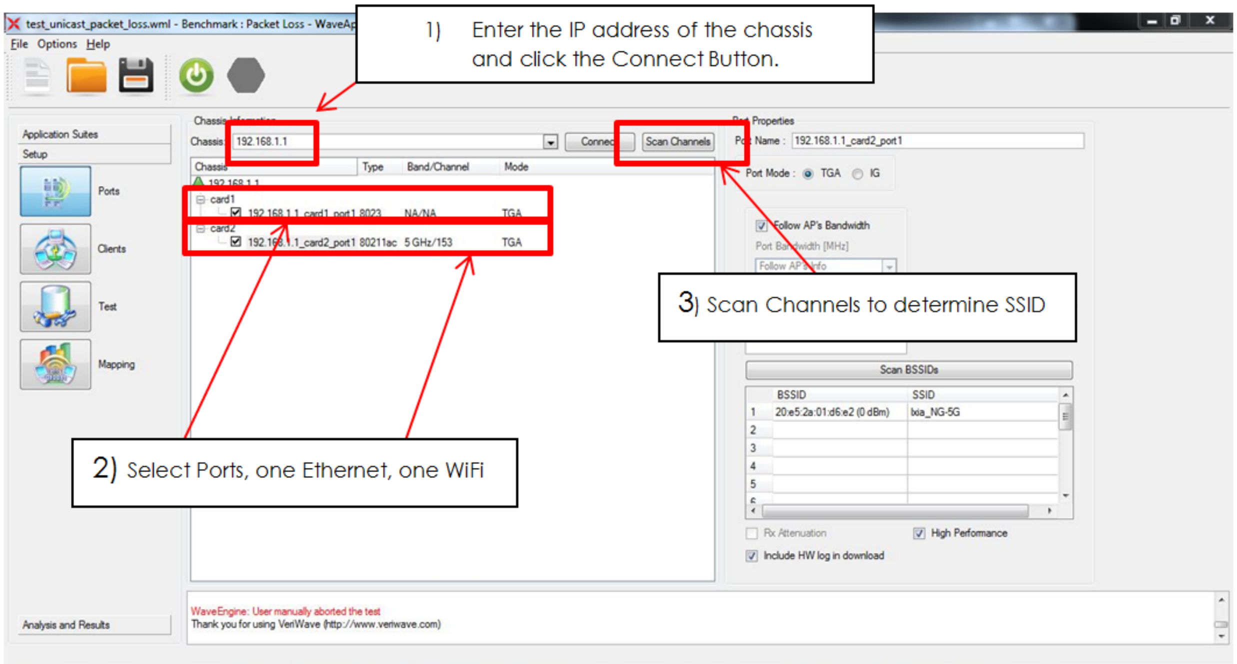


Figure 3 Port Selection

Figure 4. Create and name the clients. Click the Clients button on the left navigation panel. Click on the "+" to create a client group. Type the name in the "Name" box and select the interface type from the drop down menu. Select the Wi-Fi port and configure the client as shown below.

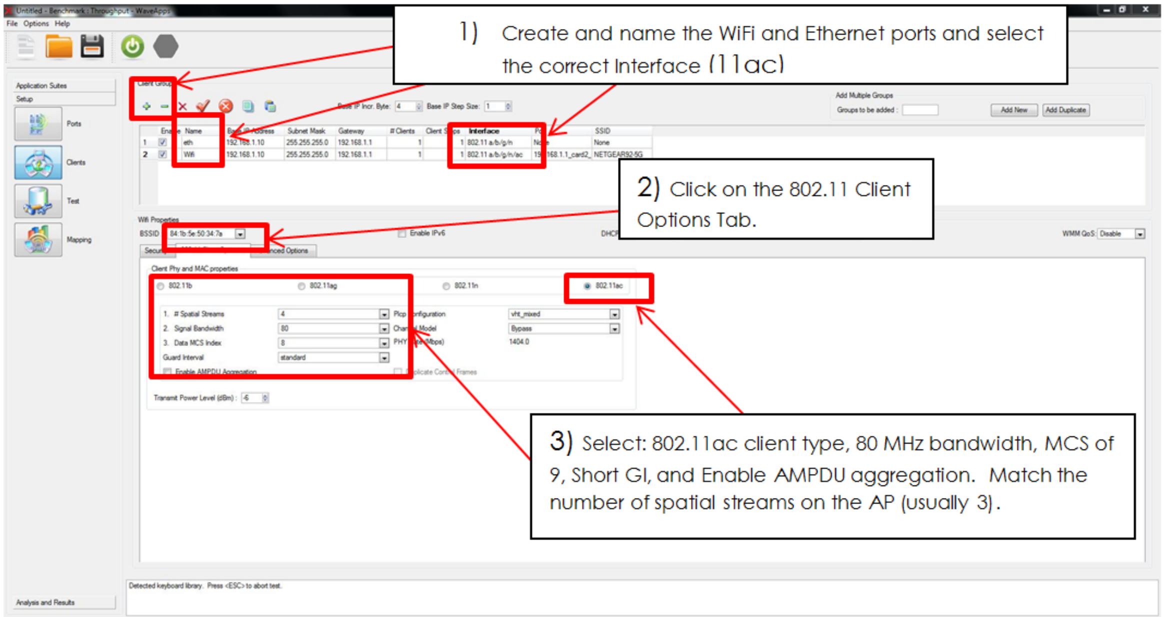


Figure 4. Client Characteristics

Figure 5. Click the Test Setup button and select the Packet Loss Properties tab. Specify the frame size and frame rates that you want to use to run a packet loss test.

It is recommended to use minimum, typical, and maximum length frames in order to test the maximum frame rate that the AP must handle. Short frames test the maximum frame rate and long frames test the maximum bit rate.

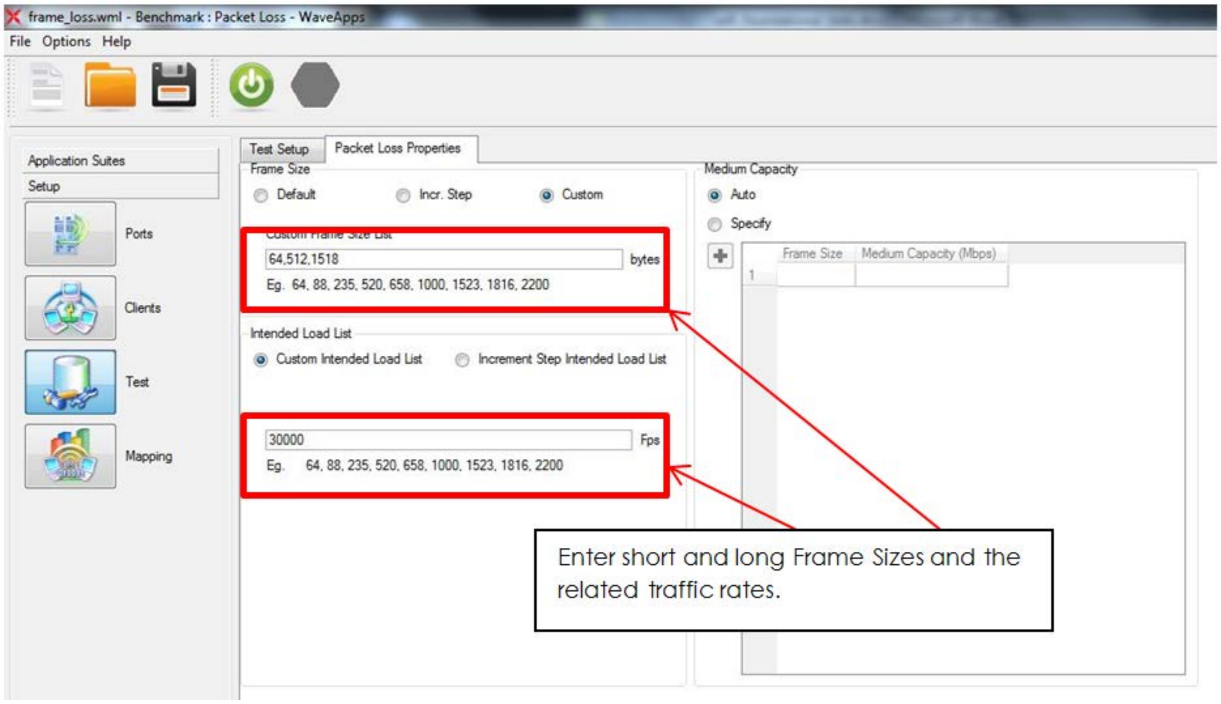


Figure 5. Test Parameters

Figure 6. Click the Mapping button and select the Mapping Option Wireless to Ethernet to perform an upstream packet loss and forwarding rate test.

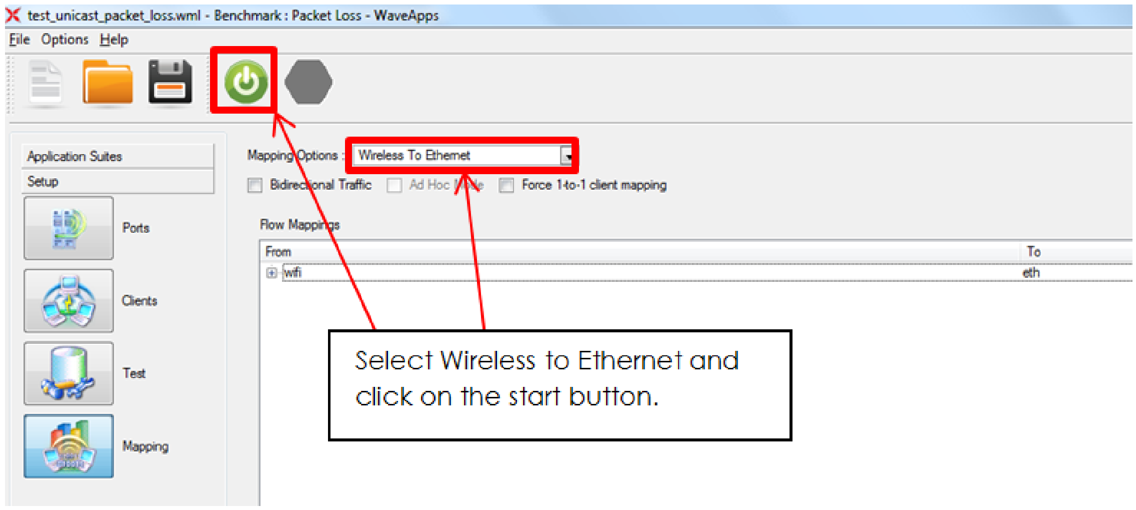
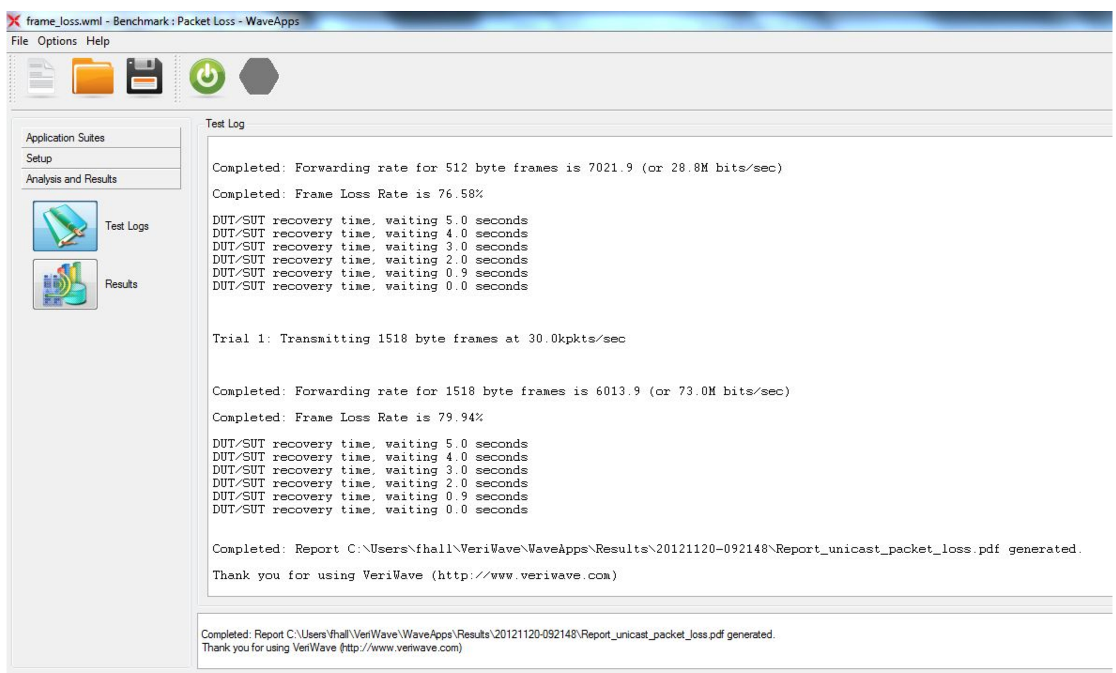


Figure 6. Mapping Options

Click the start button to start the Packet Loss test. The status window shows the progress of the test.



The following test results will show on the screen at the conclusion of a test. The results report is a .pdf file that can be found in the directory specified on the Test/Advanced Test Parameters page. See Figure 7 below:

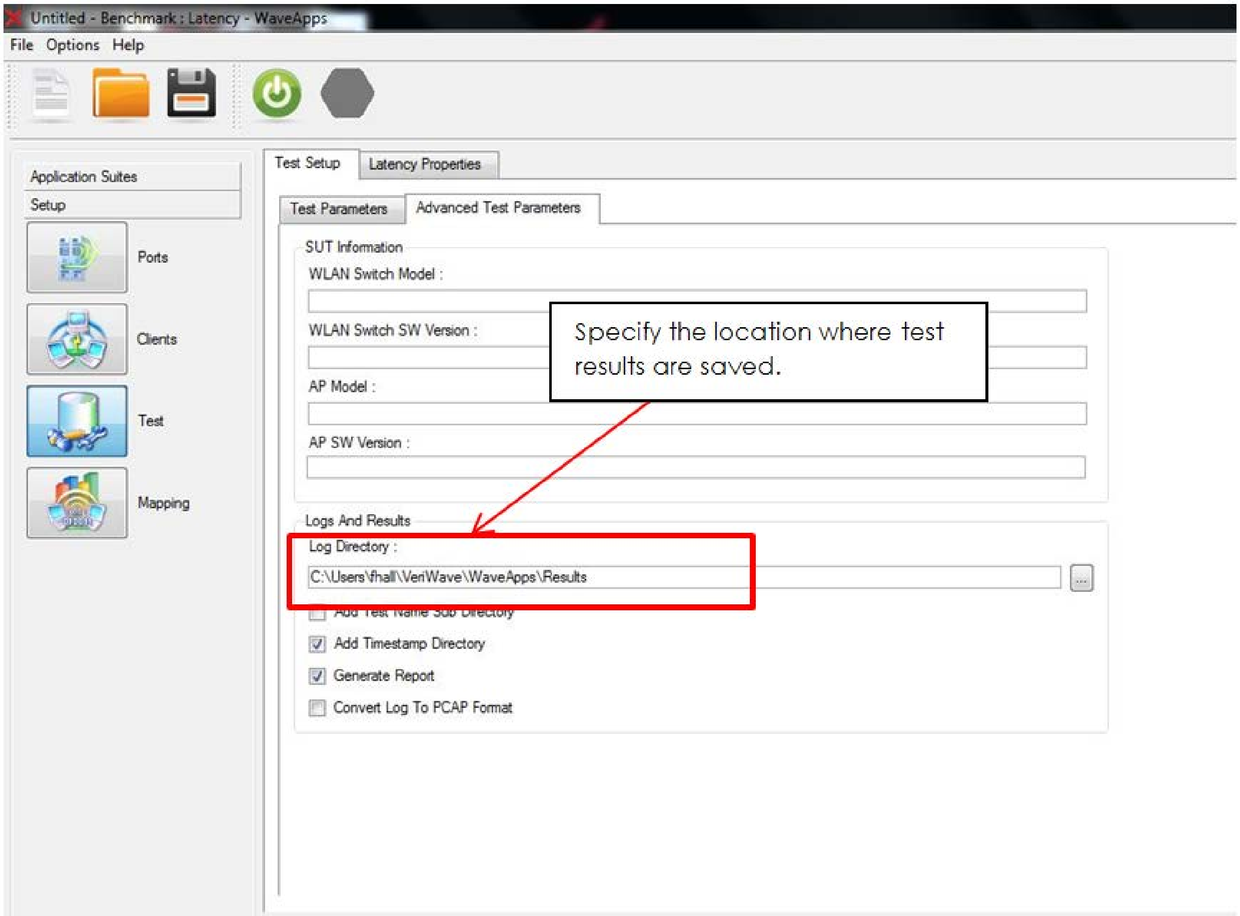


Figure 7. Specify Location for Results Directory

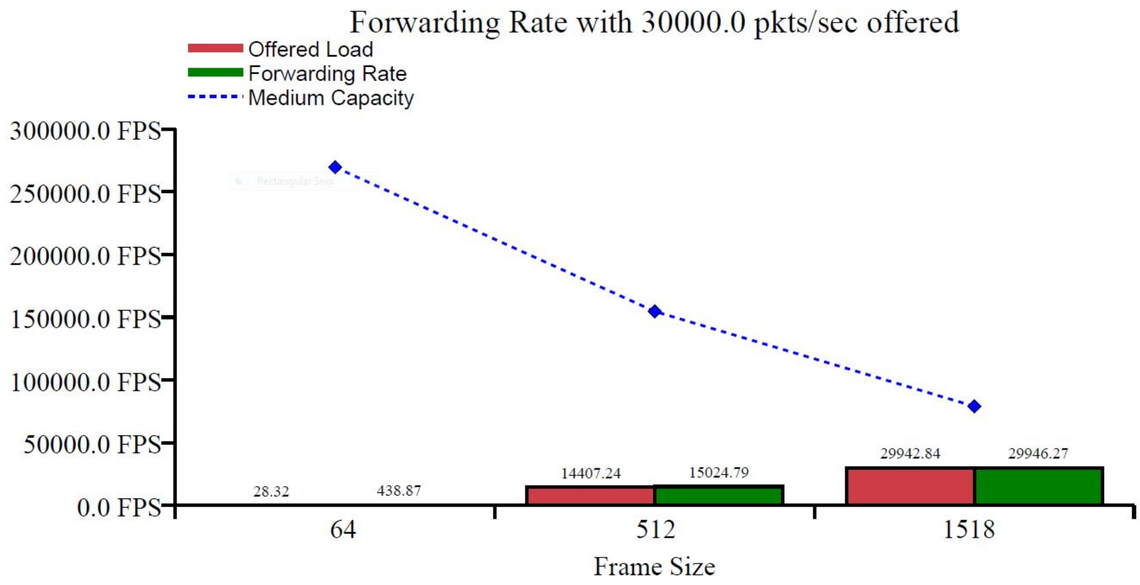


Figure 8. Packet Loss Test Results Downstream

Save the configuration file from the test before exiting the test or continuing with the next benchmark test.

Result Analysis

The packet loss and forwarding rate test is a simple, but very effective means to determine an access point's ability to deliver high performance. If an AP cannot deliver high forwarding rates with little or no loss under relatively benign benchmarking conditions then the behavior should be investigated immediately.

Performance issues with small frame sizes are most common and indicate that there is a performance bottleneck related to frame-level operations such as:

- Determining the forwarding port for a particular frame
- Aggregating multiple frames into a single AMPDU
- Legacy protection
- Bridging the frame from wireless to Ethernet

Performance issues with large frame sizes are less common, but do occur. These errors may be related to bit-level functions such as encryption / decryption operations.

Troubleshooting and Diagnostics

The following table lists the common access point performance problems and the tips to troubleshoot these problems.

Issue	Troubleshooting Tip
Test fails because it is unable to connect to the clients.	Make sure that the client configuration of the Ixia Wi-Fi client matches the configuration of the AP. For example, if the client is configured for 802.11ac operation, but that functionality is disabled in the AP then the client will not be able to connect. Also note that some APs have a preferred antenna for transmitting management frames. Consider trying a different cabling sequence between the Ixia test equipment and the AP.
The packet loss is 100% for all test conditions.	Double check that the AP is configured to support the MCS rate specified in the test on the client options tab. The Ixia test equipment does not change its PHY rate in a test (also known as rate adapt) because dynamically adjusting the client's PHY rate would not allow for repeatable testing. If the AP is configured properly, use a lower MCS rate, such as MCS 1. If a lower rate works as expected then the AP has a receiver problem that prevents it from receiving the less SNR (signal to noise ratio)-tolerant, high MCS rates. In order to establish the root cause of a performance issue it is necessary to examine the capture file of the test. This file is available from the IxVeriWave test system.
The AP does not achieve full theoretical line rate.	It is a common misconception that it is not possible to achieve the theoretical 802.11 maximum rate during testing. In controlled tests such as this one, all RF impairments are removed and the test setup is as reliable and as repeatable as a traditional Ethernet test bed. Any performance degradations are directly due to the hardware and software implementation within the DUT. Try to improve these designs in order to increase the forwarding rate. For 802.11ac, it may be a little while still before the chipsets are capable of achieving the full theoretical rates, but it is common to see the same chipset achieve two vastly different performance profiles when incorporated into two competitors' designs.

Test Variables

The following table lists the parameters you can vary when performing this test.

Test Variable	Description
Traffic Direction	It is common to see vastly different performance profile in the upstream (Wireless to Ethernet) and downstream (Ethernet to Wireless) directions. Upstream traffic largely tests an AP's 802.11 receive capabilities, while downstream mostly tests an AP's transmit capabilities.
Frame Size	Testing should be conducted at every frame size to ensure that there are no algorithmic bugs that cause performance degradation at specific frame sizes.
Encryption	802.11 makes extensive use of encryption to protect data frame contents. Testing should be conducted with no encryption, TKIP, and AES encryption (also known as open, WPA, and WPA2, respectively).
number of wireless clients	Increase the number of wireless clients to validate the DUT's ability to continue to achieve high rates as it needs to handle a larger amount of state information. You may want to run the Maximum Client Capacity test first, in order to determine the maximum number of clients the AP can support under low-stress conditions before running this variation.
Client PHY Configuration	Each MCS index, channel bandwidth, and guard interval condition should be tested to ensure that transmit and receive chains work as expected across all encodings.
Transmit Power Level	Forwarding rate and loss should be checked at a variety of power levels to determine the range of input power levels to the AP that results in optimal AP performance. **Note** – higher power is not always better! At higher power levels, the RF components can saturate and corrupt the RF signal. It is important to identify the range of power levels that produce optimal results for each setting.
Channel Model	Apply each of the IEEE channel models in the 802.11 client options tab. Each channel model should have no impact on performance relative to the bypass (no interference) mode in a well-designed receiver.
IPv6	Enable IPv6 and re-run the tests. For a true layer 2 AP, the performance should be identical. However, many APs perform some operations at layer 3 and can see significantly lower performance with IPv6 enabled.

Conclusion

A simple packet loss test can be used to identify a large variety of performance degradations in an 802.11ac access point. The test results are highly repeatable when the test bed is properly RF-isolated in a chamber and tested using RF cables and is therefore ideal for testing performance under a wide variety of conditions. This test should always be the first test run when assessing an AP. Poor test results should never be ignored because they manifest themselves as much more complicated issues in the advanced testing.

Test Case: Maximum Client Capacity

Overview

The Maximum Client Capacity test measures the number of clients that can successfully associate with APs in the SUT and transfer traffic to the distribution system (wired LAN). It measures the ability of APs in the SUT to support a large number of concurrent users.

The Maximum Client Capacity is intended to be a test of the AP's control plane capacity and not the data forwarding rate capacity. Once the maximum client capacity is known, the other tests in this document can be performed to determine the corresponding data forwarding performance.

The test methodology is to slowly connect clients to the system until the target numbers of clients are connected or until the AP refuses any further client connections. Once this state is achieved, a low rate of traffic is transmitted to each client in order to ensure that the AP has, in fact, loaded the client into the forwarding table and can maintain the state for all of the clients concurrently. If there is excessive packet loss during this test, then the number of clients is reduced and the traffic test is re-run. This pattern continues until all connected clients receive a minimal rate of traffic.

Objective

The objective of this test is to determine the maximum number of clients the DUT can serve.

Setup

As shown in Figure 1 below, the test consists of a DUT acting as an access point, and two Ixia test ports.

The 802.11 Ixia test port emulates up to 500 stateful Wi-Fi clients sending and receiving traffic from the wireless interface on the DUT. The other Ixia port emulates servers on the Ethernet network that source and sink the traffic from the Wi-Fi clients.

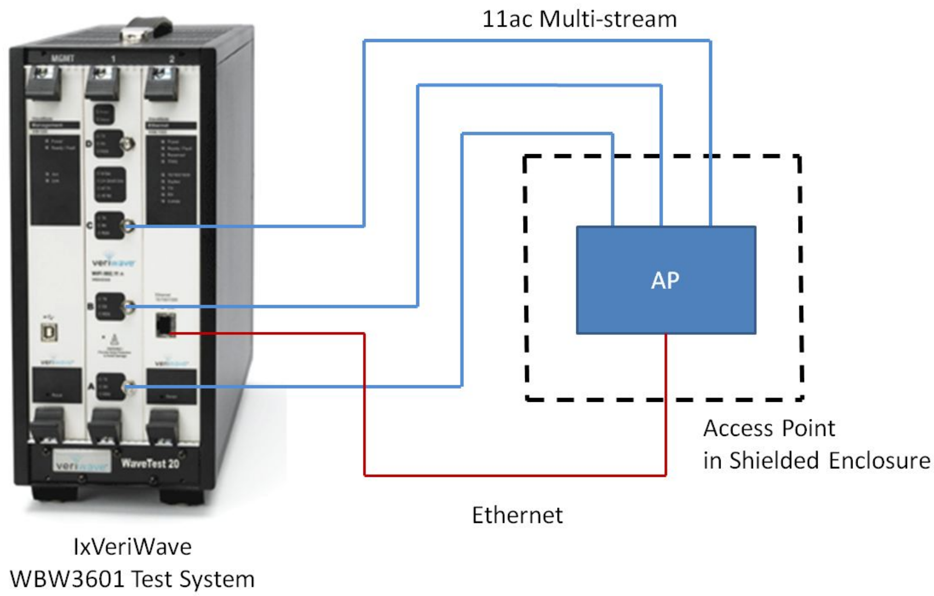


Figure 1. Test Setup

In the test setup above the DUT is placed in an isolation chamber to ensure that external signals do not affect test results. By connecting the AP to the test chassis with RF cables and enclosing the AP in an RF isolation chamber, you can be sure that other devices using the same frequencies do not affect the test results.

Step-by-step Instructions – Maximum Client Capacity

Follow the step-by-step instructions to create a Client Capacity benchmark test.

1. Select File Open and select the configuration file from step 8 from the Packet Loss test.

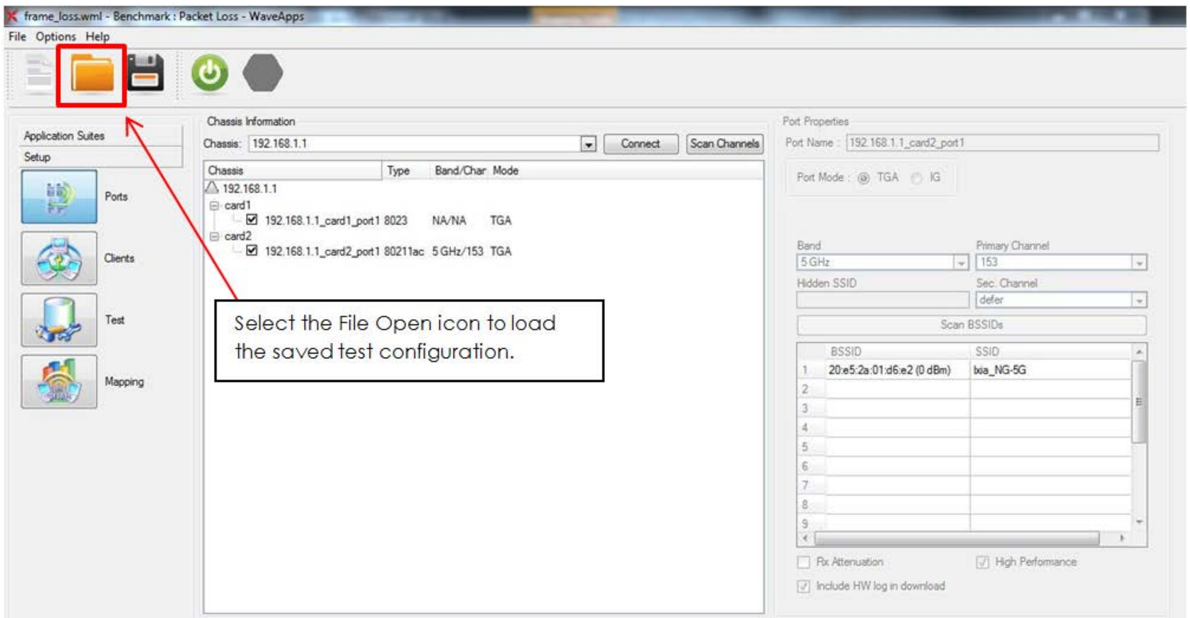


Figure 9. Test Suite Selection

2. Select Maximum Client Capacity Test Suite and click start test configuration.

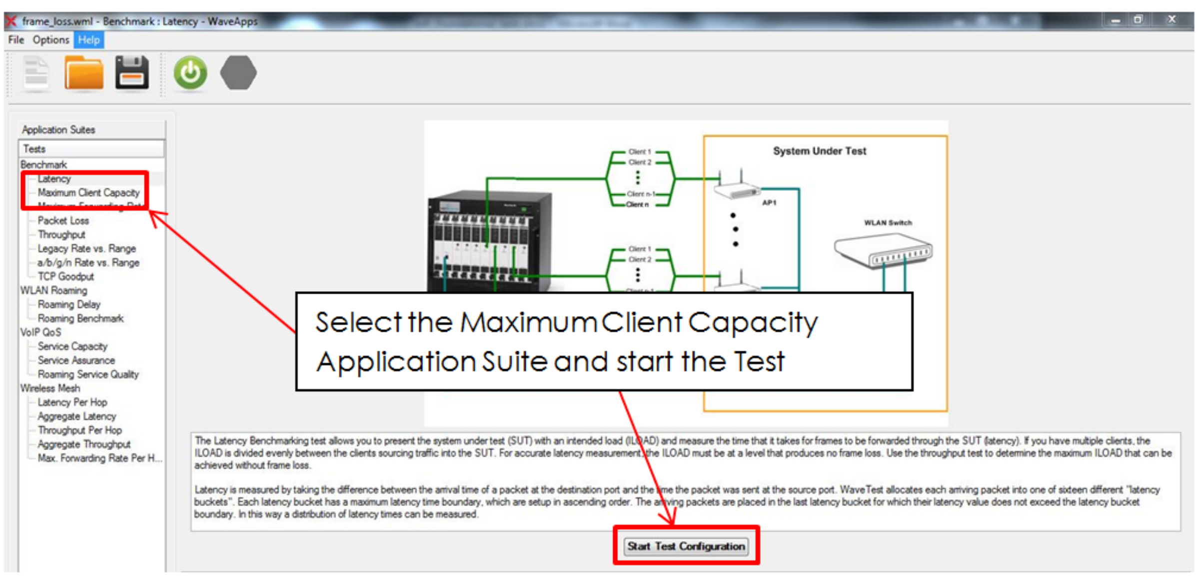


Figure 10. Application Suite Selection

Figure 11. Connect to the test chassis and select the port to use for following tests.

Note: When scanning for channels the scan stops at the lowest channel that has an active signal on it. If the channel detected is not the channel desired for the test enter the band and channel using the drop down menus at the right, then click the Scan BSSISs button to obtain the desired BSSID/SSID.

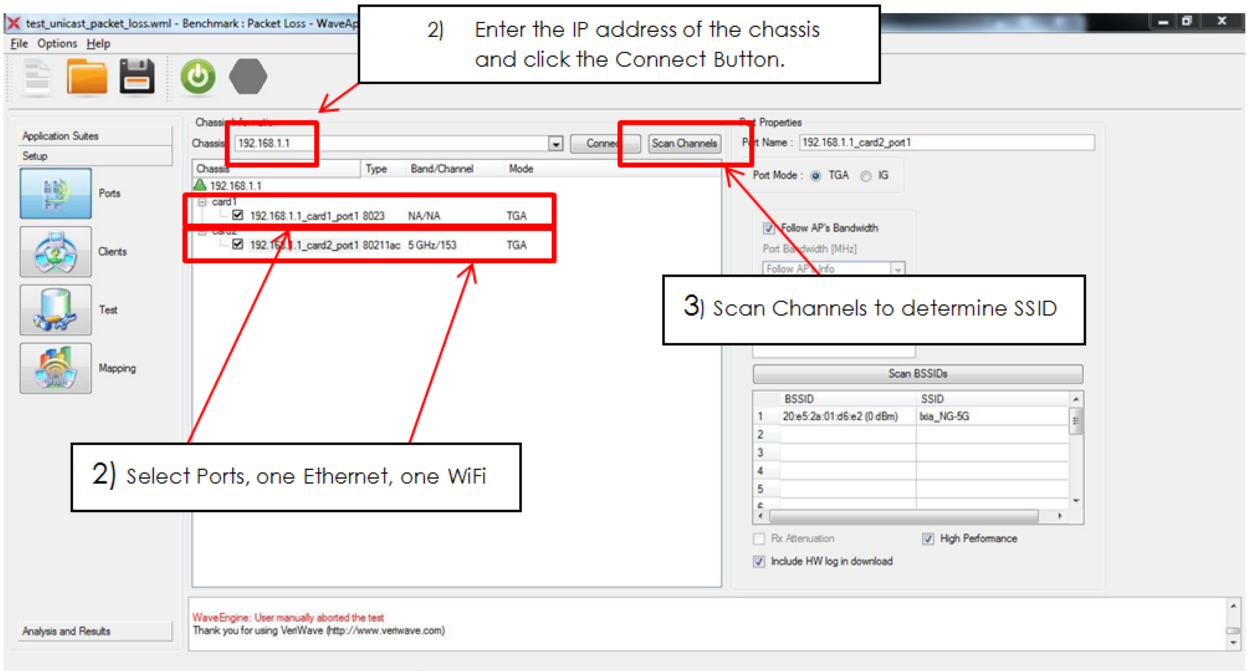


Figure 11. Port Selection

Figure 12. Create and name the clients. Click the Clients button on the left navigation panel. Click on the "+" to create a client group. Type the name in the "Name" box and select the interface type from the drop down menu. Select the Wi-Fi port and configure the client as shown below.

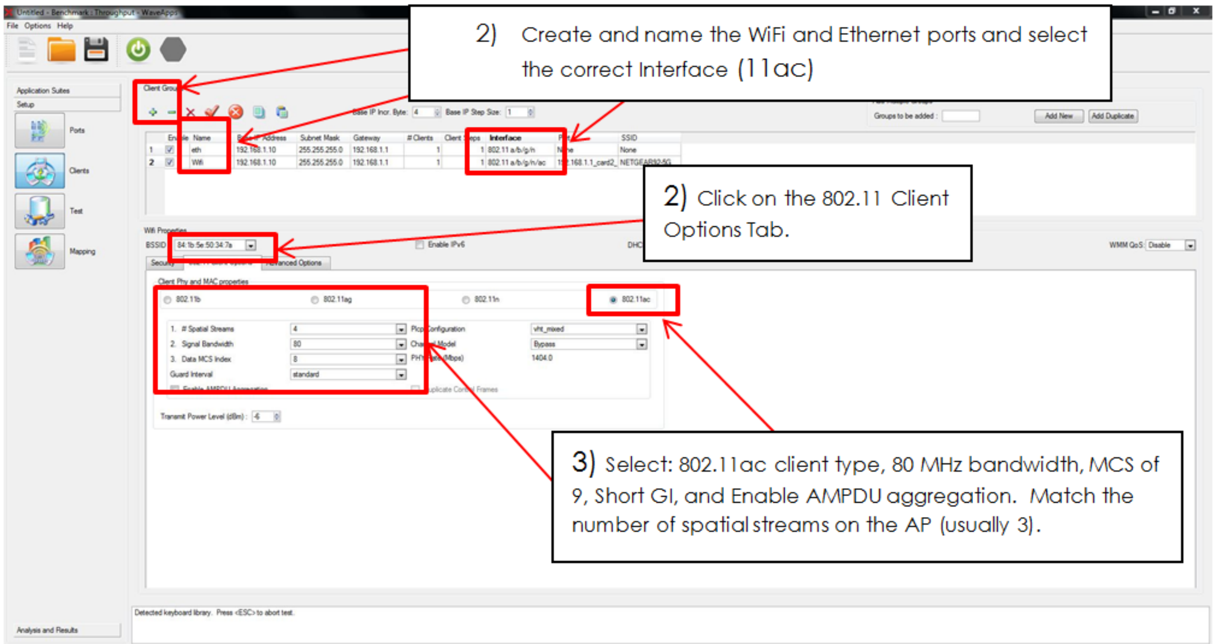


Figure 12. Client Characteristics

3. Click the Test setup button and select the Maximum Client Capacity Properties tab. Enter the Search Maximum of 100 clients.

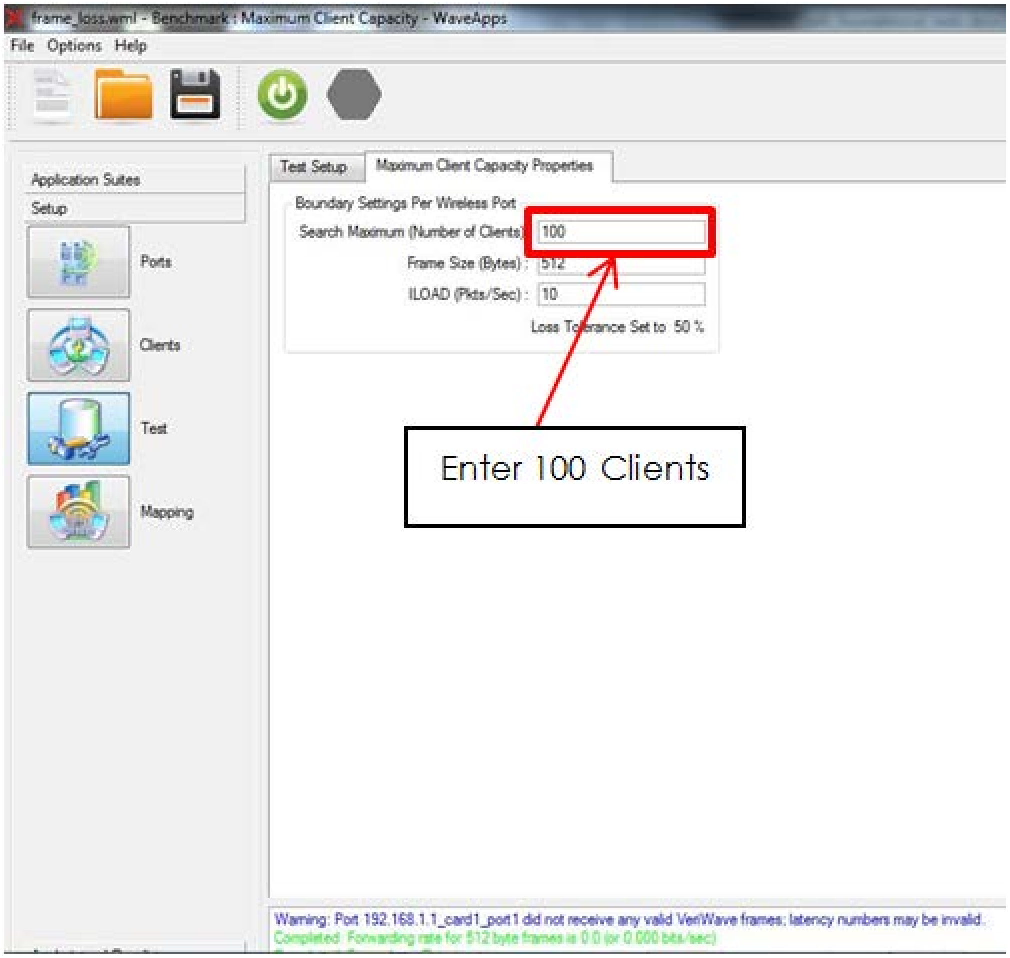


Figure 13. Enter Search Maximum

4. Click the Mapping button and select the Mapping Option Wireless to Ethernet to perform an upstream Maximum Client Capacity test.

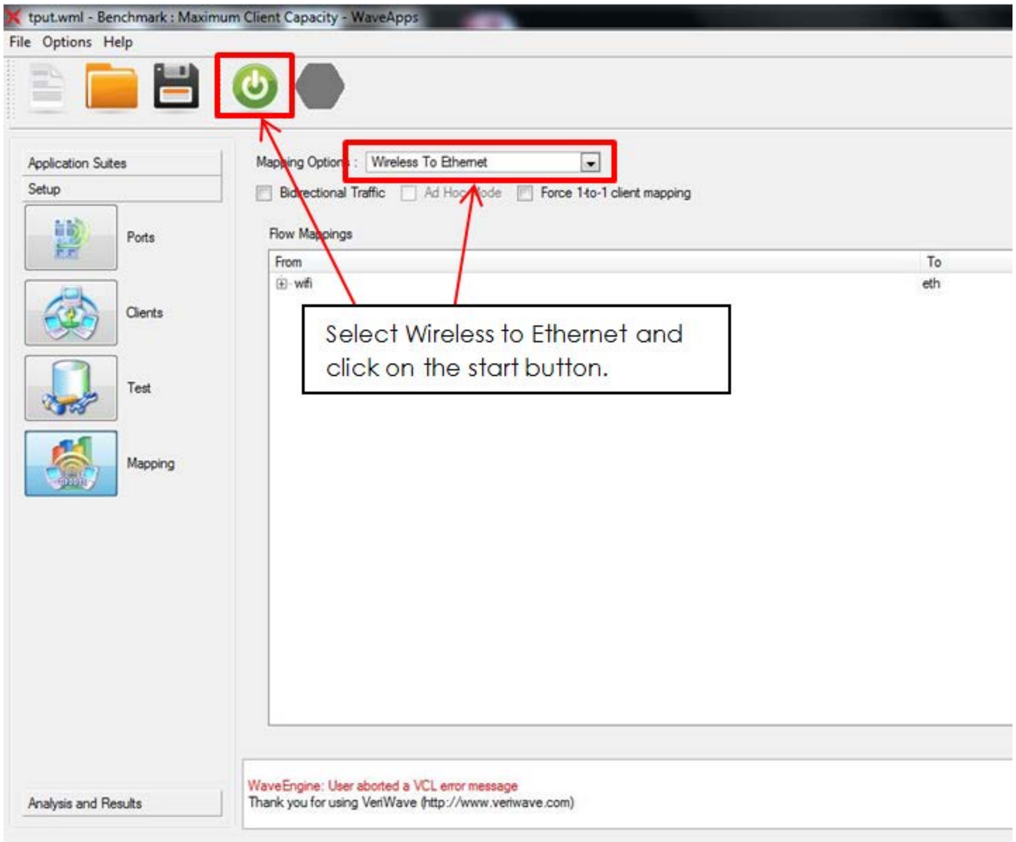
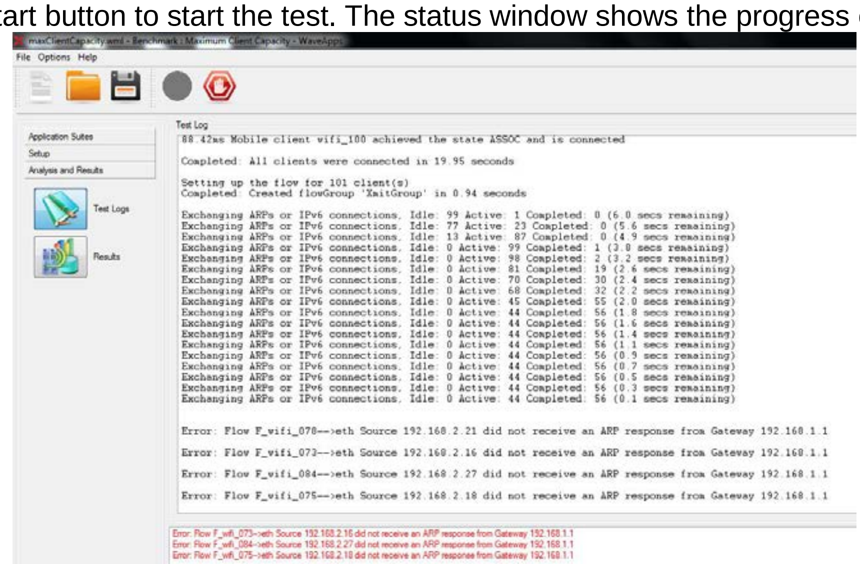


Figure 14. Mapping Options

5. Click the start button to start the test. The status window shows the progress of the test.



Test Results

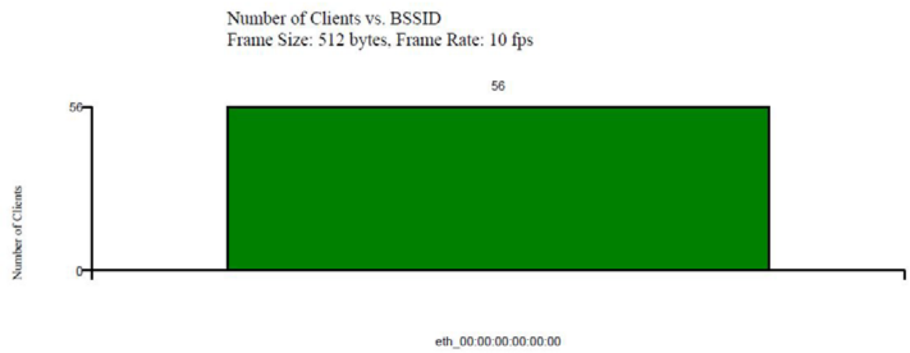


Figure 15. Maximum Client Capacity Test Results

Result Analysis

The maximum client capacity test determines the maximum number of clients that can be connected to an AP under low traffic load conditions. This metric can be extremely useful when running the remaining benchmark tests because it defines an upper limit on the number of clients that should be tested.

It should be noted that many APs may not support the maximum client capacity when subjected to a heavier traffic load or realistic mixes of traffic. The result of this test should only be considered as the best possible case to determine the number of clients that can be connected simultaneously to the AP. For a more realistic idea of the number of clients that can be supported in a typical deployment, it is necessary to perform more stressful or real-world test cases using WaveQoE.

Troubleshooting and Diagnostics

The following table lists the common access point performance problems and the tips to troubleshoot these problems.

Issue	Troubleshooting Tip
Test always succeeds at maximum number of clients.	The AP is capable of supporting your maximum number of configured clients. Repeat the test after increasing the number of clients as described in step 3 above. Ensure that you maintain appropriate address spacing for the targeted number of clients on the client page.
The test runs for a long time and then aborts saying that a result could not be found.	This condition occurs when the AP is able to connect to a lot of clients, but cannot forward traffic to all of the clients that are connected. The test logic will try to lower the number of connected clients a few times, but if the situation does not improve, the test ends. Consider re-running the test with either a lower client count or a lower intended load (ILOAD in step 3 above).

Test Variables

The following table lists the parameters you can vary when performing this test.

Test Variable	Description
Client Type	Re-run the test for different client types such as 802.11a, b, g, n, and ac.
DHCP Enabled	Enable DHCP to see the impact on the number of connected clients. Most 802.11 networks utilize DHCP.
IPv6	Enable IPv6 and re-run the tests. For a true layer 2 AP, the performance should be identical. However, many APs perform some operations at layer 3 and require more memory and resources to support IPv6.

Conclusion

The maximum client capacity is good to know in order to assess the best case scenario for the DUT. This number should not be mistaken for an accurate prediction of the number of clients that can be supported by the AP with real application traffic.

It is important to view this number as a boundary case only and use it to shorten the timing of your remaining tests by limiting your client scale in those tests accordingly.

Test Case: Latency Benchmark Test

Overview

The latency test measures the delay incurred by frames passing through the system under test (SUT). It also measures the amount of jitter, which is the variation in latency over many frames. Latency and jitter are key performance metrics that determine how well the SUT can handle critical real-time traffic, such as, voice and video that is sensitive to the delay between source and destination. This test measures latency and jitter according to RFC 2544 and RFC 3550, respectively.

Objective

The objective of this test is to determine the average and worst case latency of the DUT.

Setup

As shown in Figure 1 below, the test consists of a DUT acting as an access point, and two Ixia test ports.

The 802.11 Ixia test port emulates up to 500 stateful Wi-Fi clients sending and receiving traffic from the wireless interface on the DUT. The other Ixia port emulates servers on the Ethernet network that source and sink the traffic from the Wi-Fi clients.

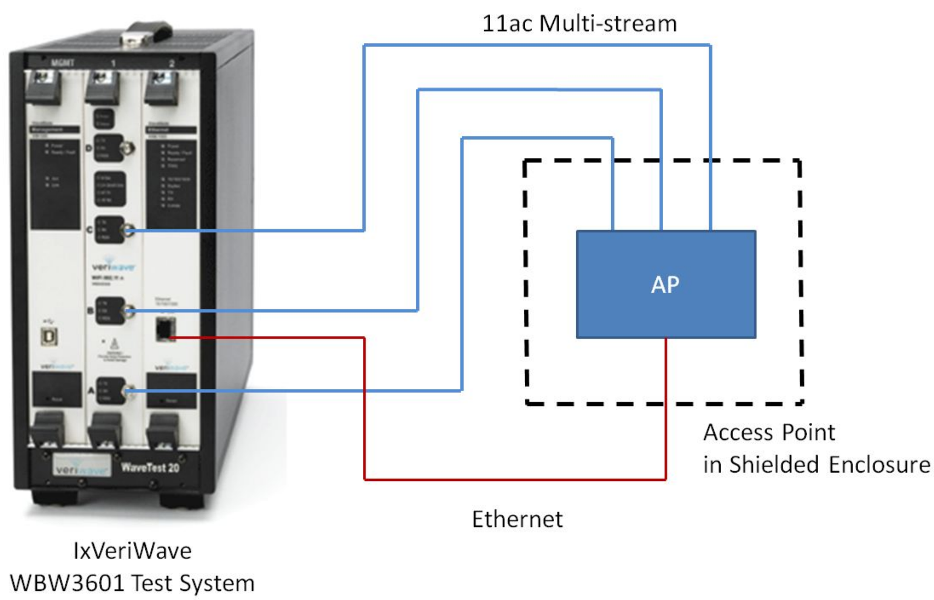


Figure 1. Test Setup

In the test setup above the DUT is placed in an isolation chamber to ensure that external signals do not affect test results. By connecting the AP to the test chassis with RF cables and enclosing the AP in an RF isolation chamber, you can be sure that other devices using the same frequencies do not affect the test results.

Step-by-step Instructions – Latency Test

Follow the step-by-step instructions to create a latency benchmark test. In addition, you can use the steps below as a guide for building many other layer 2/3 WLAN benchmark tests scenarios.

1. The easiest way to create a test is to start with a configuration from a similar test. In this case we will start with the packet loss benchmark test and modify it to run a latency test. Select File Open and select the configuration from the previous test.

2. Select the Application Suites thumb in the left-side navigation bar and then select the Latency Test Suite. Click the Start Test Configuration button.

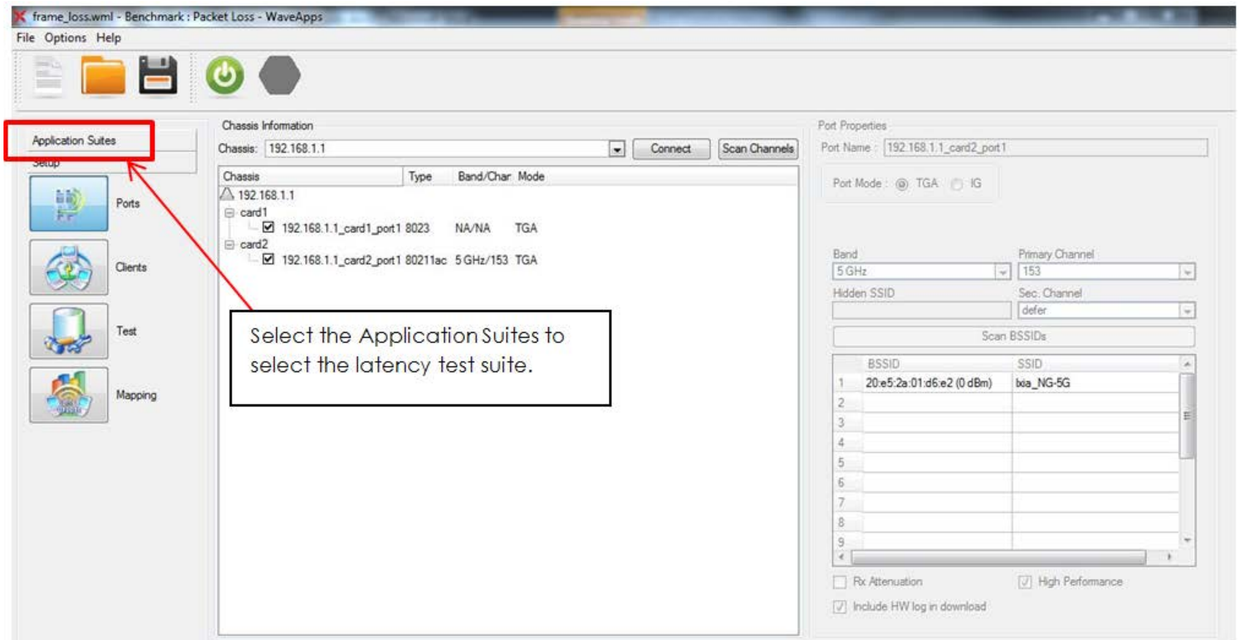


Figure 16. Test Suite Selection

3. Click the Start Test Configuration button.

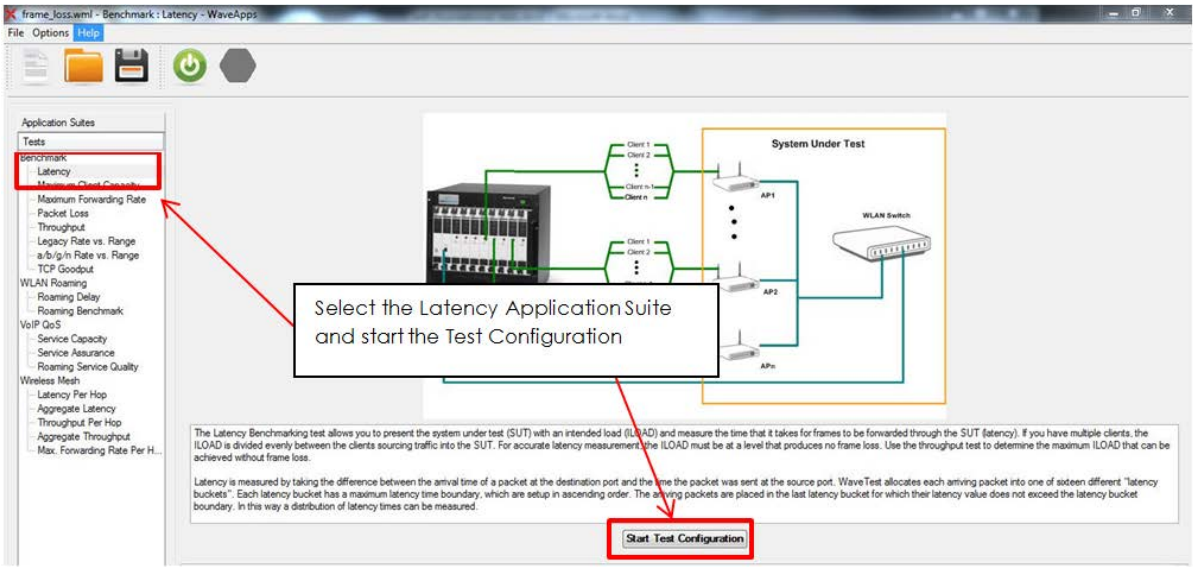


Figure 17. Application Suite Selection

Figure 18. Connect to the test chassis and select the port to use for following tests.

Note: When scanning for channels the scan stops at the lowest channel that has an active signal on it. If the channel detected is not the channel desired for the test enter the band and channel using the drop down menus at the right, then click the Scan BSSISs button to obtain the desired BSSID/SSID.

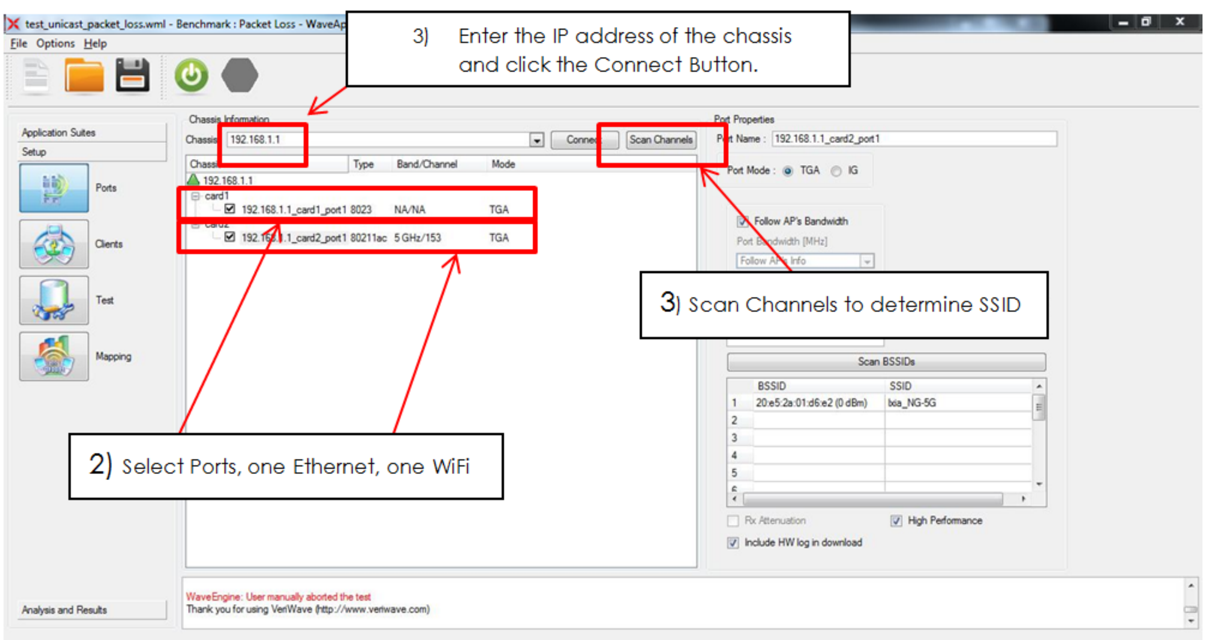


Figure 18. Port Selection

Figure 19. Create and name the clients. Click the Clients button on the left navigation panel. Click on the "+" to create a client group. Type the name in the "Name" box and select the interface type from the drop down menu. Select the Wi-Fi port and configure the client as shown below.

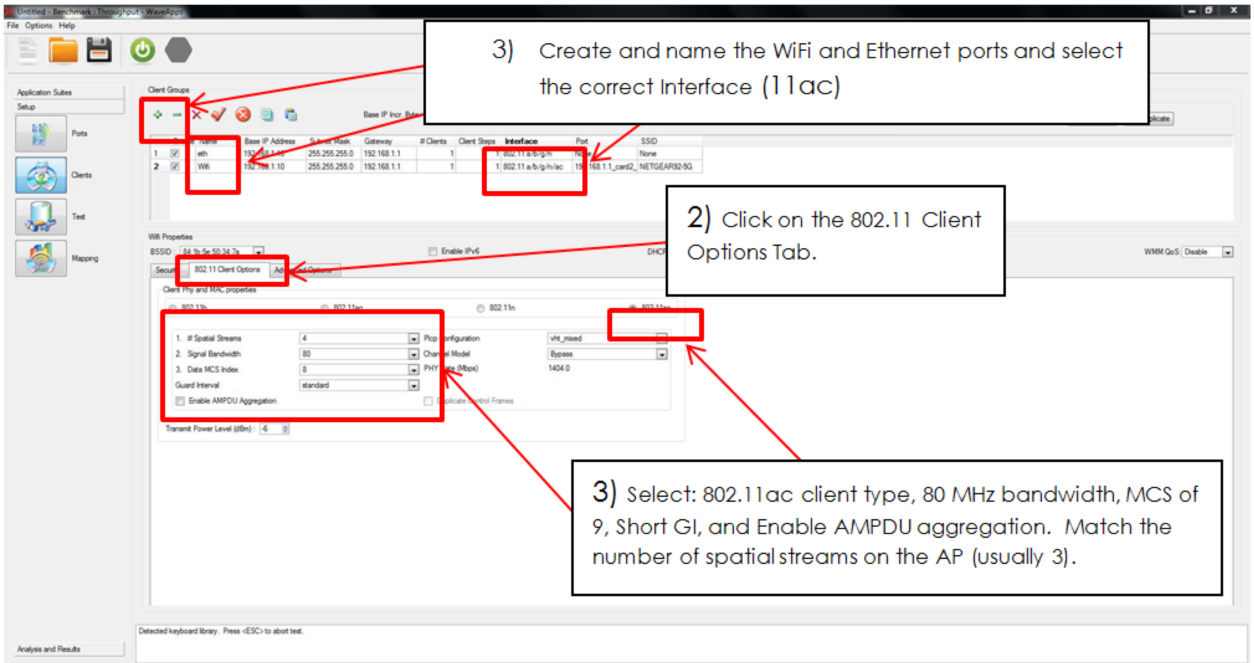


Figure 19. Client Characteristics

4. Click the Test setup button and select the Latency Properties tab. Using g maximum throughput numbers derived by doing a Throughput Benchmark test, set the ILOAD for each packet size.

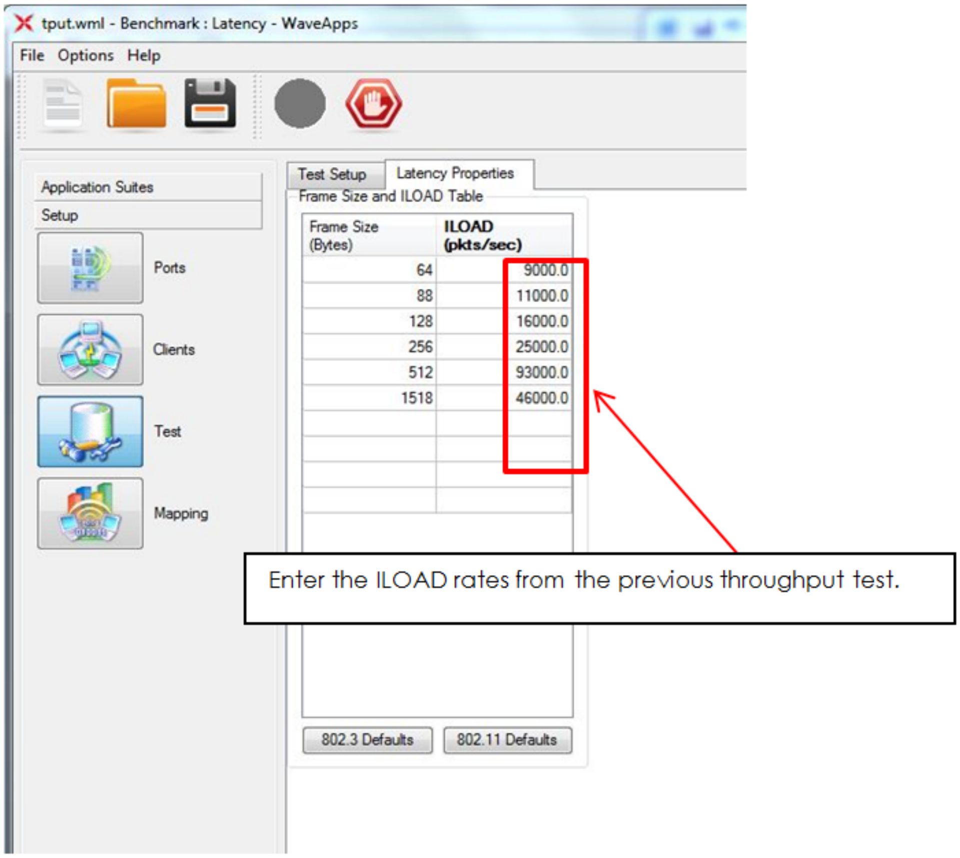


Figure 20. Test Parameters

5. Click the Mapping button and select the Mapping Option Wireless to Ethernet to perform an upstream latency test.

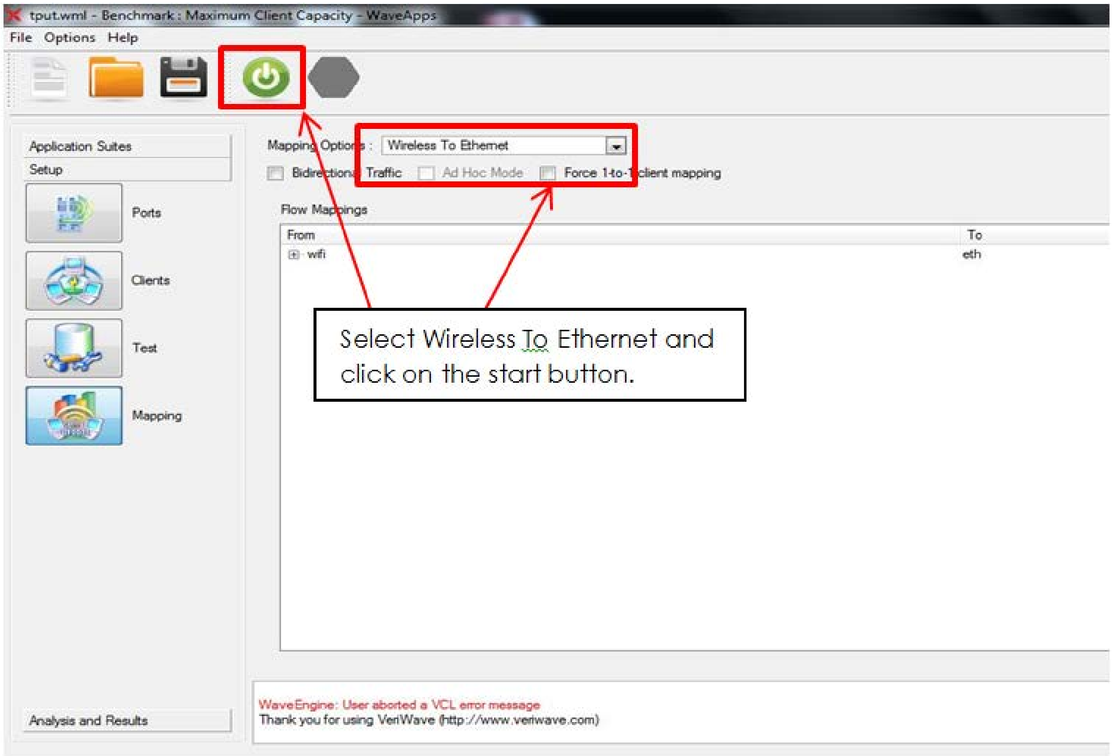
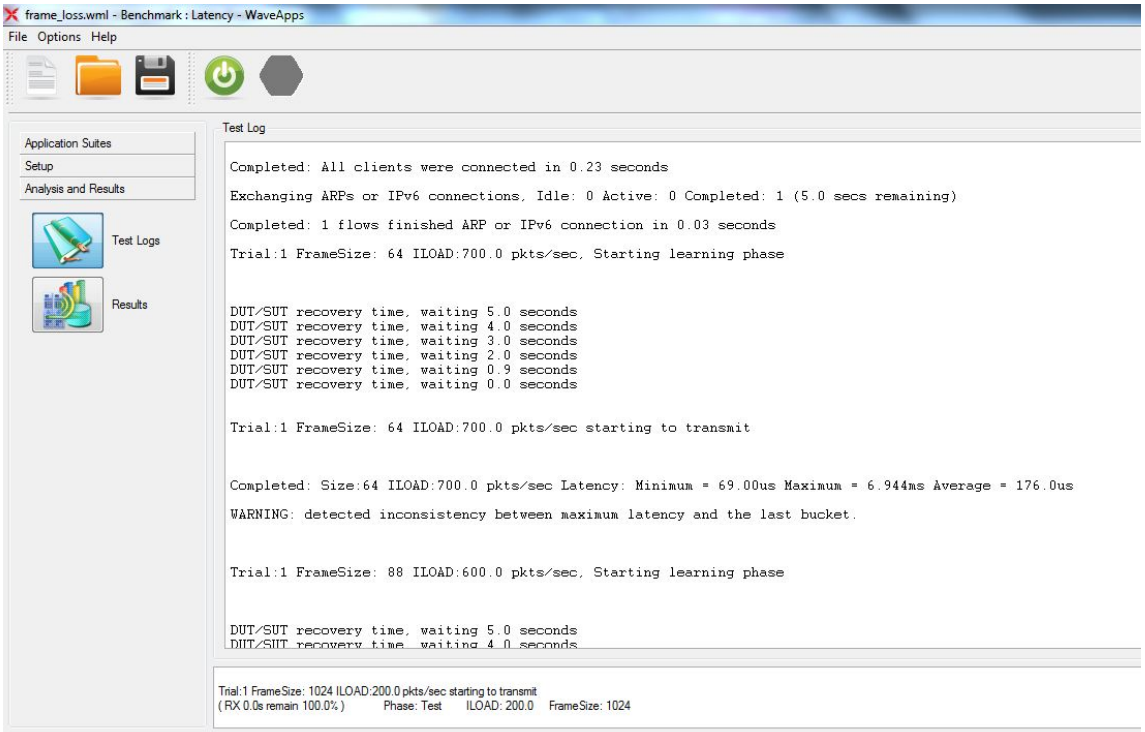


Figure 21. Mapping Options

6. Click the start button to start the Latency test. The status window shows the progress of the test.



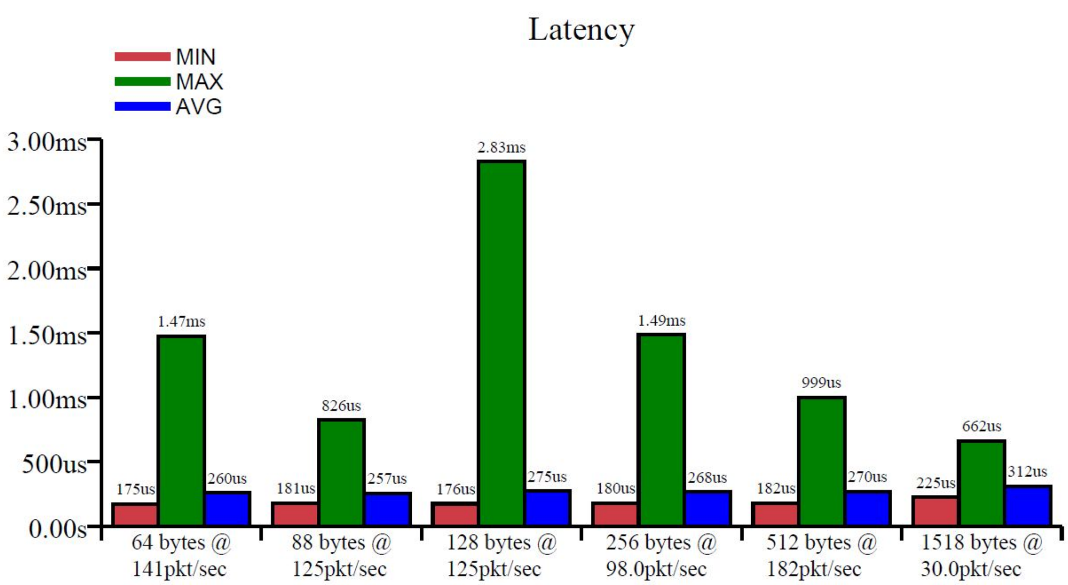


Figure 22. Latency Test Results

Detailed Results

Frame Size	Frame Rate	Trial Number	Minimum Latency	Maximum Latency	Average Latency	Average Jitter
64	141.0	1	175.0us	1.475ms	260.0us	39.58us
88	125.0	1	181.0us	826.0us	257.0us	41.89us
128	125.0	1	176.0us	2.828ms	275.0us	69.80us
256	98.0	1	180.0us	1.486ms	268.0us	48.46us
512	182.0	1	182.0us	999.0us	270.0us	45.32us
1518	30.0	1	225.0us	662.0us	312.0us	53.23us

Figure 23. Jitter Test Results

7. Save the configuration file from the test before exiting the test or continuing with the next benchmark test.

Result Analysis

The latency and jitter at different frame sizes are useful for indicating areas where the DUT takes extra time processing the frames when forwarding. Ideally, the latency would be consistent across all frame sizes and have a low overall absolute value.

High latency can lead to issues with responsiveness in real-time, interactive applications such as changing TV channels with a set top box. It also can have a throttling effect on TCP which slows down all the applications that run over TCP.

Troubleshooting and Diagnostics

The following table lists the common access point performance problems and the tips to troubleshoot these problems.

Issue	Troubleshooting Tip
The maximum latency is hundreds of milliseconds or more, but the average and minimum latency are reasonable.	This could happen due to one of the following: • The AP takes a long time delivering the first few frames before it has "learned" the location of the destination. After the first few frames, the ensuing traffic is placed onto the "fast path" and the latency improves dramatically. • There is an intermittent or recurring interruption in the system that is affecting the delivery of frames. For example, in APs where the firmware handles the frame delivery, it is common to have the firmware perform a management function for a short period of time and stall all the frame deliveries during that interval.

Issue	Troubleshooting Tip
	The key to identify and eliminate these issues is to examine the packet captures.

Test Variables

The following table lists the parameters you can vary when performing this test.

Test Variable	Description
Traffic Direction	It is common to see vastly different performance profile in the upstream (Wireless to Ethernet) and downstream (Ethernet to Wireless) directions. Upstream traffic largely tests an AP's 802.11 receive capabilities, while downstream mostly tests an AP's transmit capabilities.
Frame Size	Testing should be conducted at every frame size to ensure that there are no algorithmic bugs that cause performance degradation at specific frame sizes.
Encryption	The 802.11 standard makes extensive use of encryption to protect data frame contents. Testing should be conducted with no encryption, TKIP, and AES encryption (also known as open, WPA, and WPA2, respectively).
Number of wireless clients	Increase the number of wireless clients to validate the DUT's ability to continue to achieve high rates as it needs to handle a larger amount of state information. You may want to run the Maximum Client Capacity test first, in order to determine the maximum number of clients the AP can support under low-stress conditions before running this variation.
Client PHY Configuration	Each MCS index, channel bandwidth, and guard interval condition should be tested to ensure that transmit and receive chains work as expected across all encodings.
Transmit Power Level	Performance should be checked at a variety of power levels to determine the range of input power levels to the AP that results in optimal AP performance. **Note** – higher power is not always better! At higher power levels, the RF components can saturate and corrupt the RF signal. It is important to identify the range of power levels that produce optimal results for each setting.

Test Variable	Description
Channel Model	Apply each of the IEEE channel models in the 802.11 client options tab. Each channel model should have no impact on performance relative to the bypass (no interference) mode in a well-designed receiver.
IPv6	Enable IPv6 and re-run the tests. For a true layer 2 AP, the performance should be identical. However, many APs perform some operations at layer 3 and can see significantly lower performance with IPv6 enabled.

Conclusion

The latency test is a good choice for identifying behaviors that limit the performance of the AP. The unique patterns of the latency can be used to identify the portion of the design that is contributing to the problem. For example, a slowly increasing latency with time indicates a buffering issue. A spike in latency at a particular frame size indicates a new operation that must be undertaken to forward the frame. With low, predictable latency and latency variation, you can be reasonably certain that real-time, delay-sensitive applications run smoothly and that the TCP-based protocols are not delay-bound.

Test Case: Throughput Benchmark Test

Overview

The throughput test measures a key performance metric, the maximum rate at which frames can be injected into the system under test (SUT) without exceeding a pre-set loss threshold. If the loss threshold is zero, this corresponds to the classical definition of throughput as per RFC 2544.

Throughput is very important in assessing performance under higher-layer protocols such as TCP, where even small amounts of loss can significantly impact user applications.

Note that customers, and even some test tools, commonly confuse throughput with forwarding rate. The two measurements are not the same. Classical throughput, the maximum rate at which frames can be forwarded without any packet loss, can commonly be zero while the forwarding rate can be in the hundreds of megabits per second with a small amount of loss. The troubleshooting section describes this in more detail.

Also note that a throughput test is a “goal-seeking” test. That means that it can take many test trials and a fair amount of time to identify the throughput of an access point. In contrast, forwarding rate runs one trial and then reports the results and is therefore much faster. For these two reasons, we highly recommend that the forwarding rate and packet loss test be run first before running a throughput test. The throughput test is very useful, but it can be confusing to interpret if you do not have the forwarding rate results.

Objective

The objective of this test is to determine the maximum throughput rate the DUT is capable of supporting at a set of frame sizes. The throughput is the maximum rate at which frames can be injected into the system under test (SUT) without exceeding a pre-set loss threshold.

Setup

As shown in Figure 1 below, the test consists of a DUT, acting as an access point, and two Ixia test ports.

The 802.11 Ixia test port emulates up to 500 stateful Wi-Fi clients sending and receiving traffic from the wireless interface on the DUT. The other Ixia port emulates servers on the Ethernet network that source and sink the traffic from the Wi-Fi clients.

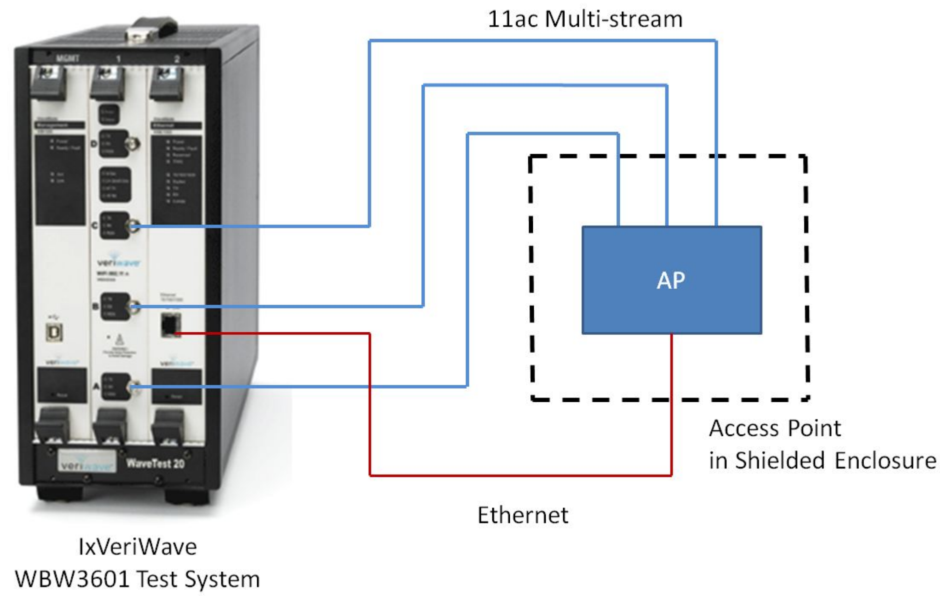


Figure 1. Test Setup

In the test setup above the DUT is placed in an isolation chamber to ensure that external signals do not affect test results. By connecting the AP to the test chassis with RF cables and enclosing the AP in an RF isolation chamber, you can be sure that other devices using the same frequencies do not affect the test results.

Step-by-step Instructions – Throughput Test

1. Select File Open and select the saved .wml configuration file from the packet loss test.

2. Select the Application Suites button in the left-side navigation bar and then select the Throughput test suite. Click the Start Test Configuration button.

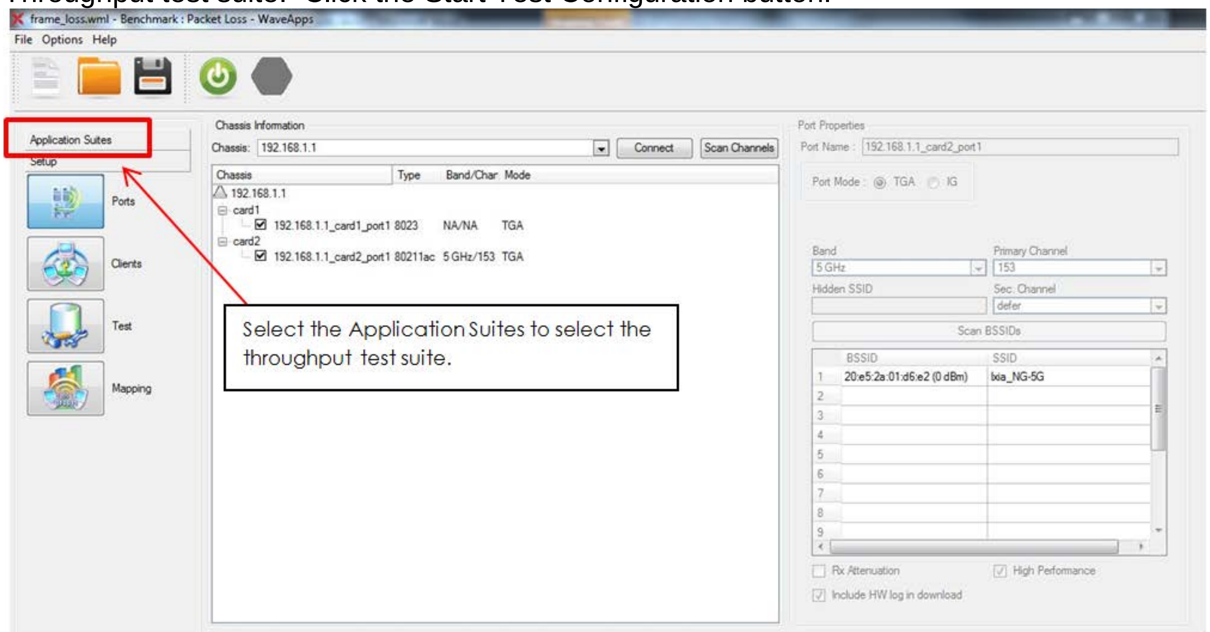


Figure 24. Test Suite Selection

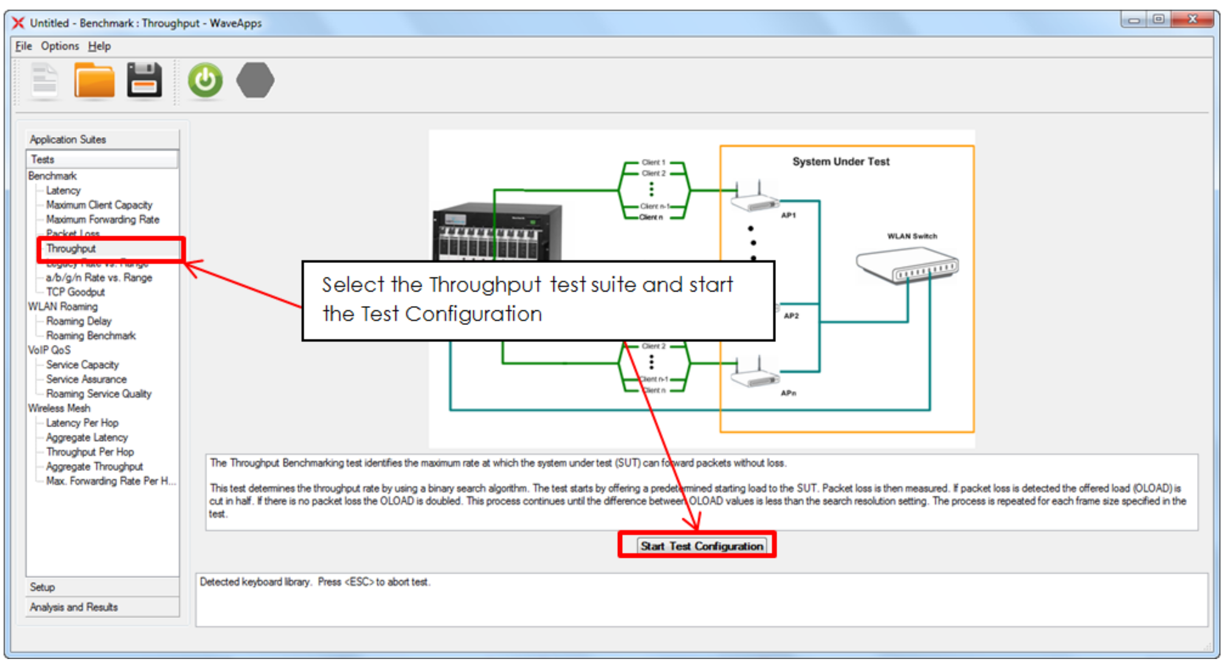


Figure 25. Application Suite Selection

3. Connect to test chassis and select port to use for following test.

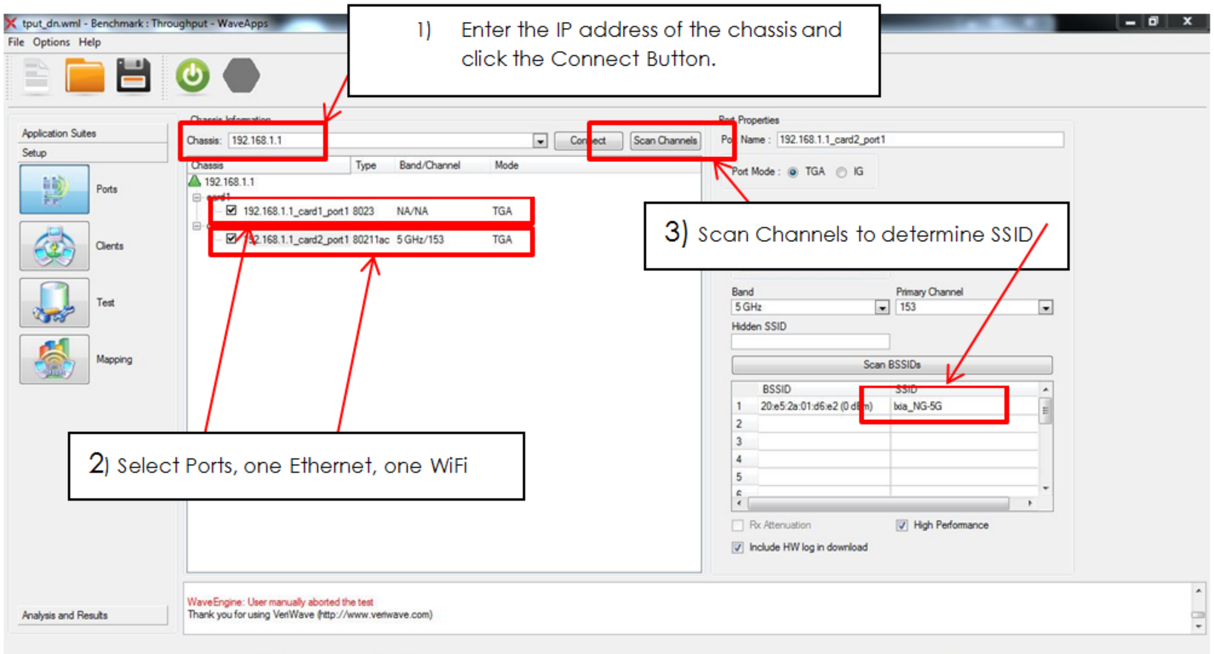


Figure 26. Port Reservation

Click the Test setup button to configure the test. The defaults on this page are used to perform the throughput tests. Make sure the loss tolerance is set for 0.1%.

Note: The loss tolerance allows the throughput trial to pass if there is a small amount of loss. This loss will commonly occur with the first few frames in a trial. If this value is set to zero loss tolerance, which is the definition in RFC-2544, it is not un-common for APs to have a throughput of 0 for all the frames.

Figure 27. Connect to the test chassis and select the port to use for following tests.
Note: When scanning for channels the scan stops at the lowest channel that has an active signal on it. If the channel detected is not the channel desired for the test enter the band and channel using the drop down menus at the right, then click the Scan BSSISs button to obtain the desired BSSID/SSID.

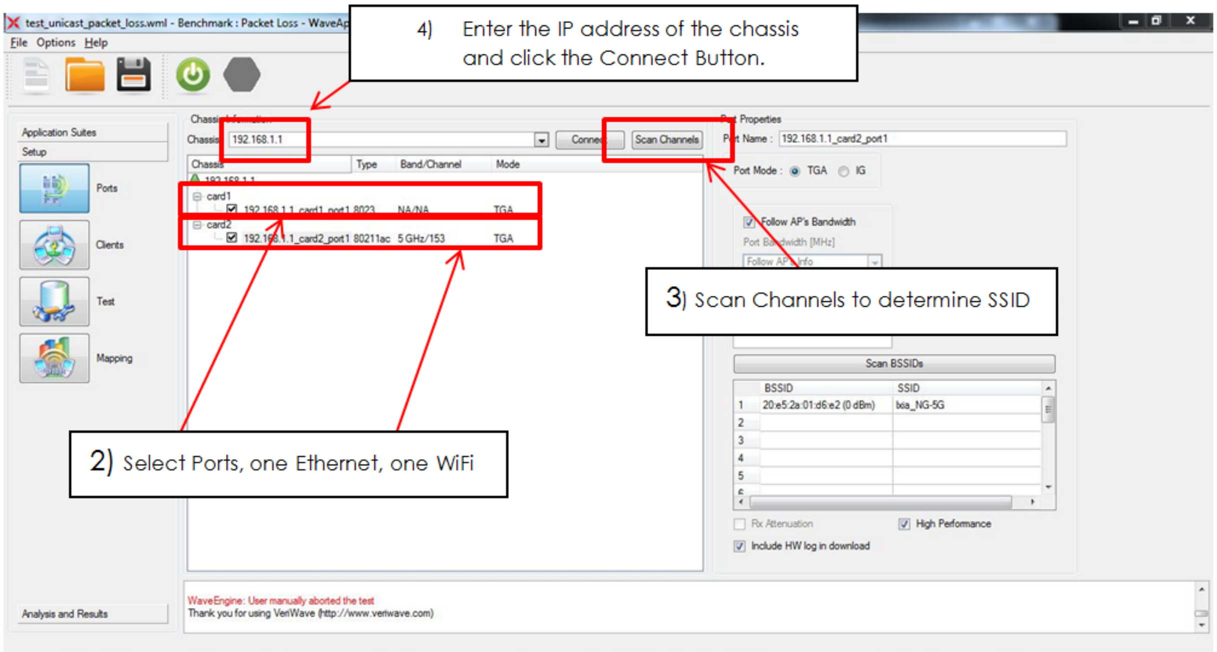


Figure 27. Port Selection

Figure 28. Create and name the clients. Click the Clients button on the left navigation panel. Click on the "+" to create a client group. Type the name in the "Name" box and select the interface type from the drop down menu. Select the Wi-Fi port and configure the client as shown below.

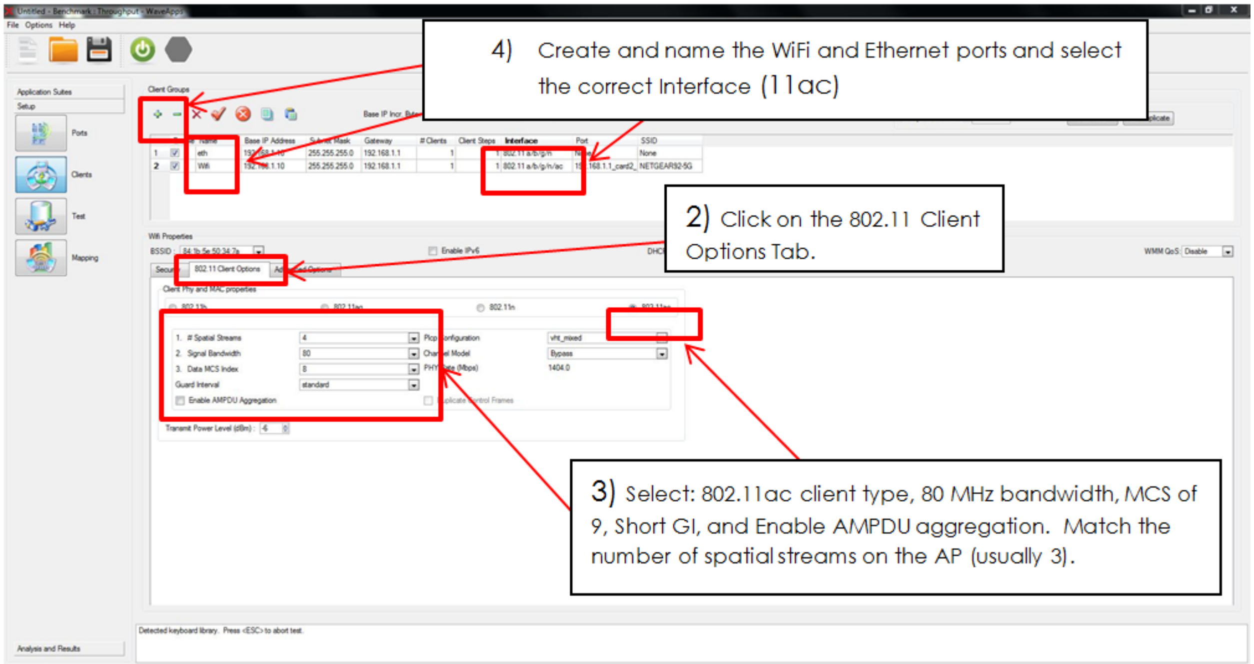


Figure 28. Client Characteristics

Click the Test setup button and select the Throughput Properties tab. Specify the frame size and frame rates that you want to use to run a Throughput test. It is recommended to use minimum, typical, and maximum length frames in order to test the maximum frame rate that the AP must handle. Short frames test the maximum frame rate and long frames test the maximum bit rate.

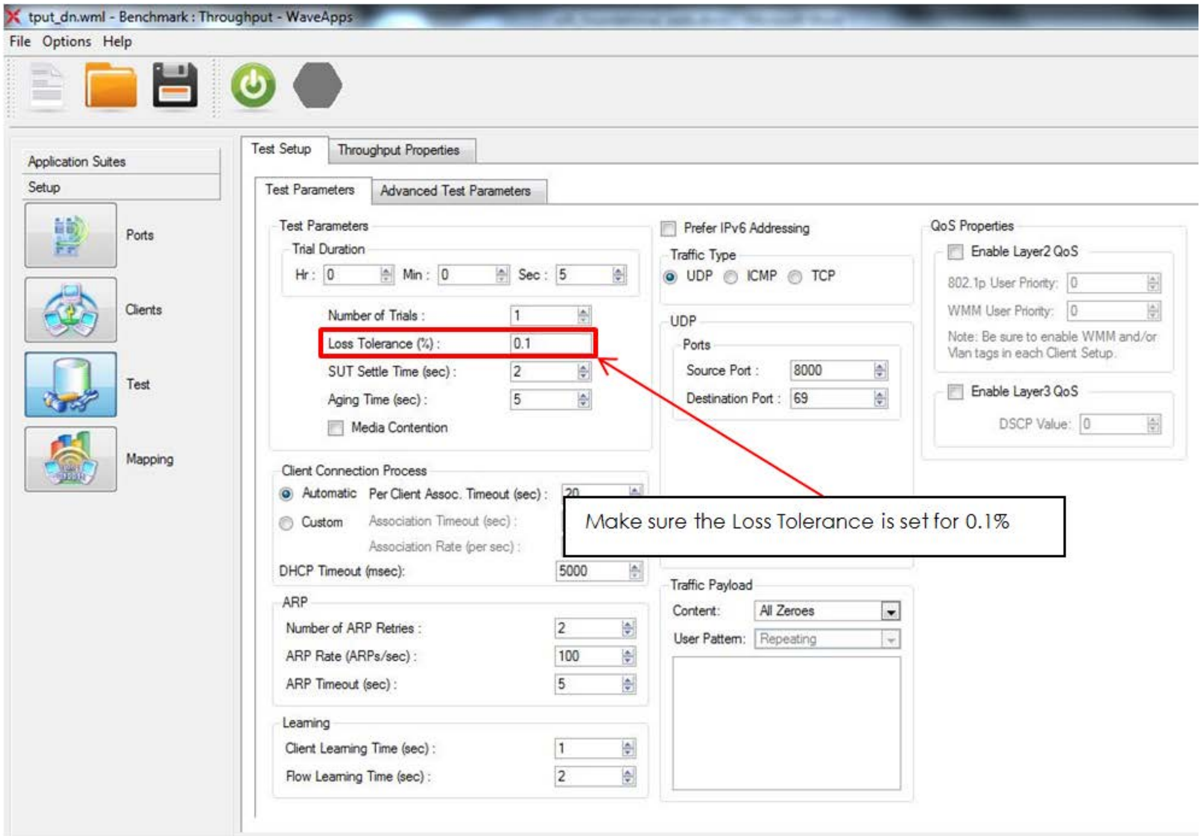


Figure 29. Test Parameters

4. Click the Throughput Properties tab and select the Default Frame Size for 802.3.

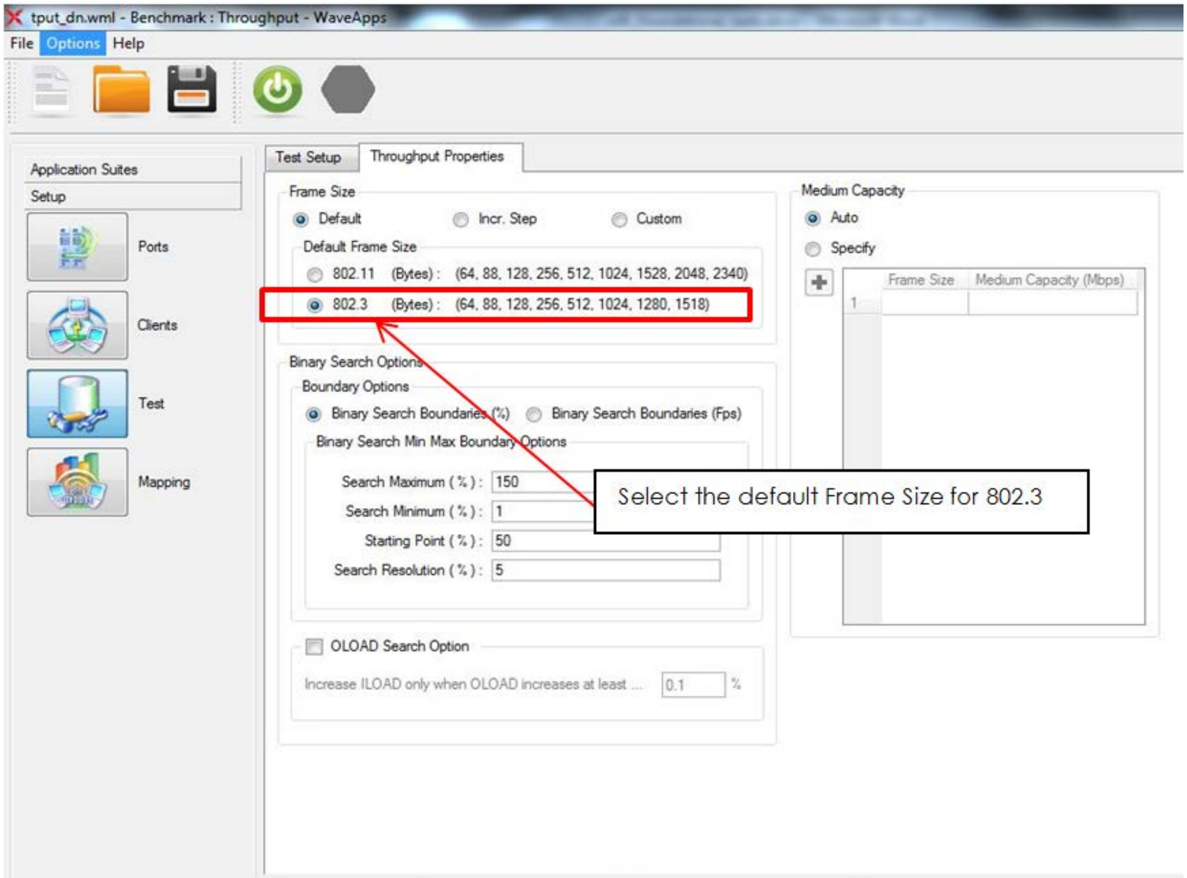


Figure 30. Throughput Properties

5. Click the Mapping button and select the Mapping Option Ethernet to Wireless to perform an upstream throughput test.

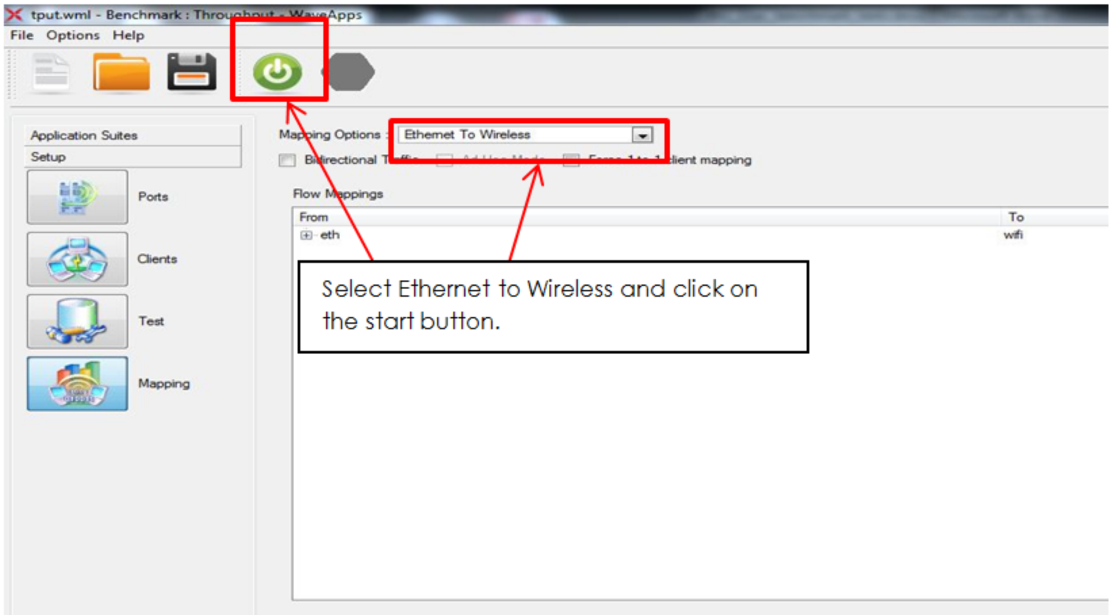


Figure 31. Mapping Options

6. Click the start button to start the throughput test. The status window shows the progress of the test.

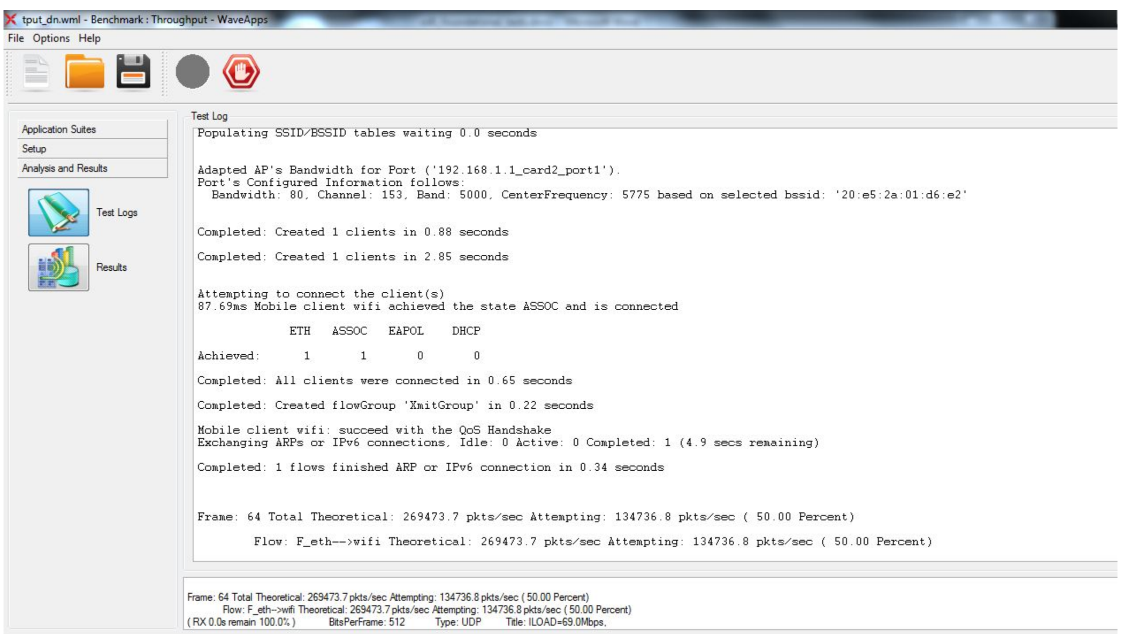
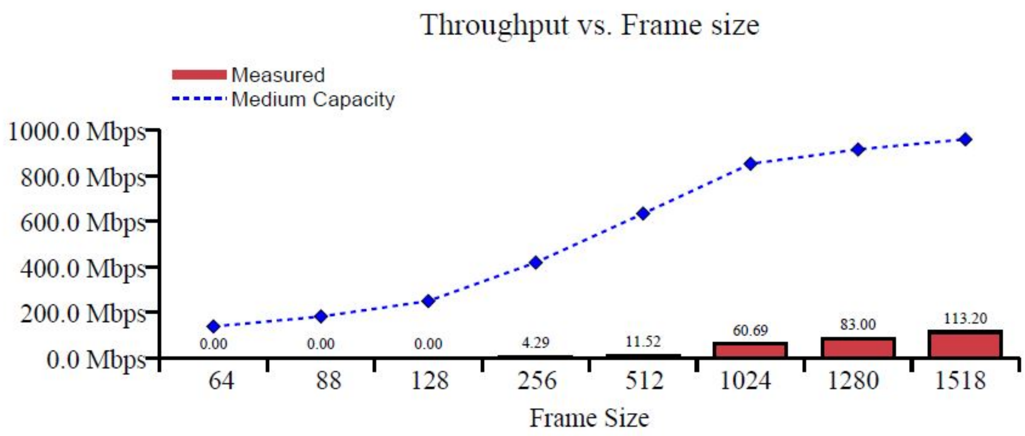


Figure 32. Test Status Window

7. The results graph from the Throughput report showing a maximum throughput of 113 Mbps with 1518 byte frames.



8. Save a copy of the test configuration for later use.

Result Analysis

The throughput at different frame sizes is commonly referenced by users as one of their key performance metrics. As such, it is critical that testers understand the throughput values and address any issues before they are uncovered by customers.

The throughput test is highly sensitive to packet loss as well as a variety of layer 2 protocol issues. By examining the results of the throughput test and the results of the other benchmark tests, it is possible to significantly improve the throughput of the AP.

Troubleshooting and Diagnostics

The following table lists the common access point performance problems and the tips to troubleshoot these problems.

Issue	Troubleshooting Tip
Throughput is zero for all frame lengths	This usually indicates that the AP is dropping a few frames every time a trial is run. Compare the results of the throughput test with the forwarding rate test for the same frame lengths. If the forwarding rate is high, but the throughput is low, then look for issues with the first few frames being dropped. If both the throughput and the forwarding rate are low then there is an issue with basic frame forwarding that must be better understood. Change the test parameters such as the MCS index to determine if there are issues with specific conditions. Ultimately, an examination of the capture file is the best way to identify the cause.

Issue	Troubleshooting Tip
Throughput is low for some specific frame lengths	A drop in throughput for specific frame lengths usually indicates a change in frame handling internal to the AP at those frame lengths. For example, a frame may go from requiring one memory buffer, to needing two memory buffers in order to be stored in the AP. These "holes" in performance should be understood and eliminated, if possible.
Throughput is low for small frames and good for large frames.	Most operations inside a networking device happen on a "once per frame" basis. Shorter frame lengths lead to more frames per second reaching the AP. As such, if the AP's throughput is disproportionately low at small frame lengths, then look for performance issues with frame events such as destination lookup, QoS handling, or FCS checks and computation.

Test Variables

The following table lists the parameters you can vary when performing this test.

Test Variable	Description
Traffic Direction	It is common to see vastly different performance profile in the upstream (Wireless to Ethernet) and downstream (Ethernet to Wireless) directions. Upstream traffic largely tests an AP's 802.11 receive capabilities, while downstream mostly tests an AP's transmit capabilities.
Frame Size	Testing should be conducted at every frame size to ensure that there are no algorithmic bugs that cause performance degradation at specific frame sizes.
Encryption	The 802.11 standard makes extensive use of encryption to protect data frame contents. Testing should be conducted with no encryption, TKIP, and AES encryption (also known as open, WPA, and WPA2, respectively).
Number of wireless clients	Increase the number of wireless clients to validate the DUT's ability to continue to achieve high rates as it needs to handle a larger amount of state information. You may want to run the Maximum Client Capacity test first, in order to determine the maximum number of clients the AP can support under low-stress conditions before running this variation.
Client PHY Configuration	Each MCS index, channel bandwidth, and guard interval condition should be tested to ensure that transmit and receive chains work as expected across all encodings.

Test Variable	Description
Transmit Power Level	Performance should be checked at a variety of power levels to determine the range of input power levels to the AP that results in optimal AP performance. **Note** – higher power is not always better! At higher power levels, the RF components can saturate and corrupt the RF signal. It is important to identify the range of power levels that produce optimal results for each setting.
Channel Model	Apply each of the IEEE channel models in the 802.11 client options tab. Each channel model should have no impact on performance relative to the bypass (no interference) mode in a well-designed receiver.
IPv6	Enable IPv6 and re-run the tests. For a true layer 2 AP, the performance should be identical. However, many APs perform some operations at layer 3 and can see significantly lower performance with IPv6 enabled.

Conclusion

The throughput test is a critical benchmark test for customers and significant efforts should be made to improve the performance of this measurement. The throughput can be heavily affected by a number of conditions inside the AP, so it is useful to consider the other performance benchmarks in conjunction with throughput in order to focus development efforts into the features that make a significant impact.

The ease with which these tests can be performed makes it easy for an AP tester to quickly identify performance holes and their sources, and verify when they are fixed.

Test Case: TCP Goodput Benchmark Test

Overview

The TCP Goodput test measures the number of TCP payload bytes per second that the system under test (SUT) can transfer between its ports and the maximum segment size (MSS).The TCP payload is the sum of the TCP segment bytes minus the TCP headers and options.

Goodput results are often very different from throughput results because Goodput is a layer 4 measurement that measures the amount of application traffic that was delivered. Throughput is a layer 2 or layer 3 metric that measures the amount of data that was forwarded. The difference is that the Goodput does not include those bytes that correspond to retransmissions at the TCP layer, nor does it include any of the TCP-layer overhead.

Goodput is a critical measure because it closely corresponds to application performance of client devices connected to the AP. This test is generally performed at the end because it is the most difficult to troubleshoot. By addressing the issues that can be seen in the simpler tests first and then addressing the more complicated tests, troubleshooting can be focused on specific areas of the design and can simplify and accelerate the debugging progress.

Objective

The objective of this test is to determine the maximum rate of TCP payload delivery that the AP can support.

Setup

As shown in Figure 1 below, the test consists of a DUT, acting as an access point, and two Ixia test ports.

The 802.11 Ixia test port emulates up to 500 stateful Wi-Fi clients sending and receiving traffic from the wireless interface on the DUT. The other Ixia port emulates servers on the Ethernet network that source and sink the traffic from the Wi-Fi clients.

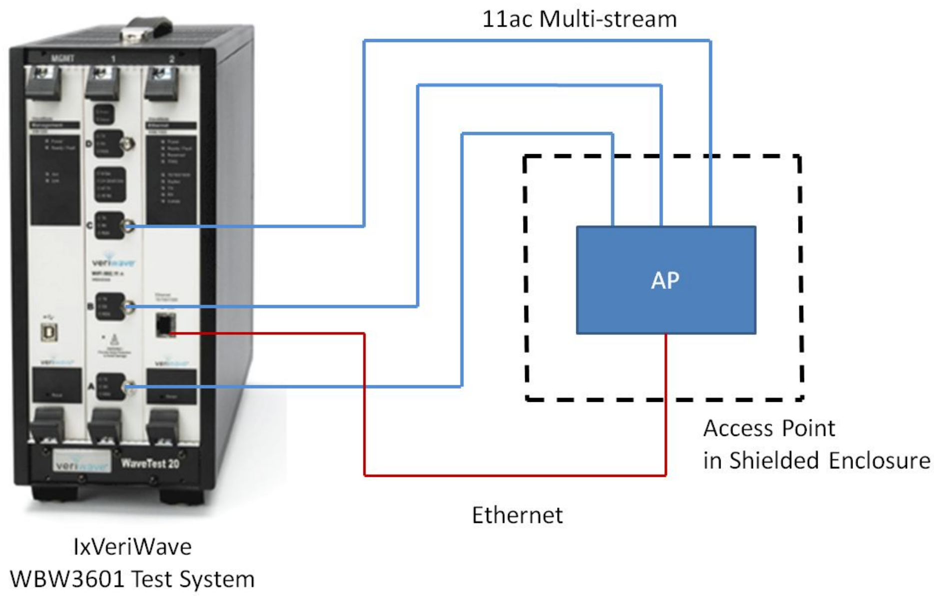


Figure 1. Test Setup

In the test setup above the DUT is placed in an isolation chamber to ensure that external signals do not affect test results. By connecting the AP to the test chassis with RF cables and enclosing the AP in an RF isolation chamber, you can be sure that other devices using the same frequencies do not affect the test results.

Step-by-step Instructions – TCP Goodput Test

Follow the step-by-step instructions to create a TCP Goodput benchmark test.

1. Select File Open and select the previously saved configuration file.

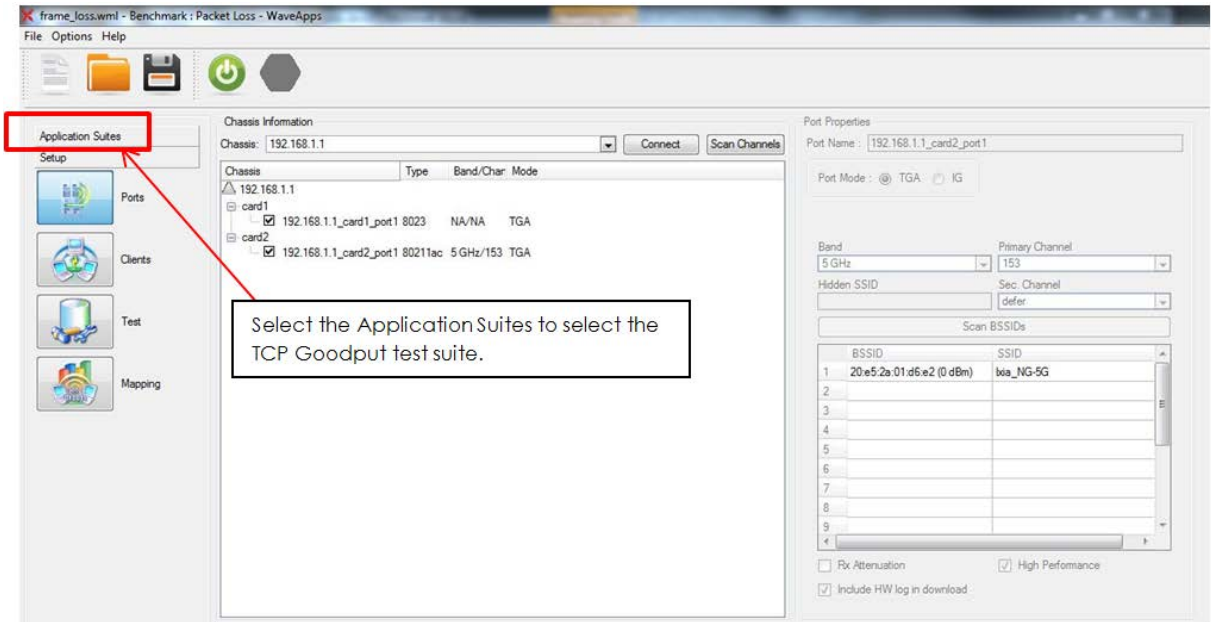


Figure 33. Test Suite Selection

2. Select TCP Goodput Test Suite and click Start Test Configuration.

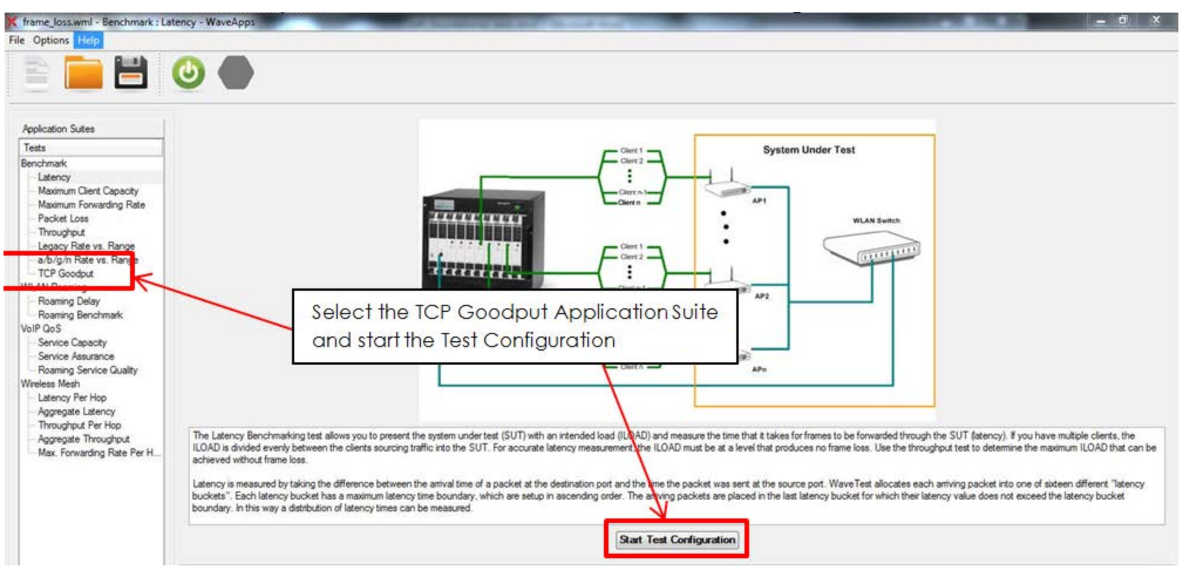


Figure 34. Application Suite Selection

Figure 35. Connect to the test chassis and select the port to use for following tests.

Note: When scanning for channels the scan stops at the lowest channel that has an active signal on it. If the channel detected is not the channel desired for the test enter the band and channel using the drop down menus at the right, then click the Scan BSSISs button to obtain the desired BSSID/SSID.

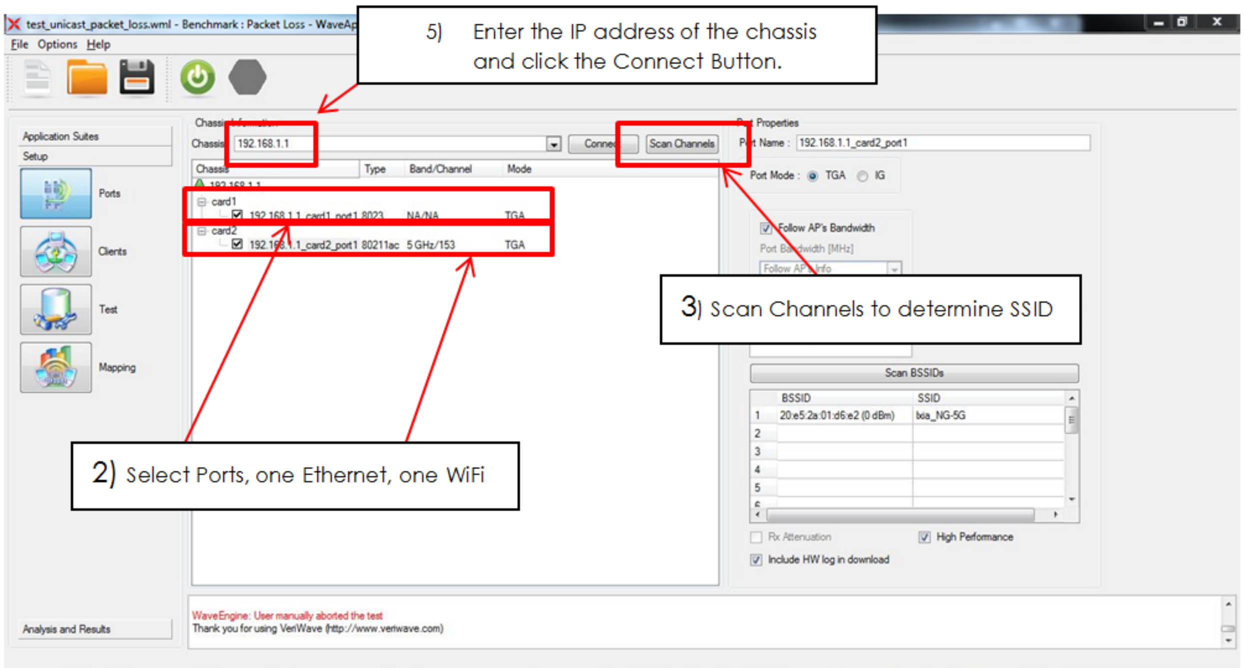


Figure 35. Port Selection

Figure 36. Create and name the clients. Click the Clients button on the left navigation panel. Click on the “+” to create a client group. Type the name in the “Name” box and select the interface type from the drop down menu. Select the Wi-Fi port and configure the client as shown below.

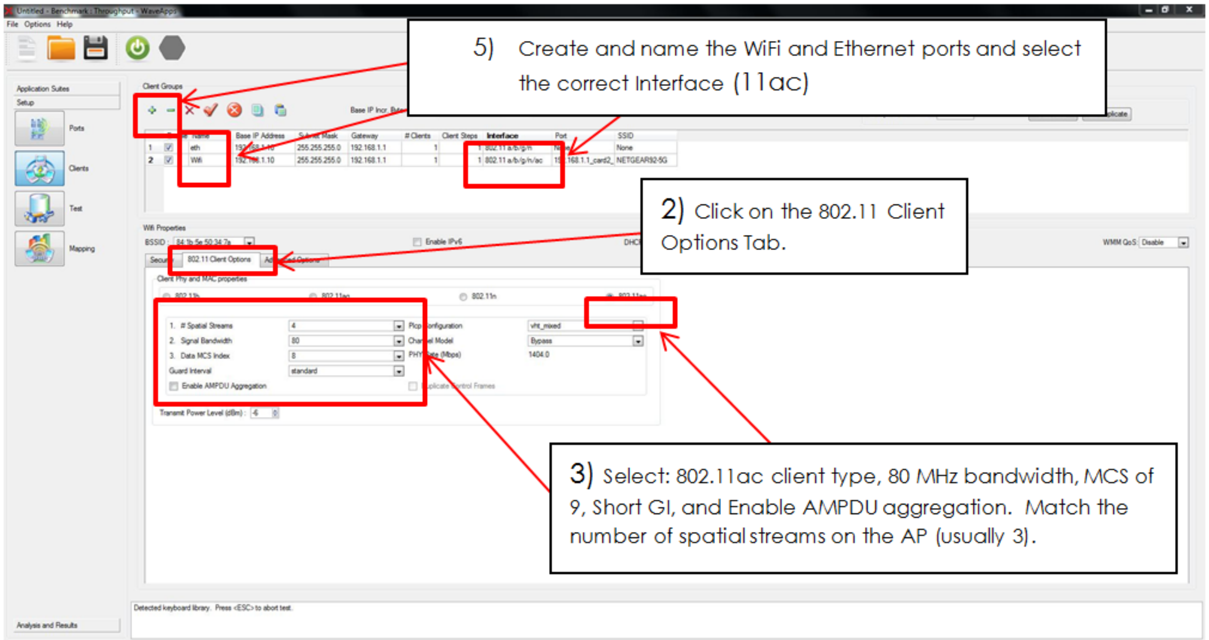


Figure 36. Client Characteristics

3. Click the Test setup button and select the Packet Loss Properties tab. Specify the frame size and frame rates that you want to use to run a packet loss test. It is recommended to use minimum, typical, and maximum length frames in order to test the maximum frame rate that the AP must handle. Short frames test the maximum frame rate and long frames test the maximum bit rate. Click the Mapping button and select the Mapping Option Ethernet to Wireless to perform a TCP Goodput test.

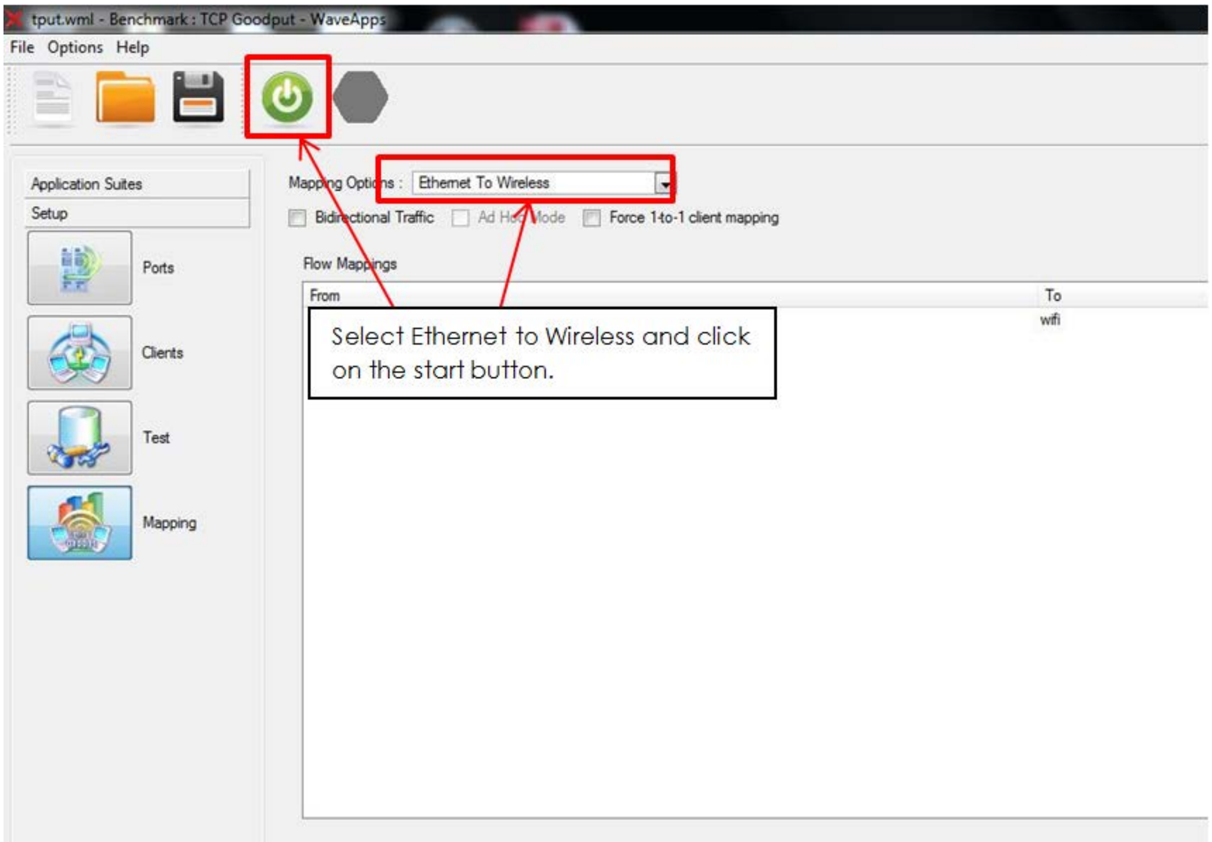
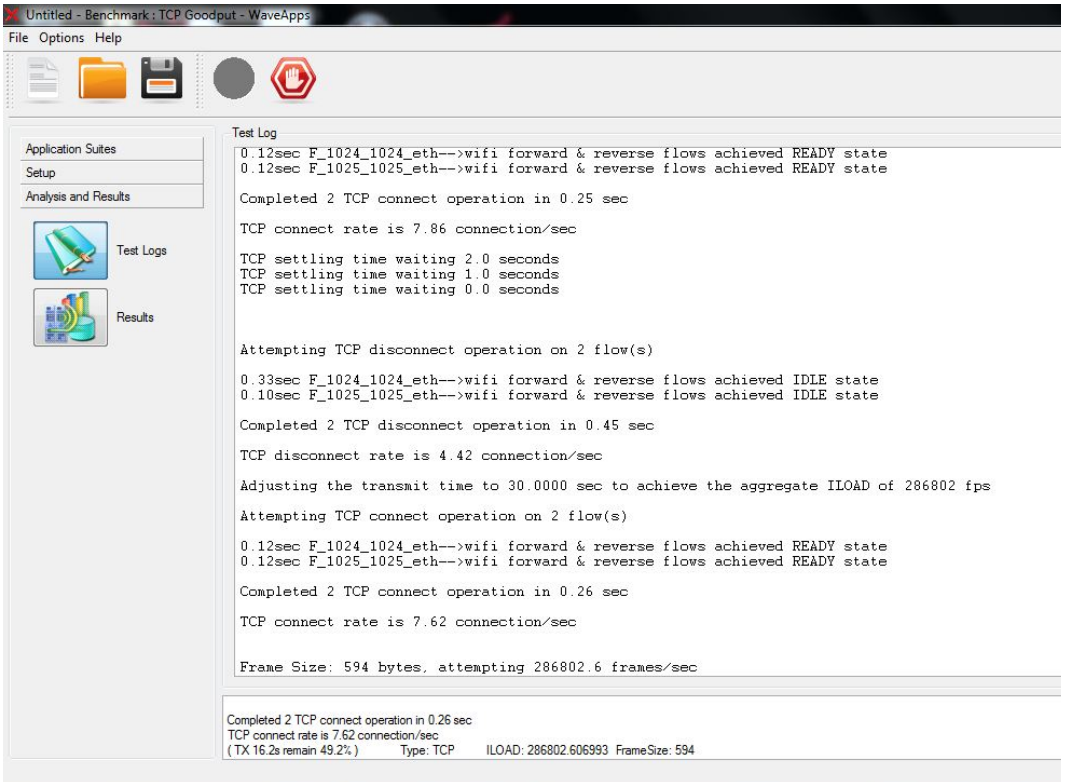


Figure 37. Set the traffic flow direction and start test

4. Click the start button to start the TCP Goodput test using default test parameters. The status window shows the progress of the test.
5.



6. TCP Goodput test results

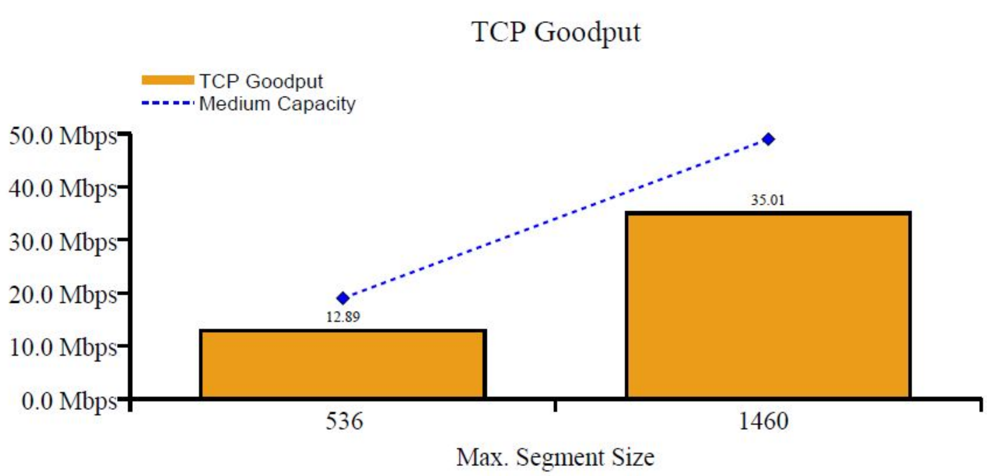


Figure 38. TCP Goodput Test Results

Result Analysis

The Goodput test shows the maximum rate of data transfer that an application running on a client that uses the DUT will achieve. Achieving a solid Goodput result is critical to delivering a strong customer experience with the applications of the Wi-Fi network.

Any results that vary significantly between the throughput and the Goodput results need to be thoroughly understood. It is not uncommon to have layer 2 issues, such as 802.11 retransmission, poor aggregation algorithms, or high latency. These issues result in much lower than expected Goodput.

Troubleshooting and Diagnostics

The following table lists the common access point performance problems and the tips to troubleshoot these problems.

Issue	Troubleshooting Tip
Goodput is unexpectedly low	Compare with the results from earlier testing and look for patterns that you may have missed when examining the results previously. If there are no clues from the previous data, then examine the capture file to identifying the underlying cause.

Test Variables

The following table lists the parameters you can vary when performing this test.

Test Variable	Description
Traffic Direction	It is common to see vastly different performance profile in the upstream (Wireless to Ethernet) and downstream (Ethernet to Wireless) directions. Upstream traffic largely tests and AP's 802.11 receive capabilities, while downstream mostly tests an AP's transmit capabilities.
Frame Size	Testing should be conducted at every frame size to ensure that there are no algorithmic bugs that cause performance degradation at specific frame sizes.
Encryption	The 802.11 standard makes extensive use of encryption to protect data frame contents. Testing should be conducted with no encryption, TKIP, and AES encryption (also known as open, WPA, and WPA2, respectively).
Number of wireless clients	Increase the number of wireless clients to validate the DUT's ability to continue to achieve high rates as it needs to handle a

Test Variable	Description
	larger amount of state information. You may want to run the Maximum Client Capacity test first, in order to determine the maximum number of clients the AP can support under low-stress conditions before performing this variation.
Client PHY Configuration	Each MCS index, channel bandwidth, and guard interval condition should be tested to ensure that transmit and receive chains work as expected across all encodings.
Transmit Power Level	Performance should be checked at a variety of power levels to determine the range of input power levels to the AP that results in optimal AP performance. **Note** – higher power is not always better! At higher power levels, the RF components can saturate and corrupt the RF signal. It is important to identify the range of power levels that produce optimal results for each setting.
Channel Model	Apply each of the IEEE channel models in the 802.11 client options tab. Each channel model should have no impact on performance relative to the bypass (no interference) mode in a well-designed receiver.
IPv6	Enable IPv6 and re-run the tests. For a true layer 2 AP, the performance should be identical. However, many APs perform some operations at layer 3 and can see significantly lower performance with IPv6 enabled.

Conclusion

After running this suite of five tests, you will have a strong understanding of how your AP performs, where the performance limitations are, and what are the causes of those performance limitations.

The speed, accuracy, and repeatability of the Ixia IxVeriWave test system enable the quick assessment of the AP. The ability to baseline and then re-test makes it easy to verify fixes. A final recommendation is to consider automating the entire test solution in order to develop a permanent regression test bed that can provide ongoing quality analysis throughout the product life-cycle.

Test Case: Rate vs. Range Test

Overview

The Rate vs. Range test measures rate adaptation performance of the system under test (SUT) using a fixed intended load (ILOAD) as clients move away from the SUT.
The distance between the client and the SUT is simulated by decreasing the transmit power of the client and the increasing the effective frame error ratio (FER) that the client presents to the SUT.

This test is especially designed to evaluate the rate adaptation behavior of the AP independent of all other variables. Traditional testing with a variable attenuator and a client device suffer from the fact that the receiver of the client device is a variable in the test, which the Ixia RvR approach eliminates.

The test expresses the range in terms of path loss (attenuation in dB). There is a direct correlation between the path loss and range. An increasing path loss usually corresponds to an increase in distance. The actual range is related to path loss by environmental factors.

Objective

The objective of the tests is to measure the forwarding rate for fixed intended loads (ILOAD) defined by user. The forwarding rate is measured by counting the number of good packets that have been successfully received at the destination WLAN ports over the course of the test. Packet loss is also calculated by taking the differences between the transmitted and received packets.

Setup

As shown in Figure 1 below, the test consists of a DUT, acting as an access point, and two Ixia test ports.

The 802.11 Ixia test port emulates up to 500 stateful Wi-Fi clients sending and receiving traffic from the wireless interface on the DUT. The other Ixia port emulates servers on the Ethernet network that source and sink the traffic from the Wi-Fi clients.

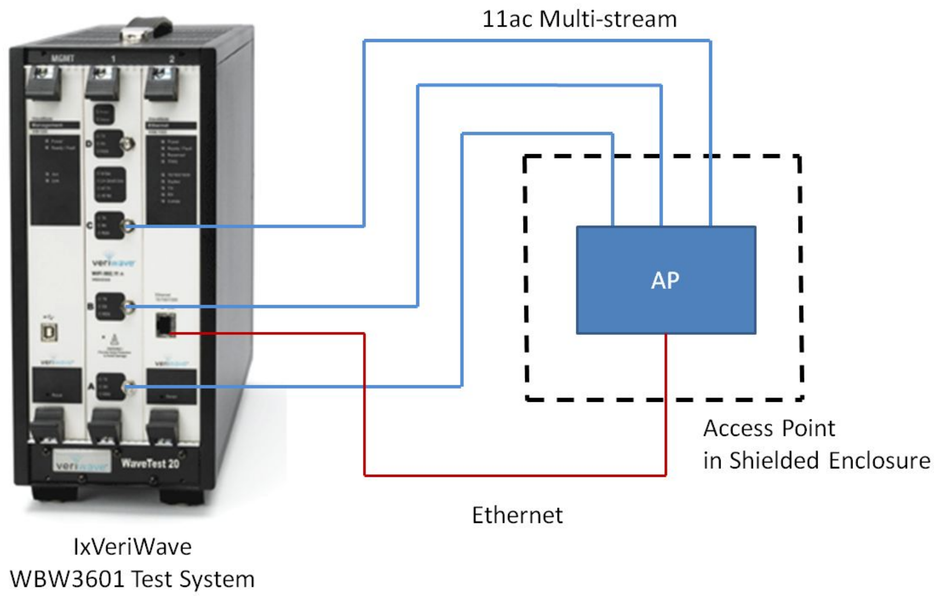


Figure 1. Test Setup

In the test setup above the DUT is placed in an isolation chamber to ensure that external signals do not affect test results. By connecting the AP to the test chassis with RF cables and enclosing the AP in an RF isolation chamber, you can be sure that other devices using the same frequencies do not affect the test results.

Step-by-step Instructions – Rate vs. Range Test

Follow the step-by-step instructions to create a Rate vs. Range test.

1. Select File Open and select the previously saved configuration file from Packet Loss test (.wml file). Select the Application Suites button in the left-side navigation bar.

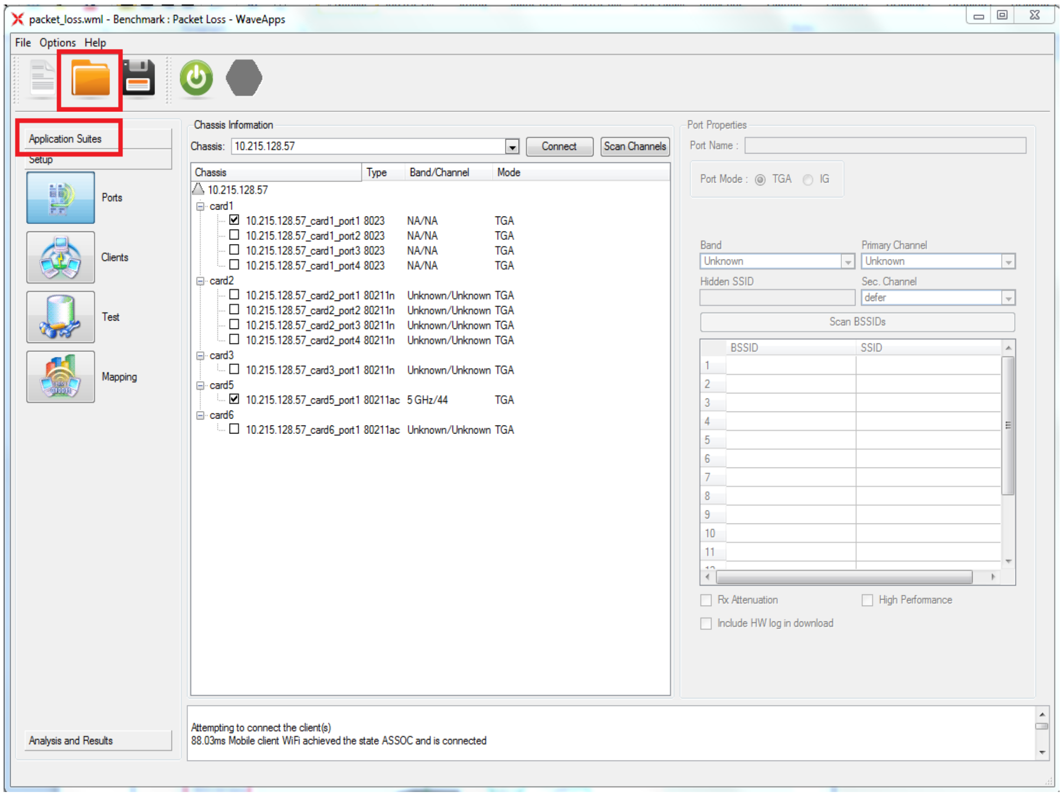


Figure 39. Test Suite Selection

2. From the available applications select “a/b/g/n/ac Rate vs. Range.” Click the Start Test Configuration button.

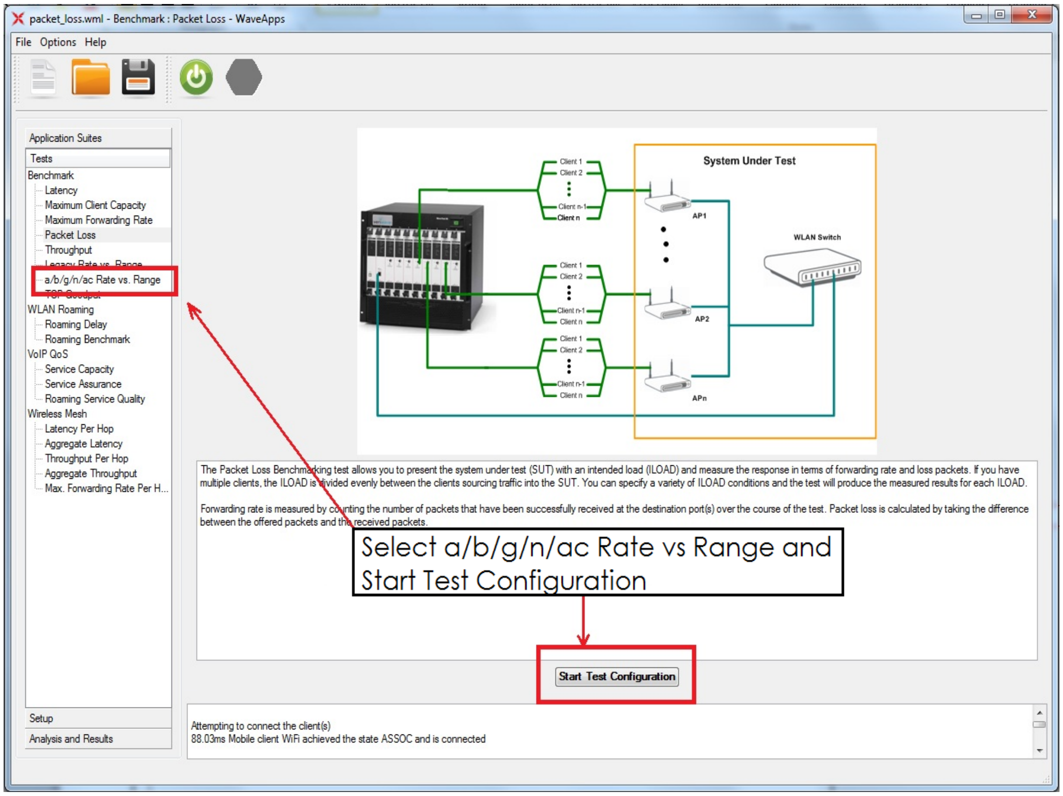


Figure 40. Application Suite Selection

3. Connect to the test chassis and select the ports to use for following tests.

Note: When scanning for channels (using “Scan Channel” button) the scan stops at the lowest channel that has an active signal on it. If the channel detected is not the channel desired for the test enter the band and channel using the drop down menus at the right, then click the Scan BSSISs button to obtain the desired BSSID/SSID. For a complete list of visible APs with their corresponding signal levels you may use also the “Channel Scanner” feature located on the top-right corner.

Selecting 5GHz band will automatically trigger the appearance of the “Follow AP’s Bandwidth” feature on the right panel. This will automatically configure the bandwidth of the simulated Wi-Fi clients to match the one configured on access point.

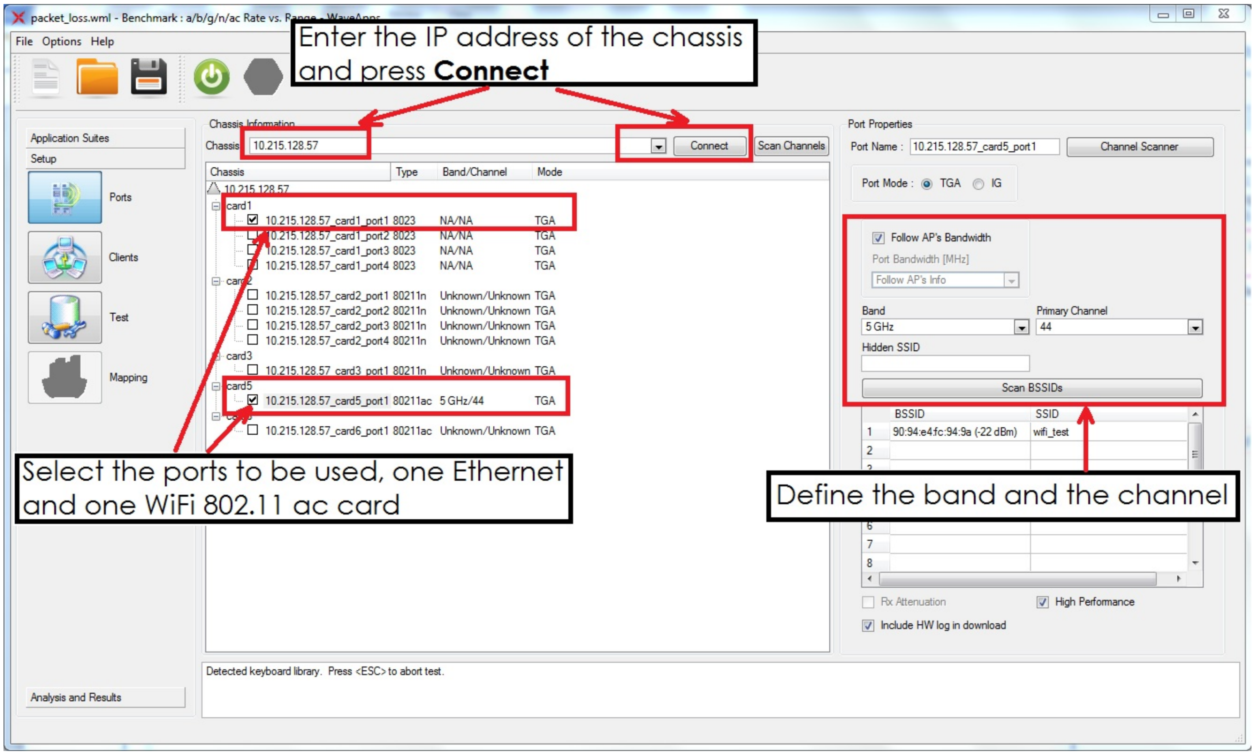


Figure 41. Port Selection

4. Create client and configure their properties. Click the Clients button on the left navigation panel. Click on the "+" to create a client group. Type the name in the "Name" box and select the interface type from the drop down menu. Select the Wi-Fi port and configure the client as shown below:

   - Client type: *ac*
   - # of spatial streams : *3*
   - Signal Bandwidth: *80MHz*
   - Data MCS index: *9*
   - Guard Interval: *Short*

Most of the APs support 3x3 MIMO, MCS9 and short guard interval. If this is not so in your case, you can change them to :*2* spatial streams, *MCS7* and *standard* guard interval.

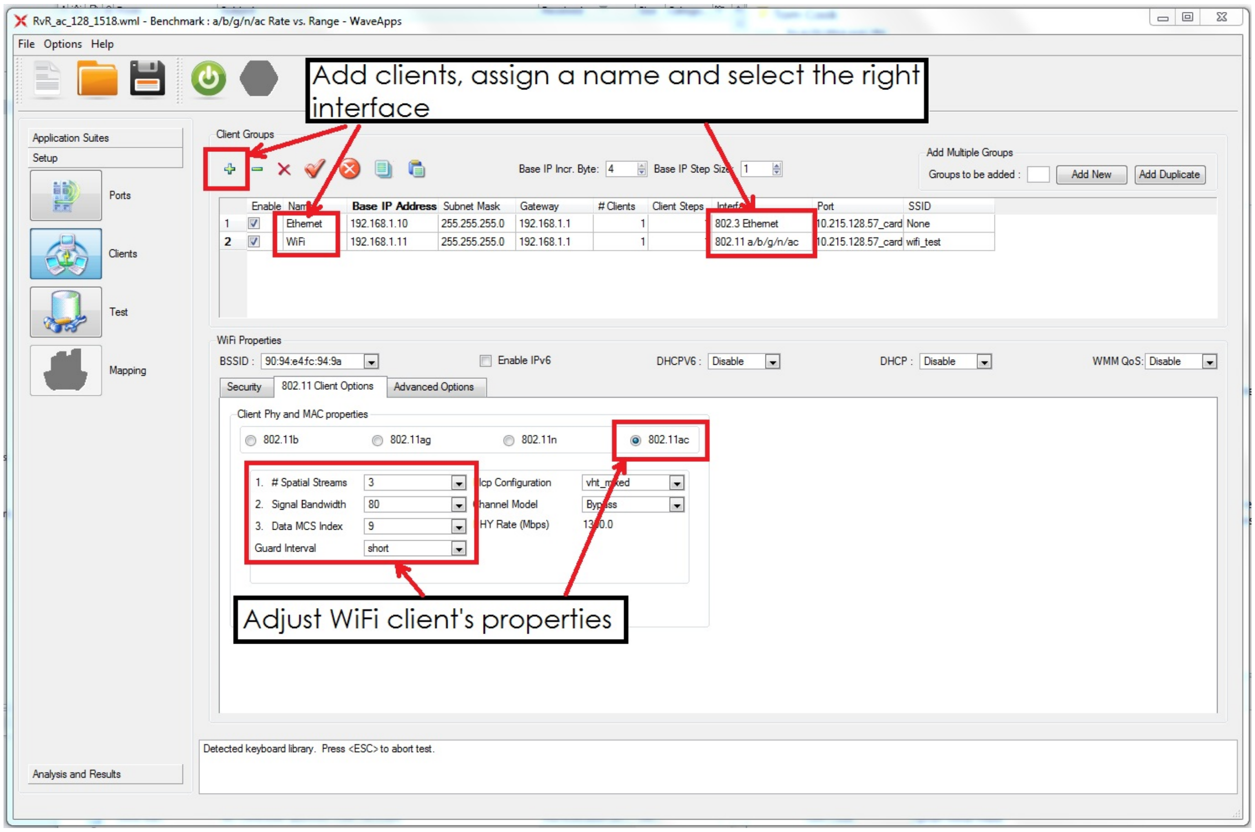


Figure 42. Client definition

5. Define Test properties. Click the Test button on the left navigation panel. The **Test Setup** tab allows you to configure various parameters (like **Trial duration**, **Number of Trails**). For the purpose of this test we'll leave them on *default* values:

   - Trial duration: 30 sec
   - Number of trials: 1

   Click on a/b/g/n/ac Rate vs. Range Properties tab and define the frame sizes and intended loads to be use during test. The table is automatically filled with 802.3 default values but you can change them according to your preferences, as shown below. Frame rates should be set to establish a downstream flow that is 90% of the throughput capability of the DUT.

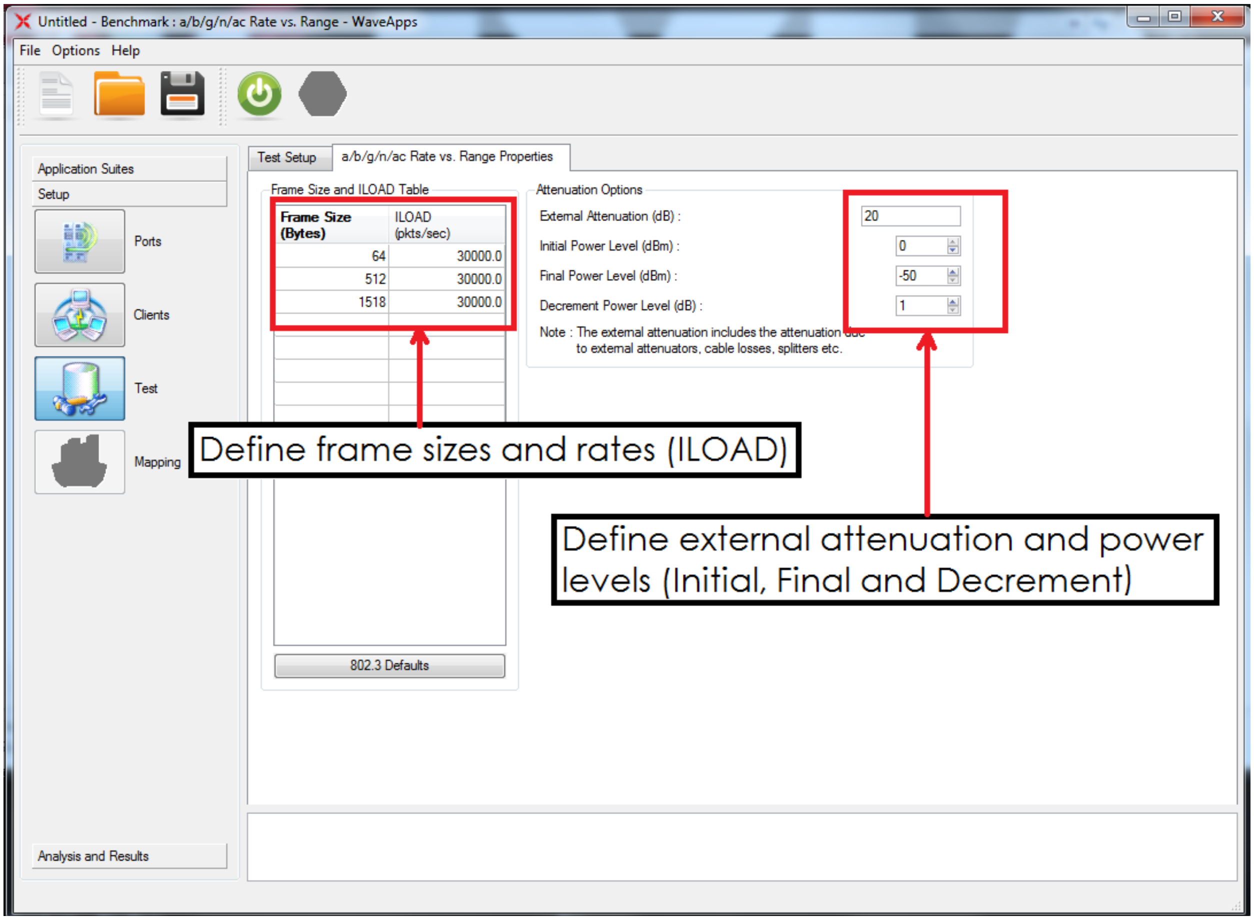


Figure 43. Test Properties

6. Click the **Start** button to start the test. The status window shows the progress of the test.

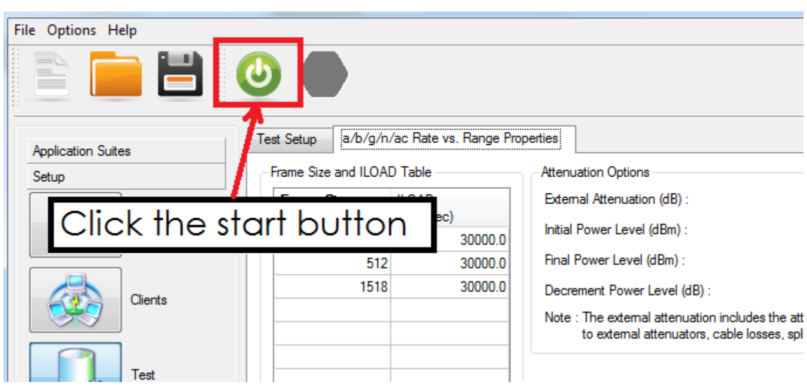


Figure 44. Start the test

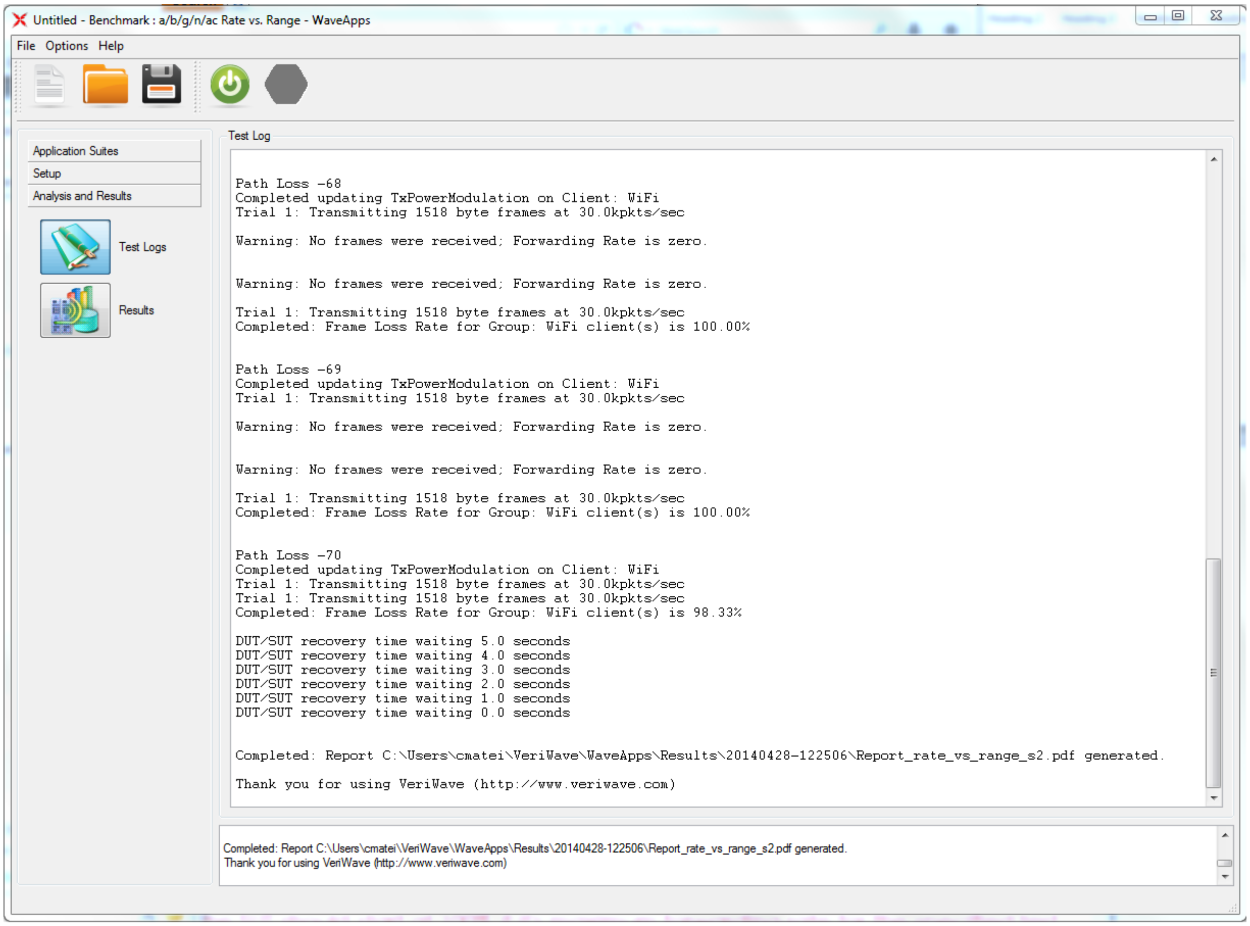
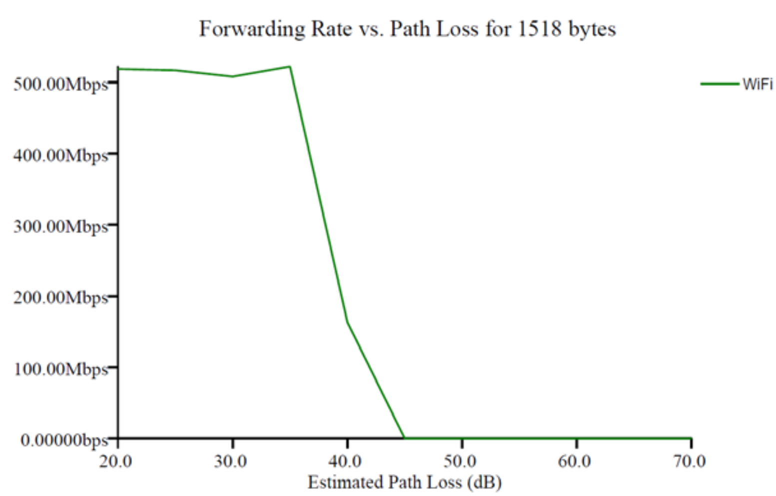


Figure 45. Test progress

7. All results will be automatically saved in the defined results folder and a complete pdf report is generated. Test results from running 1518 bytes frame size are displayed below:



Frame Size	Total ILOAD	Trial	Transmit Duration (Sec)	Group Name	Client Type	Per Group OLOAD pkts/sec	Per Group OLOAD bits/sec	Forwarding Rate pkts/sec	Forwarding Rate bits/sec	Frame Loss Rate %	Estimated Path Loss dB
1518	50000.0	1	10.0	WiFi	11ac	50005.8	607270505.1	41739.0	513557135.8	16.5	-20.0
1518	50000.0	1	10.0	WiFi	11ac	49890.2	605867102.3	41883.0	515327917.4	16.1	-25.0
1518	50000.0	1	10.3	WiFi	11ac	48590.9	590087465.7	40675.6	500472675.1	16.3	-30.0
1518	50000.0	1	10.0	WiFi	11ac	49988.7	607062772.8	42091.7	517896276.8	15.8	-35.0
1518	50000.0	1	10.0	WiFi	11ac	49996.6	607158710.4	10275.4	126428521.6	79.5	-40.0
1518	50000.0	1	10.0	WiFi	11ac	50005.0	607260721.7	0.0	0.0	100.0	-45.0
1518	50000.0	1	10.0	WiFi	11ac	50034.8	607623033.7	0.0	0.0	100.0	-50.0
1518	50000.0	1	10.0	WiFi	11ac	50007.1	607286303.9	0.0	0.0	100.0	-55.0
1518	50000.0	1	10.0	WiFi	11ac	50028.7	607548881.1	0.0	0.0	100.0	-60.0
1518	50000.0	1	10.0	WiFi	11ac	50027.4	607533078.1	0.0	0.0	100.0	-65.0
1518	50000.0	1	10.0	WiFi	11ac	50033.4	607606015.0	0.0	0.0	100.0	-70.0

8. Save a copy of the test configuration for later use

Result Analysis

The results of the test show the behavior of the rate adaptation algorithm used by the SUT to maximize transfer rate as the client increases distance.

Ideally, the SUT should start at 100% if its maximum forwarding rate for the specified test condition and keep this value constant as the path loss is increased. When the received signal at the SUT reaches the signal-to-noise ratio (SNR) threshold for the used modulation coding scheme (MCS), the AP should select a lower MCS rate according to the new signal condition (SNR or FER).

The forwarding rate should continue to decrease uniformly with increasing path loss until it reaches the point at which the SUT can no longer receive packets properly. From this point on, the received signal at the SUT is lower than the required SNR level for the lowest MCS and the forwarding rate should go to zero and remain there for the rest of the sweep. A SUT with a more sensitive receiver or a higher power transmitter will cause the transfer rate to drop off at higher path loss.

From the current test results, it can be observed that the SUT had good performance until the attenuation reached 35dB and after this point, as the attenuation increased the forwarding rate immediately dropped to zero and remained there until the end of the testing. This indicates that the adaptive rate mechanism was not using all MCS indexes to compensate for the signal decrease. SUT configuration or adaptive rate mechanism implementation can be the source of such behavior.

Troubleshooting and Diagnostics

The following table lists the common access point performance problems and the tips to troubleshoot these problems.

Issue	Troubleshooting Tip
The test fails because the clients cannot connect to AP	Make sure that the client configuration of the Ixia Wi-Fi client matches the configuration of the AP. Double-check settings like "no. of spatial streams" in accordance with the cabling scheme, channel bandwidth MCS rate, or Guard Interval. Security settings are another place to look for configuration mismatches. Verify that the AP is properly configured to support 802.11 ac- mode operation. Also note that some APs have a preferred antenna for transmitting management frames. Consider trying a different cabling sequence between the Ixia test equipment and the AP.
The test starts but the SUT is not using the maximum forwarding rate (for zero path loss)	The signal level at the SUT should be above the threshold for highest MCS rate. The SUT or simulated clients are not properly configured (no. of streams, MCS rate, aggregation, guard interval.
Forwarding rate does not decrease during the test	The signal received by the SUT is above the MCS threshold used during the test. You may increase the maximum attenuation level in the Test Configuration page up to -50dBm, or add additional external fix attenuator (20 dB or 30 dB.)
Forwarding rate dropping to zero while adding one attenuation step	Check the SUT configuration to ensure the Adaptive Transmission Rate mechanism is enabled. Some APs do not properly adjust the transmission rate while the Wi-Fi client moves away from the AP and continue to use the initial MCS until the connection is totally lost.

Test Variables

The following table lists the parameters you can vary when performing this test.

Test Variable	Description
Frame Size / Intended Load	Testing should be conducted at different frame sizes to ensure that there are no algorithmic bugs that cause performance degradation at specific frame sizes.
Initial/Final/Decrement Power Level	By selecting the entire range you can gain a complete picture of device behavior (DUT) and see how the MCS changes while the received signal is decreasing (as the client moves away from the AP). Changing the power levels allows you to focus on a specific range of received signal and analyze specific MCS changes.
Encryption	802.11 makes extensive use of encryption to protect data frame contents. Testing should be conducted with no encryption, TKIP, and AES encryption (also known as open, WPA, and WPA2, respectively).
Client PHY Configuration	Each MCS index, channel bandwidth, and guard interval condition should be tested to ensure that transmit and receive chains work as expected across all encodings.
Channel Model	Apply each of the IEEE channel models in the 802.11 client options tab. Each channel model should have no impact on performance relative to the bypass (no interference) mode in a well-designed receiver.
Trial duration/ Number of Trials	During a trial the SUT can change MCS to transmit data, especially when the SNR is marginal. Adjusting these parameters will show whether the SUT behavior is constant and independent of the time and amount of traffic passing through
IPv6	Enable IPv6 and re-run the tests. For a true layer 2 AP, the performance should be identical. However, many APs perform some operations at layer 3 and can see significantly lower performance with IPv6 enabled.

Conclusion

A Rate vs. Range test is a very good tool to identify problems with the SUT and determining whether to adjust its MCS rate to cover a large area. For high signal levels and small FER, the SUT should start with high MCS (eg. MCS 9) and decrease it accordingly as the simulated client moves away from AP.

If the AP does not smoothly and stably adjust the transmit phy rate down versus range, this will lead to decreased capacity supported by the AP due to excessive retries. This test represents an easy way for testing engineers to see complete device behavior or to narrow down and identify the root cause of the problem.

IXIA WORLDWIDE HEADQUARTERS
26601 AGOURA ROAD
CALABASAS, CA 91302

(TOLL FREE NORTH AMERICA)
1.877.367.4942
(OUTSIDE NORTH AMERICA)
+1.818.871.1800
(FAX) 818.871.1805
www.ixiacom.com

IXIA EUROPEAN HEADQUARTERS
IXIA TECHNOLOGIES EUROPE LTD
CLARION HOUSE, NORREYS DRIVE
MAIDENHEAD SL6 4FL
UNITED KINGDOM

SALES +44.1628.408750
(FAX) +44.1628.639916

IXIA ASIA PACIFIC HEADQUARTERS
101 THOMSON ROAD,
#29-04/05 UNITED SQUARE,
SINGAPORE 307591

SALES +65.6332.0125
(FAX) +65.6332.0127