Black Book

Edition 10

Ultra Low Latency (ULL) Testing

http://www.ixiacom.com/blackbook

June 2011

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, 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 Black Book website at http://www.ixiacom.com/blackbook. Registration is required to access this section of the Web site.

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.

Errol Ginsberg, Acting CEO

Ultra Low Latency

Test Methodologies

This Ultra Low Latency testing booklet provides several examples with detailed steps showing how to utilize Ixia IxNetwork emulation software and applications to achieve functional and performance test objectives for Ultra Low Latency testing. The introduction describes what parameters affect latency and how to measure them.

Introduction to Ultra-Low Latency

Computer networks are built to share resources and move information from one place to another. Legacy networks were built using Time Division Multiplexed (TDM) technologies (such as SONET/SDH and T1/E1 circuits) which had fixed bandwidth and latency attributes. The “bandwidth” of a device, network, or service is measured in bits per second – or multiples of it (kilobits/s, megabits/s etc.). The “latency,” or delay, is measured as one-way or round-trip and is affected by each device and link in the connection end-to-end and (based on the speed of light and the index of refraction) is estimated to be 5 microseconds per kilometer in most metro networks using fiber optic cable. These performance attributes determined what type of services could be provided, which primarily consisted of data and voice applications. As Ethernet and IP continue to win the battle for transport and networking technology the performance attributes continue to get better at a lower cost per bit.

With these higher bandwidth, lower latency networks new applications are possible including multi-play services with voice, video and data as well as specific applications used by enterprises such as financials, utilities and governments.

An example of this is the networks used by financial institutions for stock ticker feeds, buy and sell orders, and high frequency trading. A slight difference in the latency of the network could mean a difference of millions of dollars.

Ultra Low Latency (ULL) is one of the hottest trends in information technology. It refers to network components (routers, switches, optical equipment) providing the lowest forwarding latency, sub micro second, for network traffic. With these devices Ultra Low Latency Networks (ULLNs) are being built.

Service providers are building these ULLNs to offer differentiated services to the enterprise customers who require and are willing to pay for the premium service.

Defining How Latency is Measured

Before discussing the factors that affect network latency and how to test it, it is important to review the fundamentals of how latency is measured. The Internet Engineering Task Force (IETF) develops and promotes Internet standards and has defined several standards regarding how latency is measured which have come out of the Benchmarking Methodology Working Group (BMWG).

The **IETF RFC 1242** standard has defined latency and how to measure it for store-and-forward devices and bit forwarding devices:

For store and forward devices (like routers):
The time interval during which the last bit of the input frame reaches the input port and the first bit of the output frame is seen on the output port. This is known as Last-In-First-Out (LIFO).

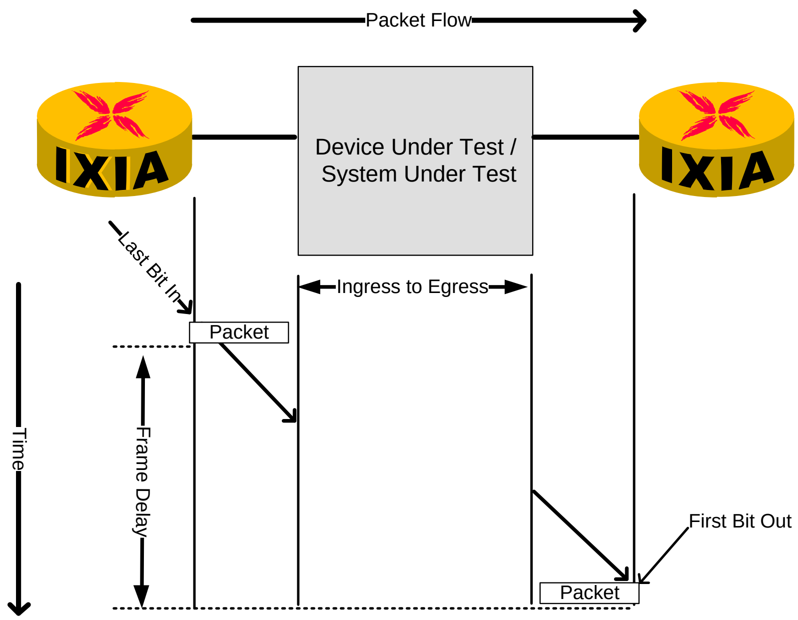

Figure 1. Last In First Out (LIFO) Measurement

For bit forwarding devices (like bridges, switches in specific modes and repeaters):
The time interval during which the end of the first bit of the input frame reaches the input port and the start of the first bit of the output frame is received on the output port. This is known as First-In-First-Out (FIFO).

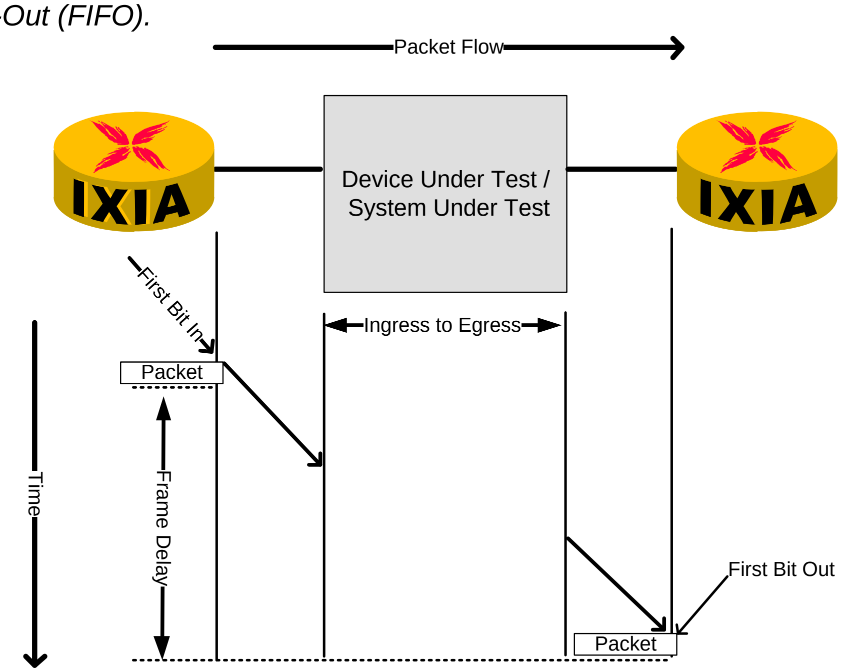

Figure 2. First In First Out (FIFO) Measurement

The **IETF RFC 3393** standard is focused on IP packet delay and delay variation measurement. It defines latency as:

The time interval between the start of the first bit out from a packet sent out by the source and the reception of the last bit received by the destination. This is known as First-In-Last-Out (FILO). This method is also the specified method to be used for Metro Ethernet Forum (MEF) based testing as defined in MEF 10.2.

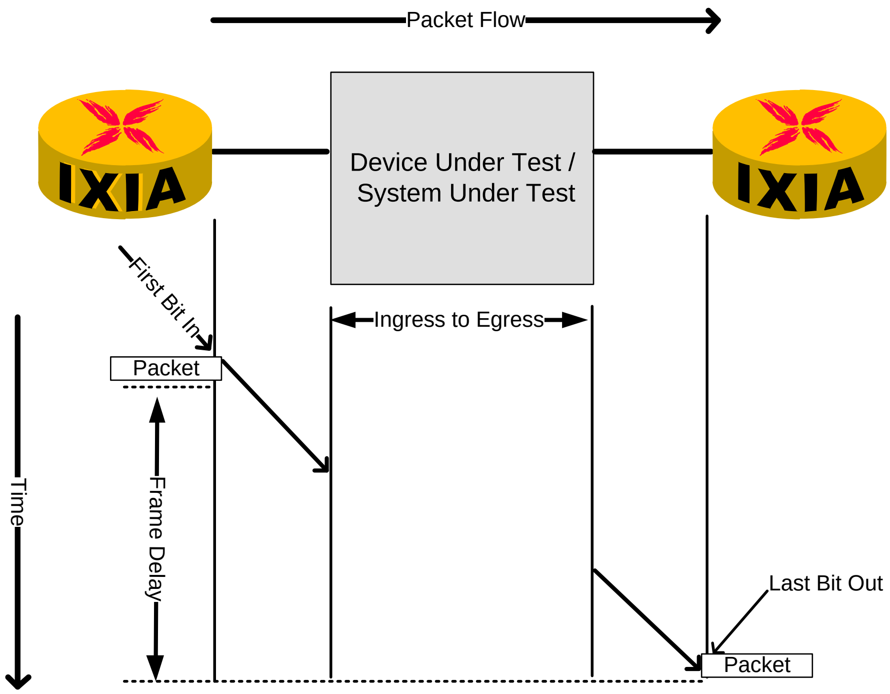

Figure 3. First In Last Out (FILO) Measurement

The **IETF RFC 4689** standard describes terminology for the benchmarking of devices that implement traffic control using packet classification based on defined criteria. It defines latency (forwarding delay) as:

The time interval during which the last bit of the input IP packet is offered to the input port of the DUT/SUT and the last bit of the output IP packet is received from the output port of the DUT/SUT. This is known as Last-in-Last-Out (LILO).

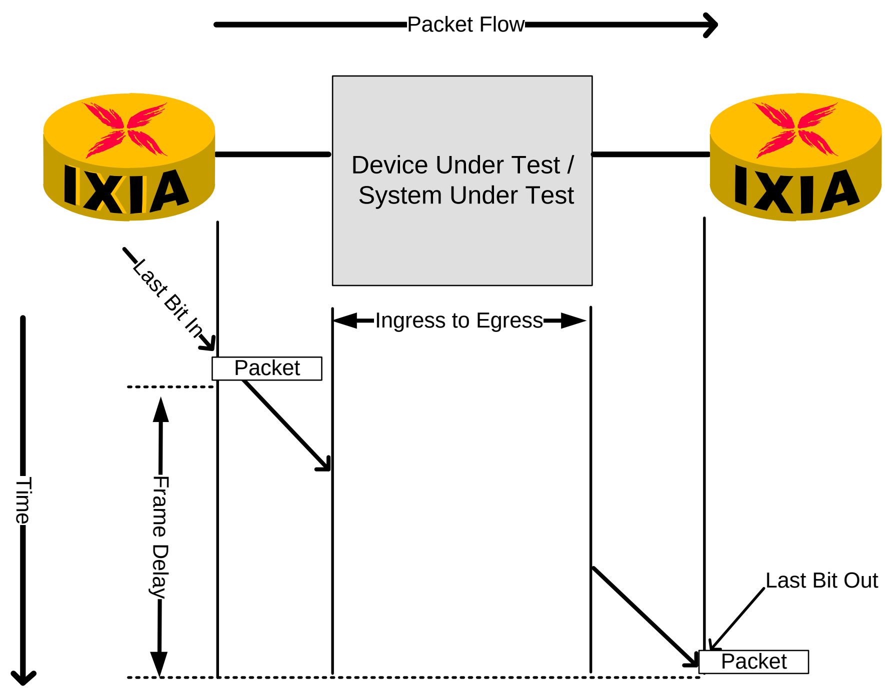

Figure 4. Last In Last Out (LILO) Measurement

These four RFCs cover the most common modes/methodologies for measuring latency. It is important to know what is being tested and how it is being measured so an “apples-to-apples” comparison can be made.

Factors that Impact Latency

With a focus on packet based, IP/Ethernet, networks there are several factors which will impact latency:

- Hop count (and path length)
- Frame length
    - Serialization delay
- Equipment used (routers, switches, SONET/SDH, DWDM)
    - Packet processing
    - Queuing

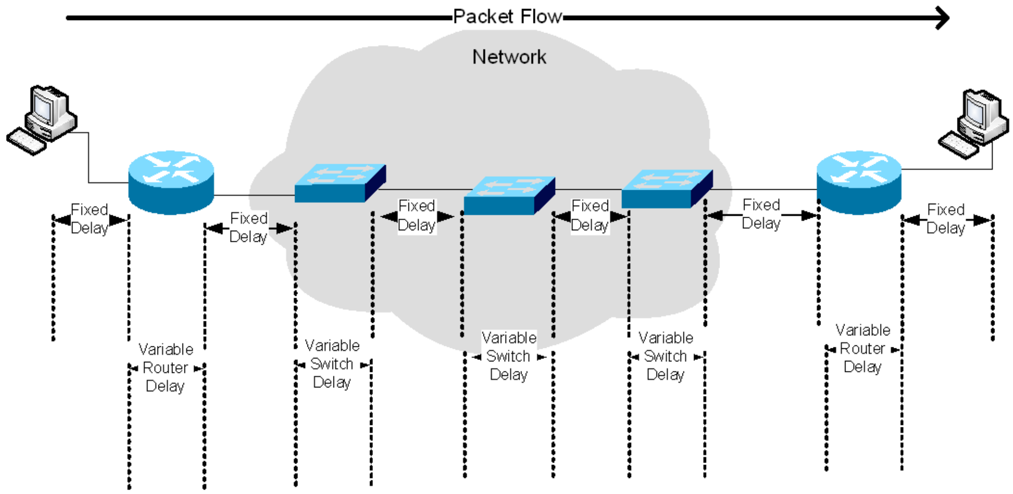

Figure 5. End-to-End Latency

Distance

As described above, latency is a function of the speed of light, which alone accounts for 3.33 microseconds of latency for each kilometer of path length. In addition, the index of refraction of most fiber optic cables adds a factor of about 1.5, bringing the typical latency up to 5 microseconds for each kilometer of path length.

Bits transmitted along a fiber optic link travel at about ⅔ of the speed of light (3x10^8 m/s). The one way latency for a 100km link works out to be:

LWL = 1x10^5 m / (0.67 × 3×10^8 m/s) ≈ 500 µs

For example, a direct fiber optic link between New York, NY and Chicago, IL would be 1158 km, times 5 microseconds is 5790 microseconds or 5.79 milliseconds.

Copper cables (like standard Unshielded Twisted Pair (UTP)) have inherently higher latency and are not certified for use in long distance connections. The Telecommunications Industry Association (TIA) has developed standards over the years to address commercial cabling for telecom products and services ensuring minimum quality thresholds are met throughout the world. Cable types are typically characterized with performance attributes like maximum propagation delay, minimum propagation speed, and maximum delay skew. On average copper cables exhibit roughly 5.48 nanosecond propagation delay per meter of cable, which is 5.48 milliseconds per kilometer. Specific category/class cabling with shielding can result in lower latency and longer distances.

The latency induced by a fiber or copper cable is commonly referred to as the propagation delay.

In addition to the latency induced by the cable, there is typically a transceiver at either end of the connection which also can add a fixed delay.

Hop Count

The "hop count" is a term used in an IP routed network which refers to the number of routers (or hops) a packet must traverse to get from the source (ingress) of the network to the destination (egress) of the network. This assumes a unicast transmission using point-to-point links. Once the latency is measured per hop the total latency of the path can be estimated as follows:

Example Per hop latency measured at 5 milliseconds:

A network path traversing 5 routers would induce 5x5 = 25 milliseconds of just hop count delay which must be added to the other factors affecting the total latency.

The ideal path through a network is typically the shortest hop-count path since additional hops add the most latency end-to-end.

In this example (figure 6) the purple path from A to B represents the shortest hop count path compared to the alternate path shown in green. The purple 5-hop path would have at least 5ms lower latency than the green 6-hop path if the hops induce equal latency.

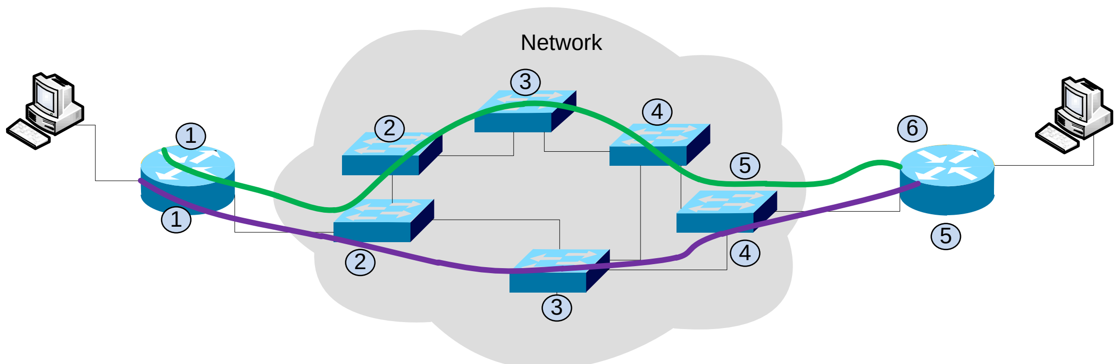

Figure 6. Hop count comparison

Frame Length

Most networking devices (like routers and switches) operate in store and forward mode. The term is descriptive of its actual operation: the device stores the received data in memory until the entire frame is received. The device then transmits the data frame out through the appropriate port(s). The latency this introduces is proportional to the size of the frame being transmitted and inversely proportional to the bit rate as follows:

Latency = Frame Size / Bit Rate (bps)

For the maximum, non-jumbo, size Ethernet frame (1500 bytes) at 100 Mbps the latency is 120 μs.

120 μs = (1500 bytes * 8 bits) / 100 Mbps

For comparison, the minimum size frame (64 bytes) at 100 Mbps speeds has a latency of just 5.12 μs.

This latency added is known as the serialization delay which is the fixed delay required to clock a frame onto the network interface. Lower speed links and larger frames will incur larger delay.

Equipment Used

A complex network can be made up of many different devices including routers, switches, firewalls, load balancers and other equipment at the optical layer. Each of these devices will add different amounts of delay depending on how they are configured and how the data frame is forward through the device.

This delay from the ingress interface to the egress interface is known as the processing delay induced by the device.

- ***Router*** – an IP router is a device with multiple network interfaces and operates at layer 3 of the OSI model. It makes forward decisions based on the destination IP address of the IP packet. Over the past ten plus years, IP routers have become very sophisticated, supporting many routing protocols and advanced features such as filtering and class of service (CoS) based forwarding. Routers come in different sizes for deployment into different areas of the network including the access, metro/aggregation, and core. Routers can vary greatly in their performance profile with the higher end devices forwarding at wire-rate with low latency.

- ***Switch*** – an Ethernet switch is a device with multiple Ethernet interfaces and operates at layer 2 of the OSI model. It makes forwarding decisions based on the destination MAC address of the Ethernet frame. Like routers, switches have also become much more sophisticated supporting many protocols and features. Switches also come purpose build for various applications including Local Area Networks (LAN), access edge, data center and core to name a few.

Both routers and switches have multiple interfaces and when traffic from multiple sources are heading to the same destination this can cause congestion (or over subscription) on the egress interface and a queuing delay can occur if the frame is buffered. The maximum queuing delay is proportional to buffer size. Although buffering will add latency to the transmission, the alternative is to drop the frame and rely on an upper layer protocol to re-transmit the frame which overall is a much higher delay. Since network traffic tends to be bursty, congestion at an egress interface should not be a common occurrence if the network is designed properly. The impact of the queuing delay can cause a variation in the delay known as “jitter”. Some applications like voice and video have specific thresholds for latency and latency variation, which can degrade the service. To address these requirements techniques are used like implementing CoS or specific queuing configurations to prioritize traffic sensitive to delay.

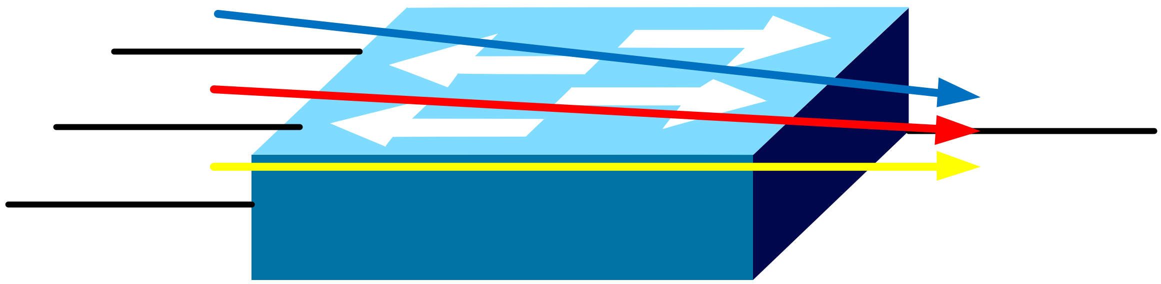

Figure 7. Congestion causing buffering which adds delay

- ***Firewall/Load balancer*** – These types of devices can make forwarding decisions on layer 2, layer 3 or even layers 4 -7 of the OSI model. With the capability of looking further into the packet, the forwarding performance is typically slower that a router or a switch resulting in a longer packet processing delay.
- ***Passive devices*** – Passive devices like transceivers, repeaters operate at layer 1 and do not make a forwarding decision on the packet. They primarily provide specific functions like changing the media or extending a network link. These are typically very low latency devices.
- ***Optical devices*** – Optical devices like SONET/SDH and DWDM operate primarily at layer 1 and once up and running provides a fixed delay. These are typically very low latency devices.

Techniques to Minimize Latency

With significant demand for low latency products and services there are several techniques and features providing lower latency.

Since the distance is one of the most significant factors on the overall latency, service providers are building more direct paths between major network hubs (like New York City and Chicago). This can provide service differentiation when selling services to large enterprise companies in the financial markets. Another technique used is to ensure that there is a redundant path available which has services within the latency threshold. Often, this requires traffic engineering and a protocol feature set which provides fast failover from primary to backup path. In addition to reducing the distance, service providers are looking to increase the bandwidth (link speed) on key paths in the network to reduce the latency.

Along with building the network to take the most direct physical path, designing the network to travel through the fewest hops end-to-end will also reduce the overall latency.

Depending on the application, some can be optimized to use smaller frames to ensure there is low latency. An example of this is Voice over IP (VoIP) which typically uses the smallest

Ethernet frames (64 byte). To minimize the impact of serialization a maximum transmission unit (MTU) can be configured to ensure voice frames won't get queued up behind large data frames on lower speed lengths.

Another one of the most significant ways to reduce the overall latency is to evaluate and select networking equipment (routers, switches…etc.) which provide the lowest latency. An example of this is in the data center top of rack switches typically differentiate themselves based on their low latency performance. An example of this in the router space is selecting a router which has hardware based forwarding which can forward packets in hardware at wire rate once a forwarding decision has been made on a flow. Although a router may have hardware based forward available, there could be specific configuration like filtering, CoS and others which can affect the processing delay.

Ultra Low Latency Test Methodologies

Testing for Ultra Low Latency occurs in two phases: the pre-deployment phase and the service activation/maintenance testing phase.

Testing methodologies for the pre-deployment phase often leverage the existing standard defined by the IETF: RFC 2544 "Benchmarking Methodology for Network Interconnect Devices". Since RFC 2544 was primarily written to test devices and not services, there is a new standard coming out of the ITU-T which defines testing a service during service activation which is ITU-T Y.1564. There is also a methodology for testing Carrier Ethernet service attributes (including latency) defined by the Metro Ethernet Forum (MEF) in the specification MEF 14.

Pre-deployment qualification testing in the lab

Before deployment into a production network, ***each device*** should be tested to determine the expected performance once in a live network.

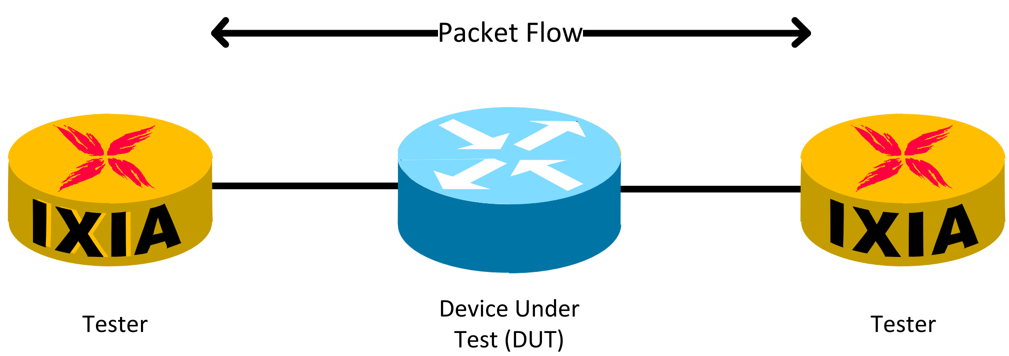

Figure 8. Device Under Test (DUT)

RFC 2544 is a widely accepted standard methodology for performance benchmarking a network device. It defines several tests including performing the latency measurement once the throughput has been established for each frame size.

Going beyond RFC 2544 it is important to be able to measure the performance (throughput and latency at a minimum) per flow and to perform advanced measurement functions including graphing over time and providing a latency histogram to see the distribution of the latency measurement.

After testing and selecting each device (switches, routers and other network equipment) additional testing should be performed end-to-end in a lab prior to deployment. This is known as the System Under Test (SUT).

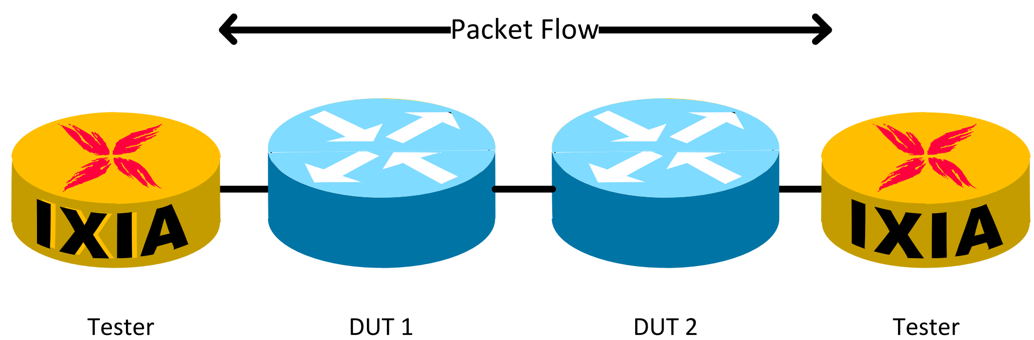

Figure 9. System under Test (SUT)

In the lab testing it is also very useful to be able to simulate a WAN link using an impairment/WAN simulator.

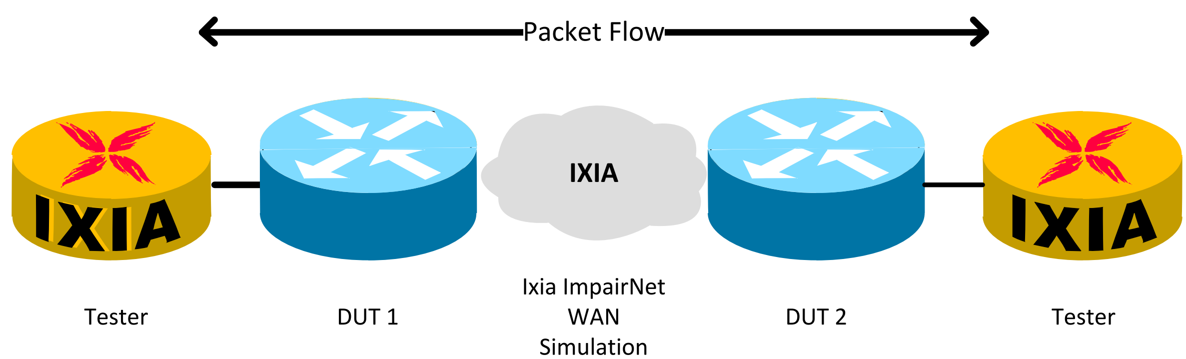

Figure 10. Impairment scenario

Another widely accepted methodology for benchmark testing a Carrier Ethernet service is defined by MEF 14. This standard defines how to test the bandwidth profile service attributes which can be defined per Ingress UNI, per EVC and per CoS. There are specific tests which measure the Frame Delay performance and the Frame Delay Variation.

Post-deployment Testing

Typically when a service is turned up there is a phase of testing known as the Service Activation Measurement (SAM) where the performance is benchmarked before turning over to a customer. At that point, it is verified that the service is delivering the correct bandwidth, latency, jitter and loss as specified in the service level agreement (SLA).

After a service is turned over to a customer there can be ongoing measurement via various techniques including features like Service OAM.

Active testing (generating traffic which would be disruptive to customer service) can also be re-run during a maintenance window.

To test between two remote locations timing synchronization is needed between the Ixia chassis to have a common clock reference. An optional AFD unit is available to connect a chassis to a GPS antenna. Once both chassis are synchronized testing between both sites can begin using the same methodology proposed below.

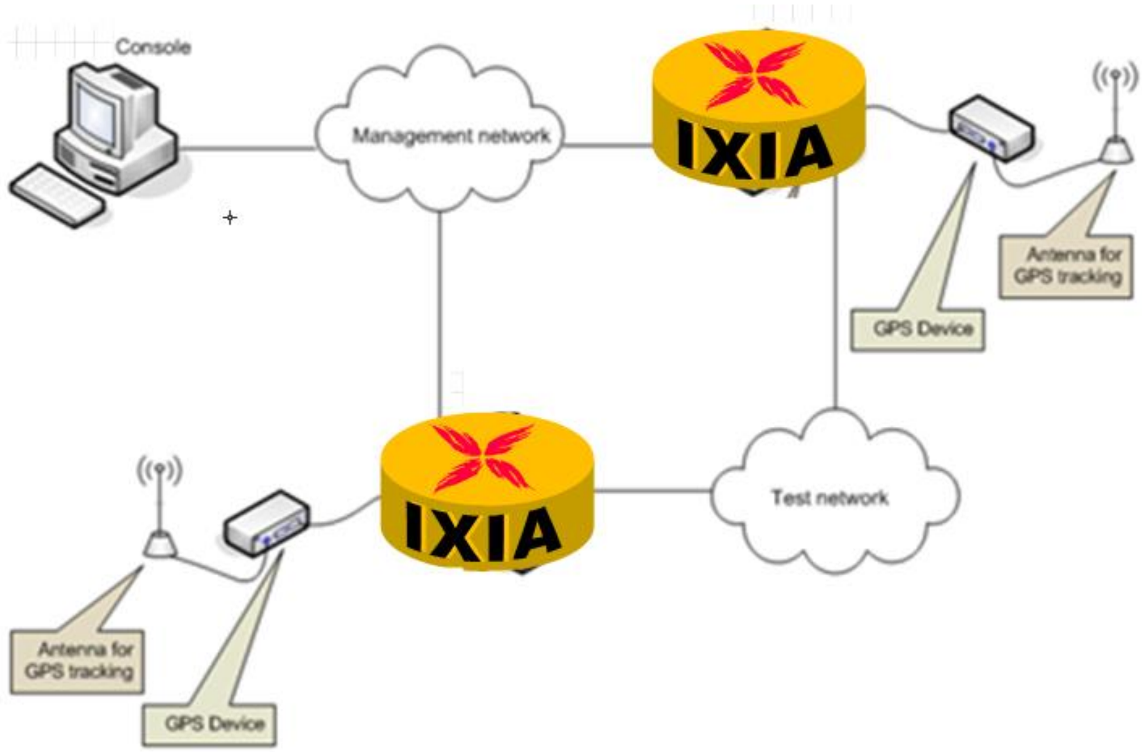

Figure 11. On-Network testing using GPS for Chassis Synchronization

Test Equipment

Specialized test equipment is required to make high precision performance and latency measurements. The Ixia system requires a chassis, a load module (which has one or more test ports on it) and client software, like IxNetwork.

The Ixia load modules have specific hardware enabled capabilities built in for performance testing. An Ixia test port can transmit up to wire-rate any packet size. It can also generate specific trackable flows of traffic. This is accomplished by inserting instrumentation into each test packet. The instrumentation block consists of a signature, a packet group ID (PGID), a Sequence Number a Data Integrity CRC and a Timestamp. The actual fields used will depend on the measurement mode enabled in the software.

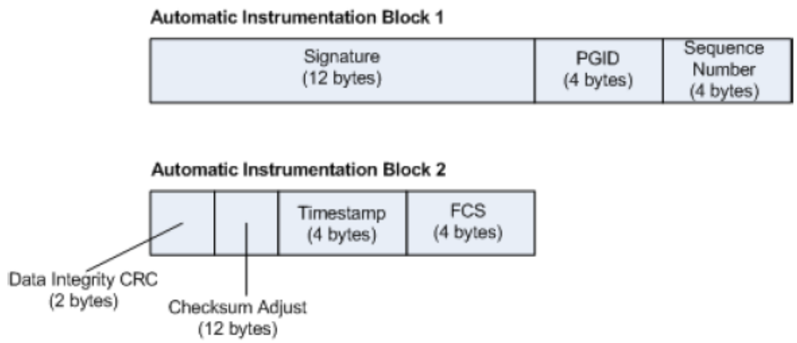

Figure 12. Ixia Instrumentation Blocks

The hardware time-stamping of the packet provides a 20ns accuracy

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Test Case: ULL Testing Throughput and Latency using RFC 2544

Overview

To measure the latency, the RFC 2544 methodology will be used which specifies determining the throughput and measuring the latency at the maximum rate per packet size.

Objective

This test will determine the throughput, which is the maximum rate at which the DUT can forward frames correctly. The latency (and optionally jitter) will be measured per frame size.

Setup

Four Ixia test ports are used in this example to test the throughput and latency of the layer 2 switch which is the Device Under Test (DUT). The IxNetwork RFC 2544 QuickTest will be used to run the test.

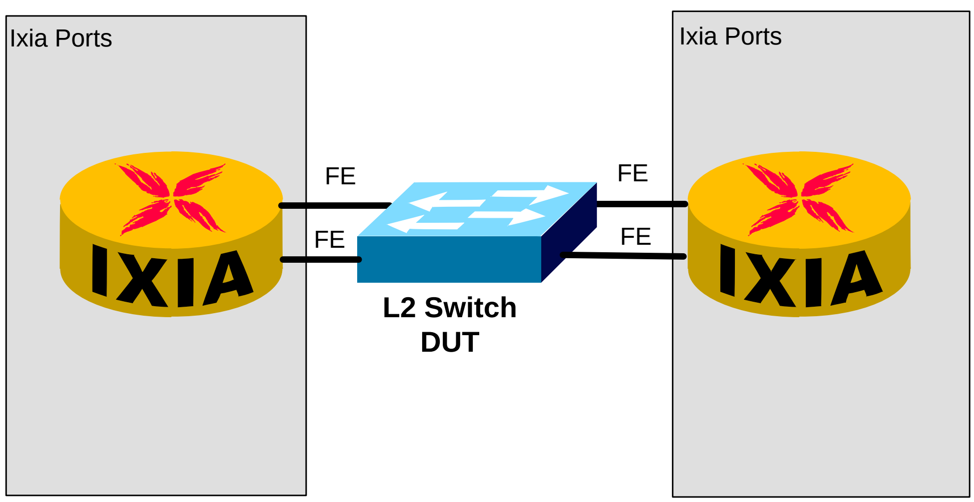


Figure 13. Four Ixia test ports connected to the layer 2 DUT

Step-by-step Instructions

1. Launch the **IxNetwork** application, then on the **Overview** view click on the link to "**Click here to create a QuickTest**".

   Note – Another option is to select "Add QuickTests" from the Home toolbar.

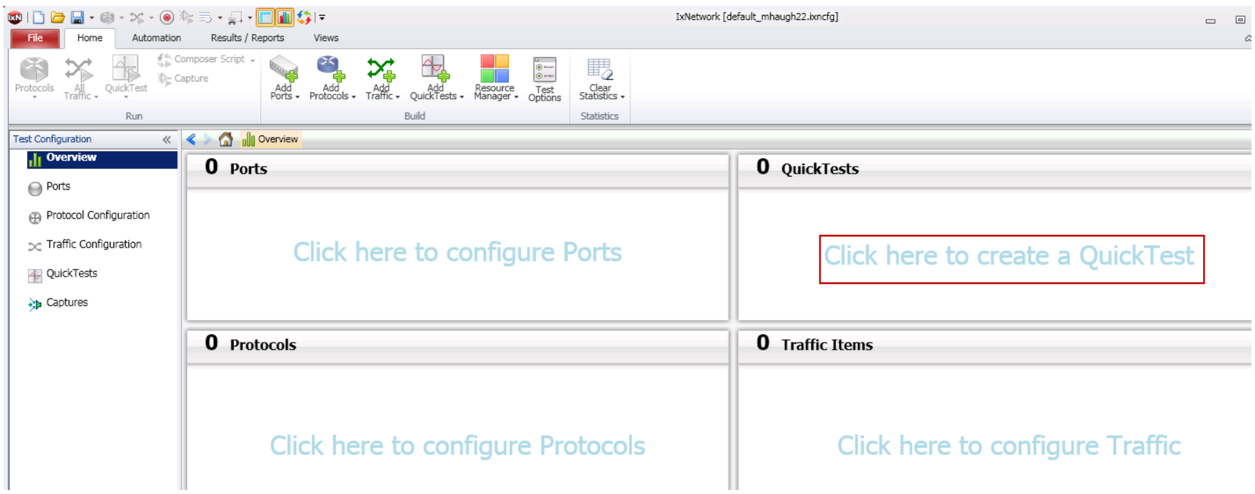


Figure 14. IxNetwork Application Overview screen

2. In the QuickTest wizard expand the RFC 2544 folder and select the **Throughput/Latency** test and click **Next**.

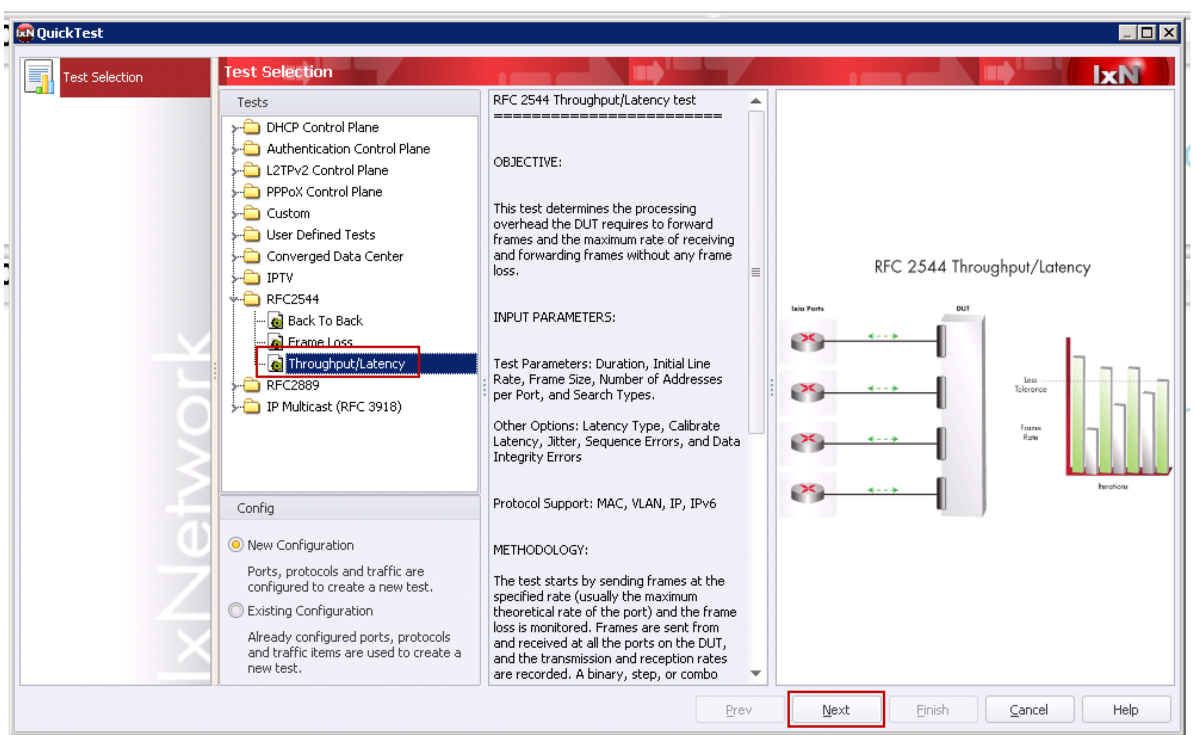


Figure 15. QuickTest Wizard – Initial Screen to Select Test

3. In the Ports configuration, click on the **+ Ports** button to add ports. In the Add Chassis pop-up, click the green **+** to add a chassis. Type the IP address of the Ixia chassis in the box and click **OK**.

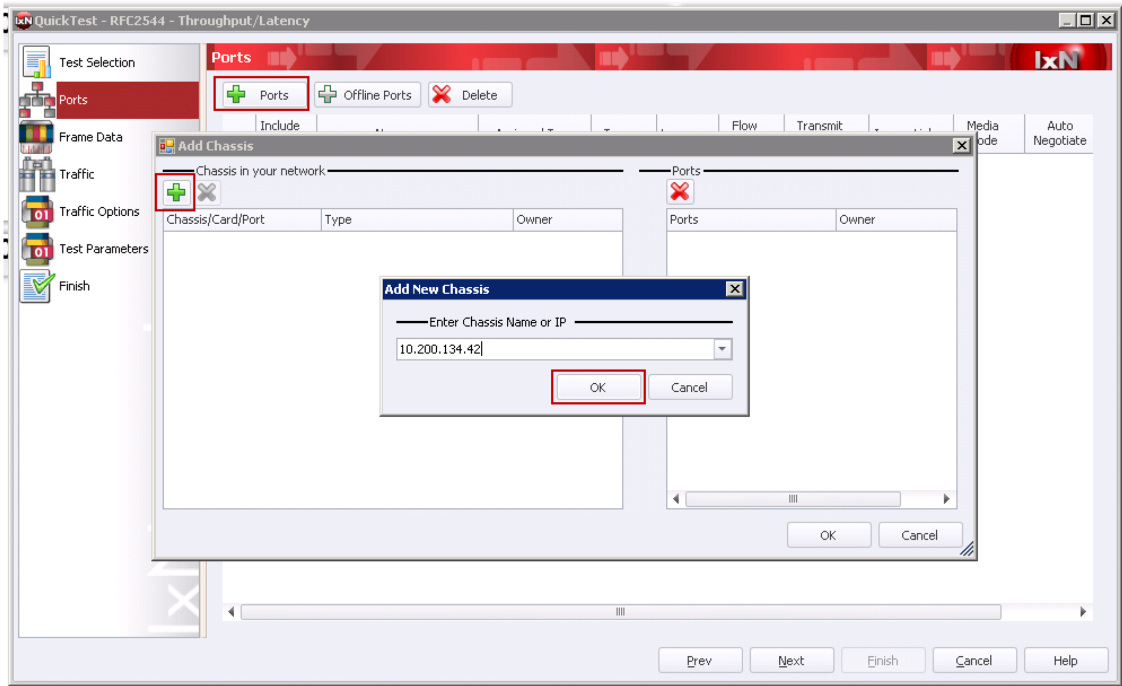


Figure 16. QuickTest Wizard – Add Chassis/Ports

4. In the Add Chassis pop-up, once connected to the Ixia Chassis expand the Card your DUT/SUT is connected using the **down arrow**. Next, **select the ports** to use and click the **>>** arrow to add them to the Ports list. Click **OK** to finish.

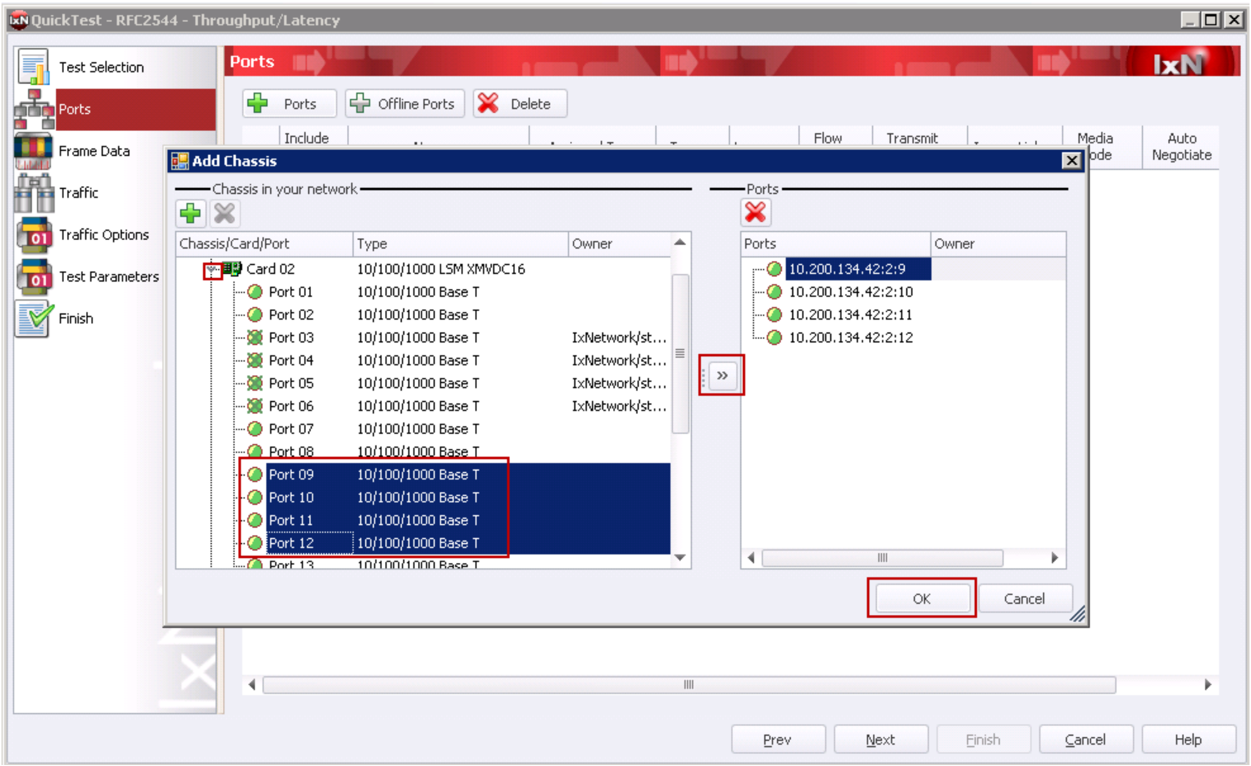


Figure 17. QuickTest Wizard – Select Ports

5. In the Ports screen, (optionally) configure the Media Mode and other Layer 1 properties. Click **Next** to move on.

Note – In this example the DUT is Copper and auto-negotiated Ethernet ports.

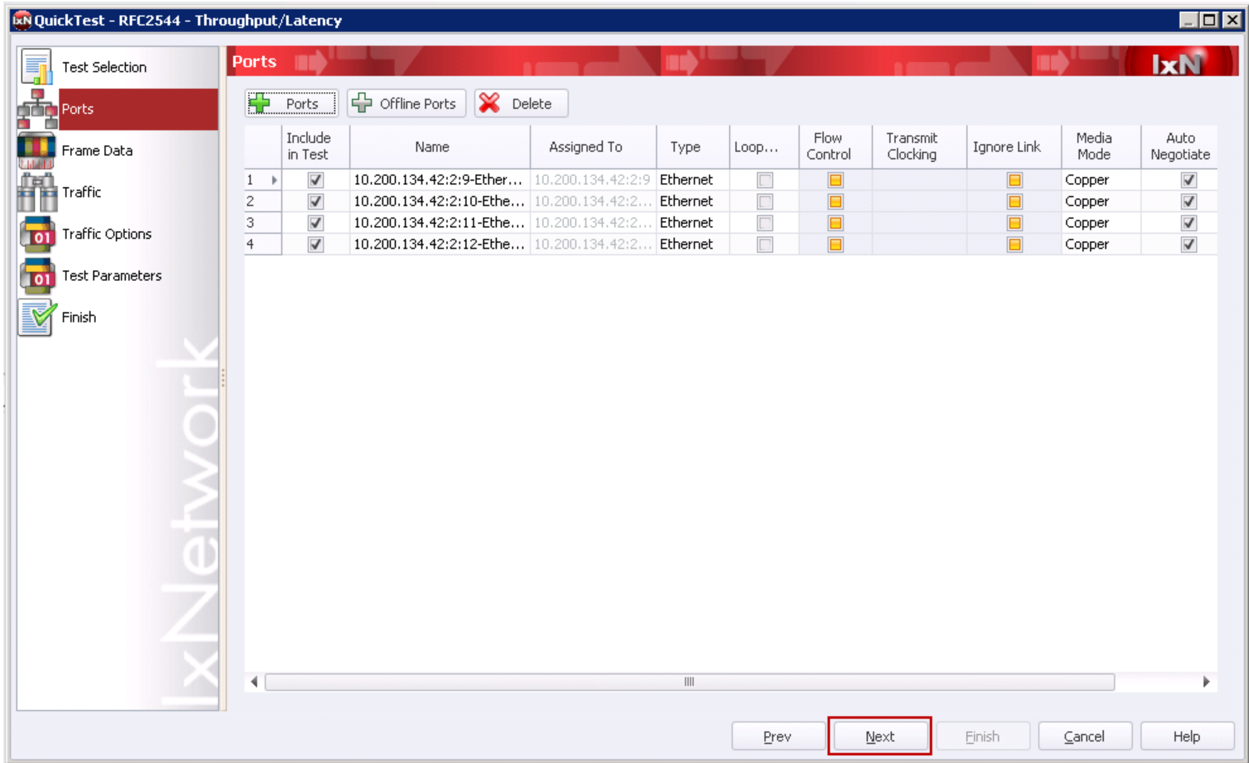


Figure 18. QuickTest Wizard - Edit Port Properties Grid

6. In the Frame Data configuration screen of the wizard select the type of traffic and configure the address, VLAN, and Payload settings. Click **Next** to continue.

   Note – In this example the DUT is a layer 2 Ethernet switch, so MAC traffic is selected.

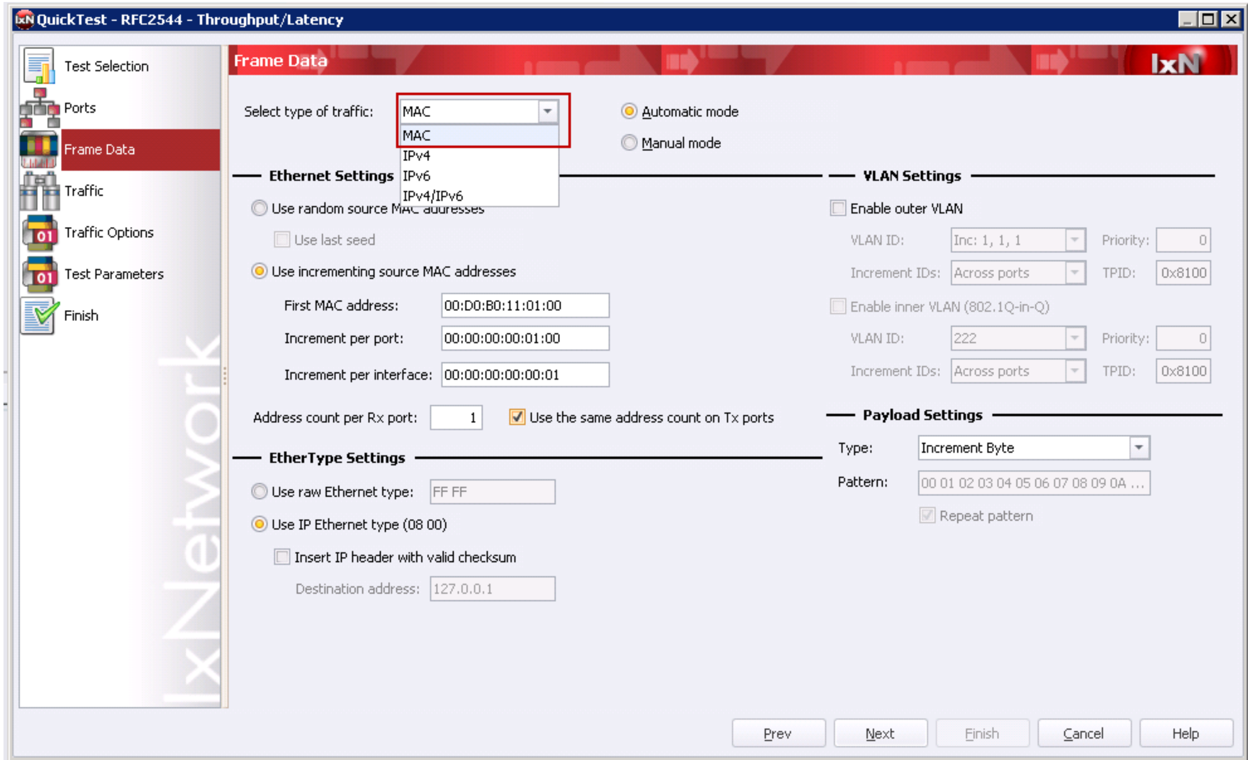


Figure 19. QuickTest Wizard – Frame Data

7. In the Traffic configuration screen select the **Traffic Mesh**, (optionally) enable **Bi-Directional** traffic, then select the **source and destination endpoints**. After selecting the Endpoint Pairs click the green down arrow to add them to the test. (Optionally) this can be repeated to add more traffic Endpoint Sets. Click **Next** to continue.

   Note – In this example the traffic pattern is One-One, with Bi-Directional enabled and all the ports were selected as source and destination creating port pairs.

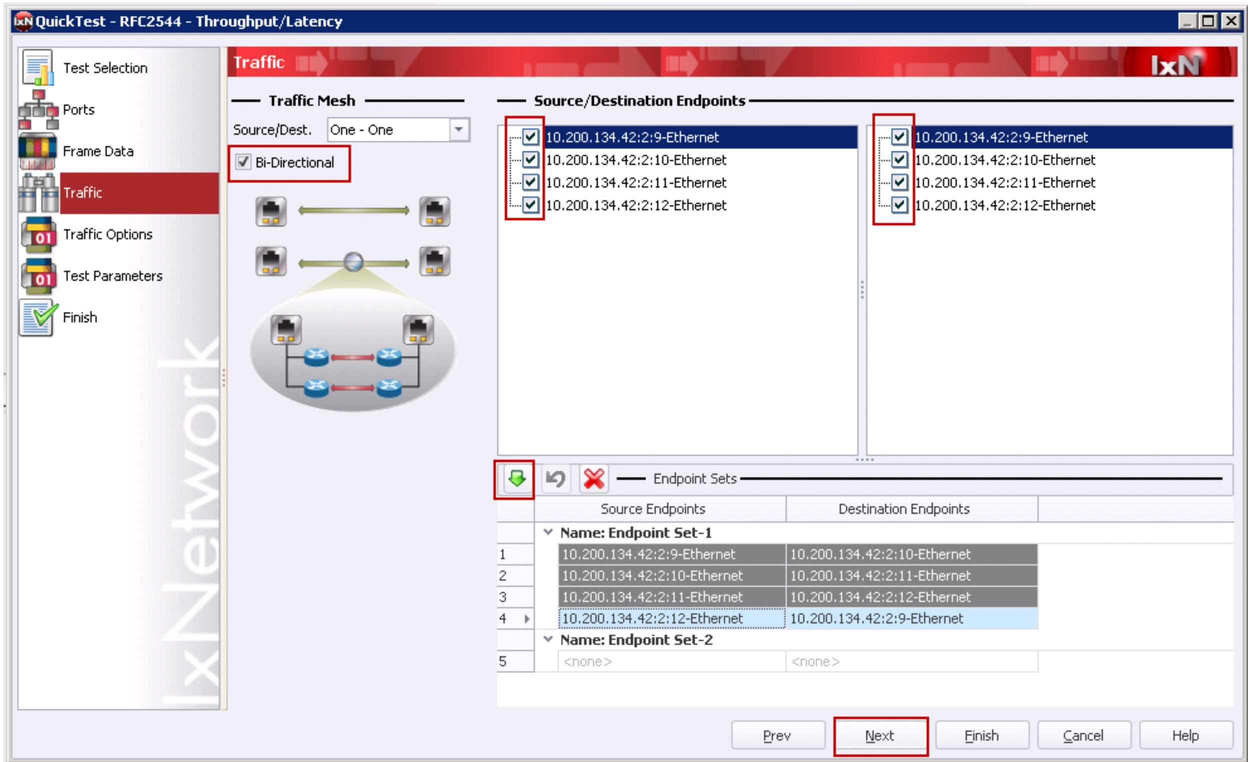


Figure 20. QuickTest Wizard – Traffic Configuration

8. In the Traffic Options screen, configure the Frame Size, Learning and Transmit Delay options. Click **Next** to continue.

   Note – In this example Custom frame size mode was selected which enables the frame sizes recommended by the RFC 2544 standard.

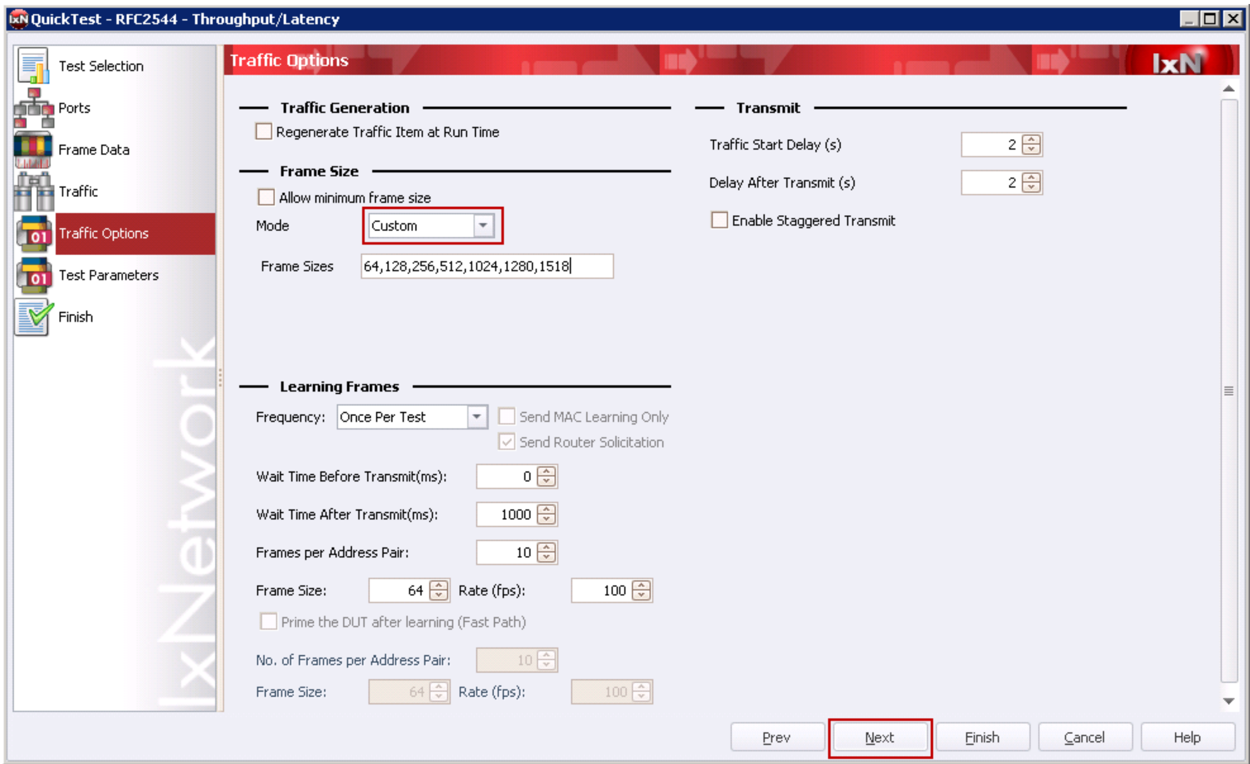


Figure 21. QuickTest Wizard – Traffic Options

9. In the Test Parameters screen configure the Test Parameters, Stats Parameters, Reporting Options, Duration and Iteration Parameters. Click **Next** to continue.

   Note – In this example the layer 2 Ethernet Switch is in Store and Forward mode so that latency mode is selected. Also, the throughput performance is expected to be 100% so to minimize iterations the Initial Rate is configured to be 100%.

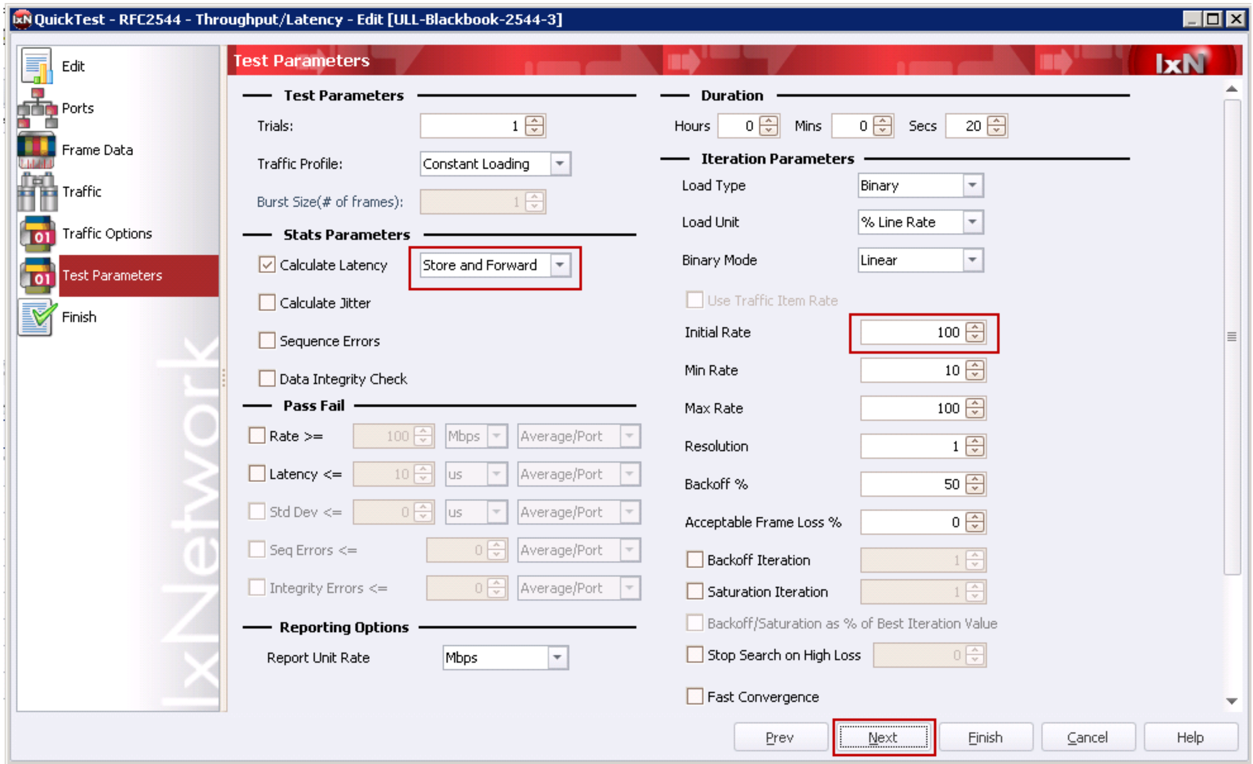


Figure 22. QuickTest Wizard – Test Parameters

10. On the Finish screen type in a name for the QuickTest configuration and click **Finish**.

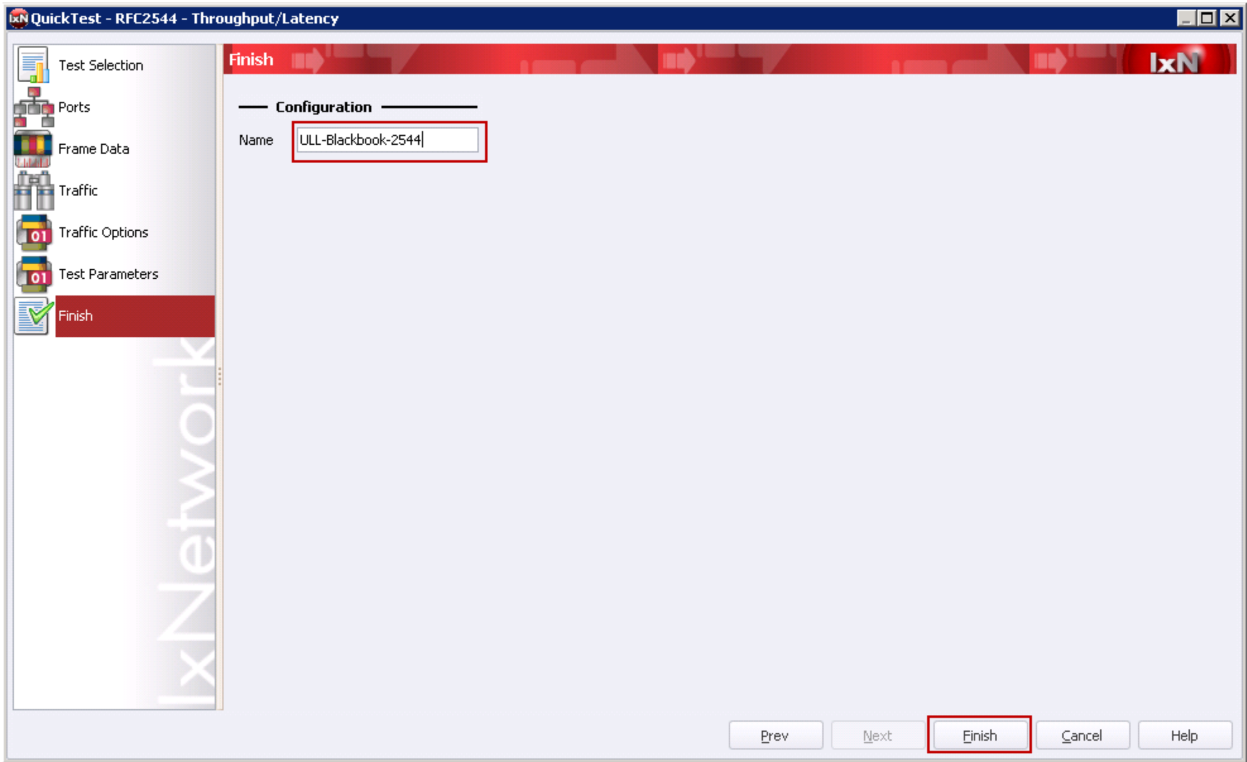


Figure 23. QuickTest Wizard – Finish and Name Configuration

11. Once the QuickTest Wizard is finished on the **Ports** view of the IxNetwork application verify that the State is up (green) and verify the Port Statistics show the expected Speed, Duplex and Link State.

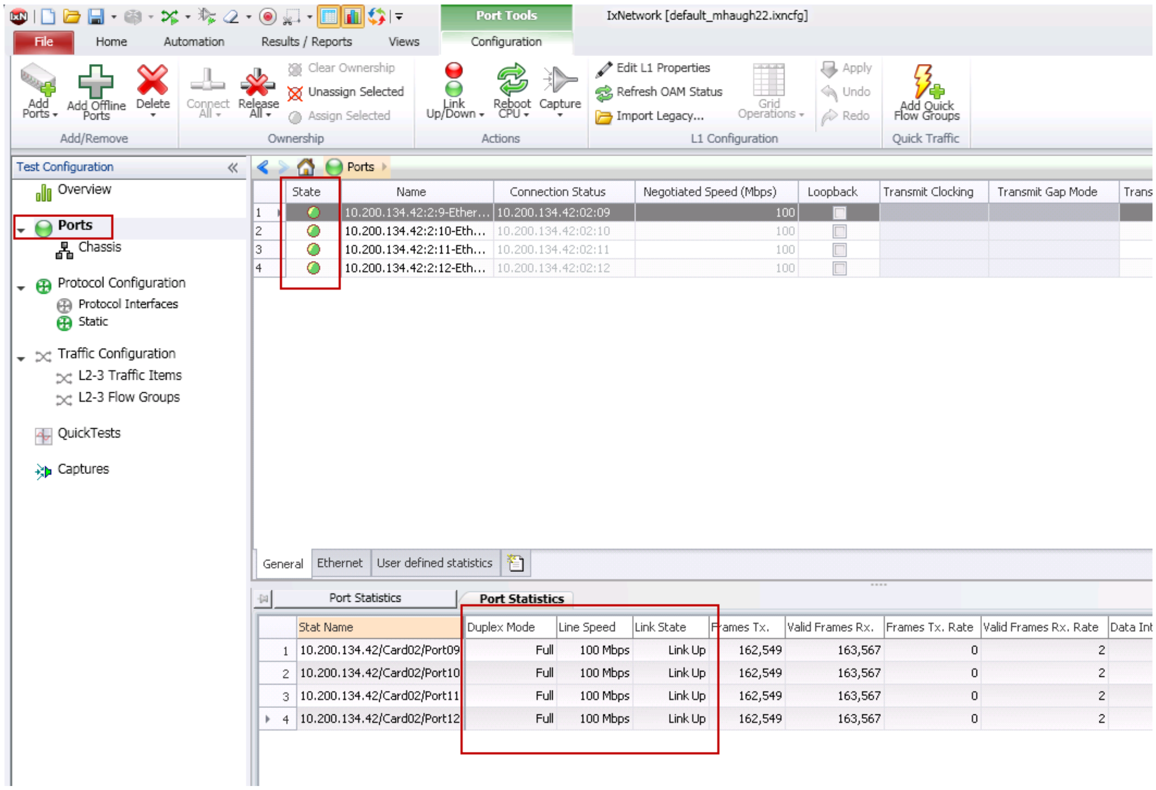


Figure 24. IxNetwork – Ports View

12. Once ready to start the test, navigate to the **QuickTests** view in the Test Configuration bar. Click on the **Play** button with the name of the configuration. Once the test is running the log tab will show the real-time progress and the Stats Viewer will show real-time stats including latency measurements at the Traffic Item and Flow views. There are tabs along the bottom to filter for specific results, like latency.

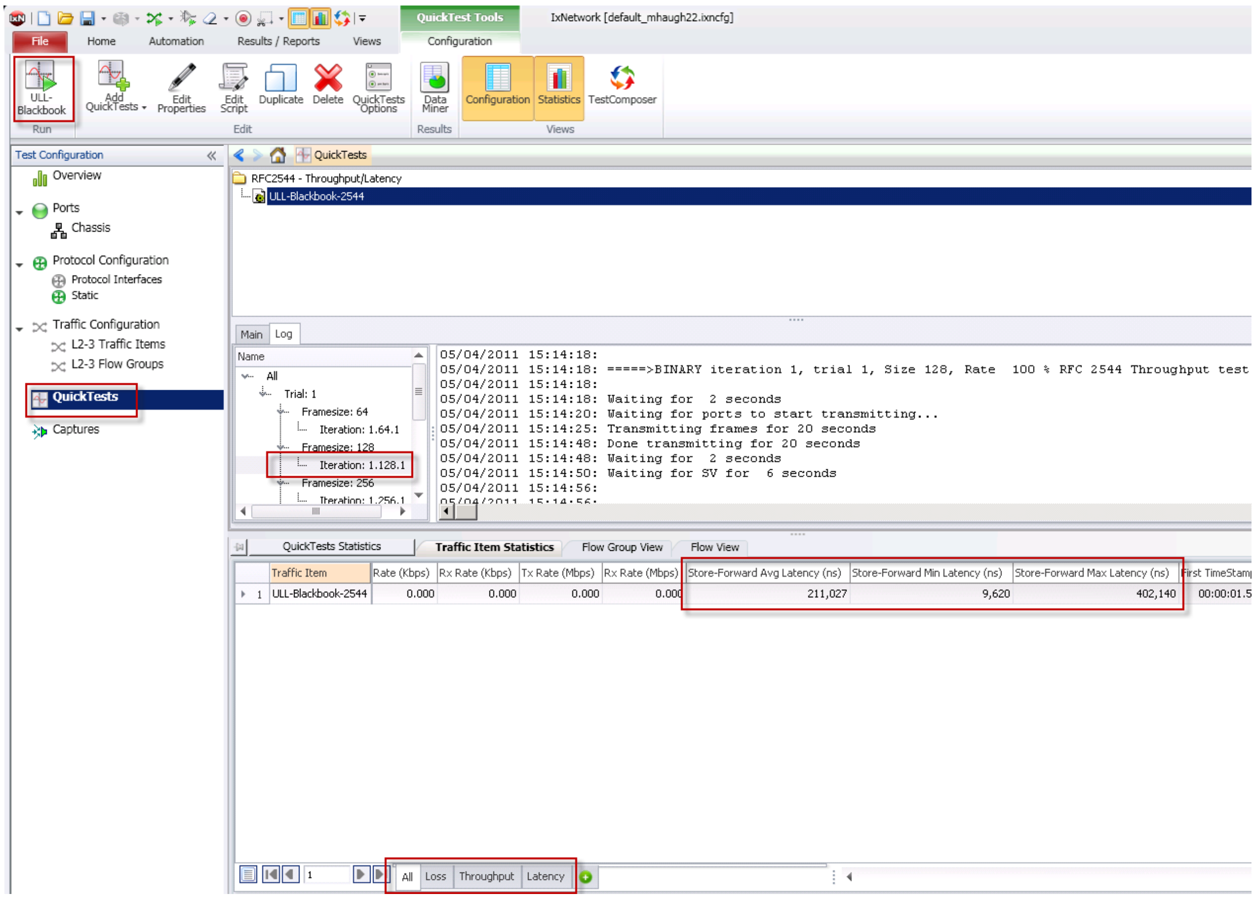


Figure 25. QuickTests View – Running Test

13. Once the test is completed the Data Miner browser will pop-up. In Data Miner the current test should be the active view and the Results can be viewed under the Details section. The latency results are available for all iterations under the Aggregated Results Tab view.

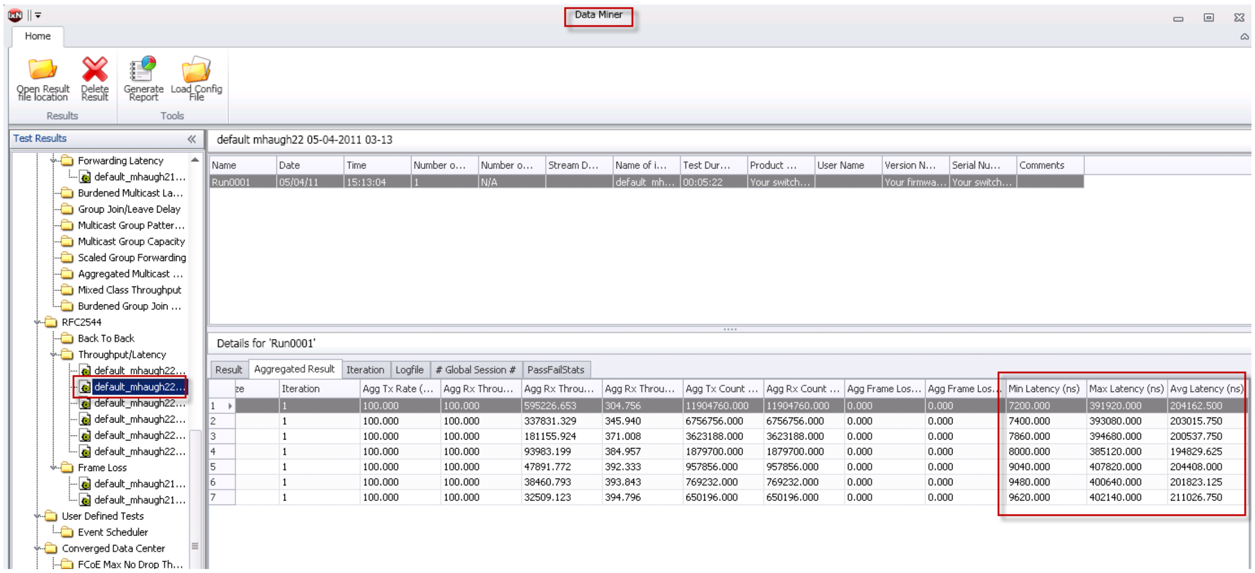


Figure 26. Data Miner – Browse Post-Test Results Files

14. In Data Miner select the test run and click on the **Generate Report** button on the toolbar to generate a PDF report. In the report the latency performance table is provided.

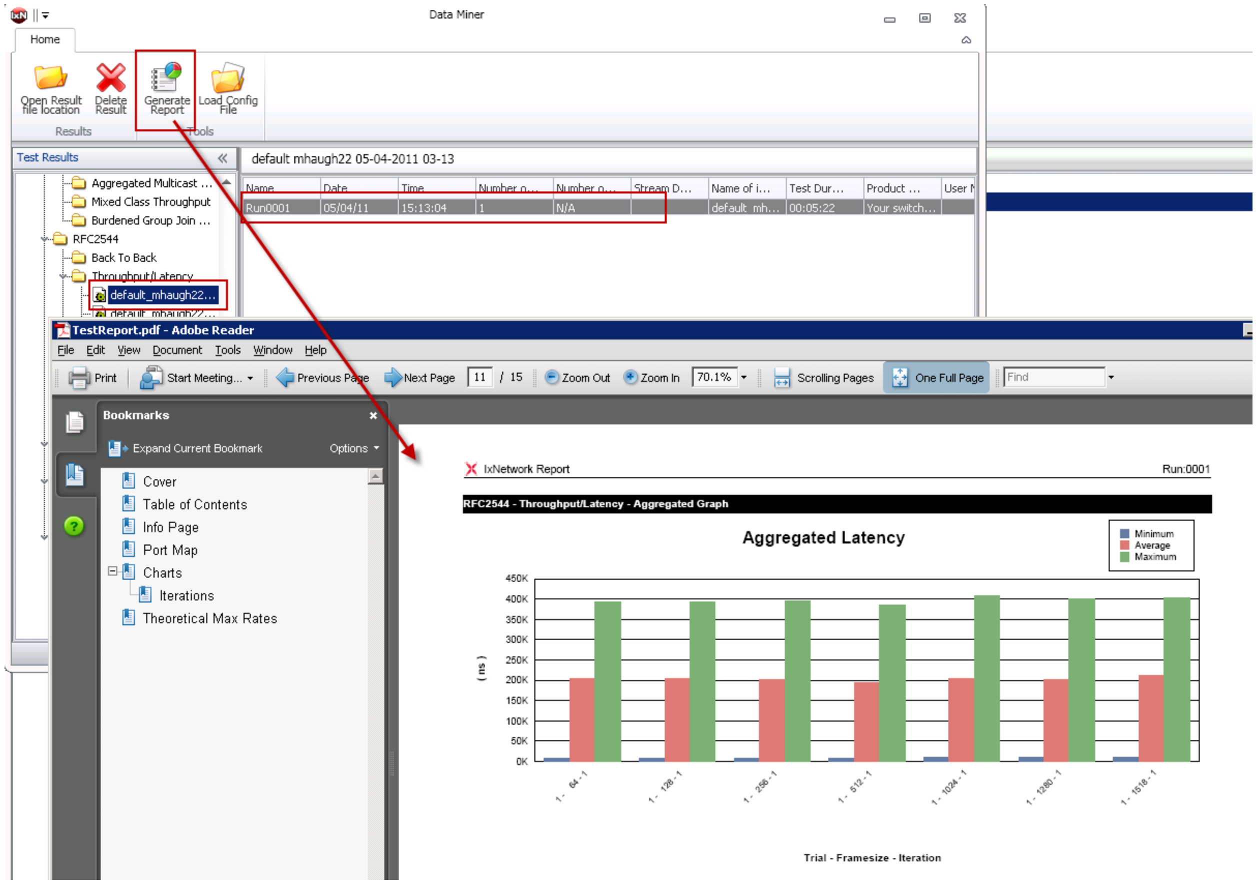


Figure 27. Data Miner – Generate Report

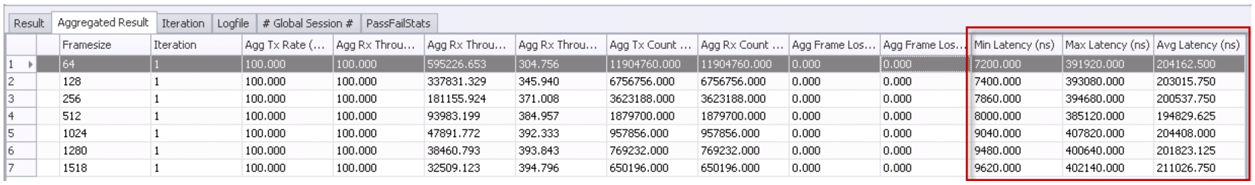
Test Variables

Any of the following variables may be scaled up in the test to further determine the scalability and performance of the DUT/SUT:

- Number of test ports
- Traffic pattern
- Measurement options enabled
- Transmit duration
- Number of frame sizes tested

Result Analysis

The focus of this test was to measure the latency of the Device Under Test, which in this case was a layer 2 Ethernet switch. Using the IxNetwork RFC 2544 QuickTest and selecting the Throughput/Latency test the throughput was confirmed to be 100% line rate at each packet size (no frame loss was measured) and the minimum, average and maximum latency was measured ranging from 7.2k ns minimum, 203k ns average and a maximum of 407k ns. To determine if this was a “pass” or a “fail” it would depend on the requirement of the application.


Result | Aggregated Result | Iteration | Logfile | # Global Session # | PassFailStats

	Framesize	Iteration	Agg Tx Rate (...	Agg Rx Throu...	Agg Rx Throu...	Agg Rx Throu...	Agg Tx Count ...	Agg Rx Count ...	Agg Frame Los...	Agg Frame Los...	Min Latency (ns)	Max Latency (ns)	Avg Latency (ns)
1	64	1	100.000	100.000	595226.653	304.756	11904760.000	11904760.000	0.000	0.000	7200.000	391920.000	204162.500
2	128	1	100.000	100.000	337831.329	345.940	6756756.000	6756756.000	0.000	0.000	7400.000	393080.000	203015.750
3	256	1	100.000	100.000	181155.924	371.008	3623188.000	3623188.000	0.000	0.000	7860.000	394680.000	200537.750
4	512	1	100.000	100.000	93983.199	384.957	1879700.000	1879700.000	0.000	0.000	8000.000	385120.000	194829.625
5	1024	1	100.000	100.000	47891.772	392.333	957856.000	957856.000	0.000	0.000	9040.000	407820.000	204408.000
6	1280	1	100.000	100.000	38460.793	393.843	769232.000	769232.000	0.000	0.000	9480.000	400640.000	201823.125
7	1518	1	100.000	100.000	32509.123	394.796	650196.000	650196.000	0.000	0.000	9620.000	402140.000	211026.750

Figure 28. Aggregated Results from Data Miner

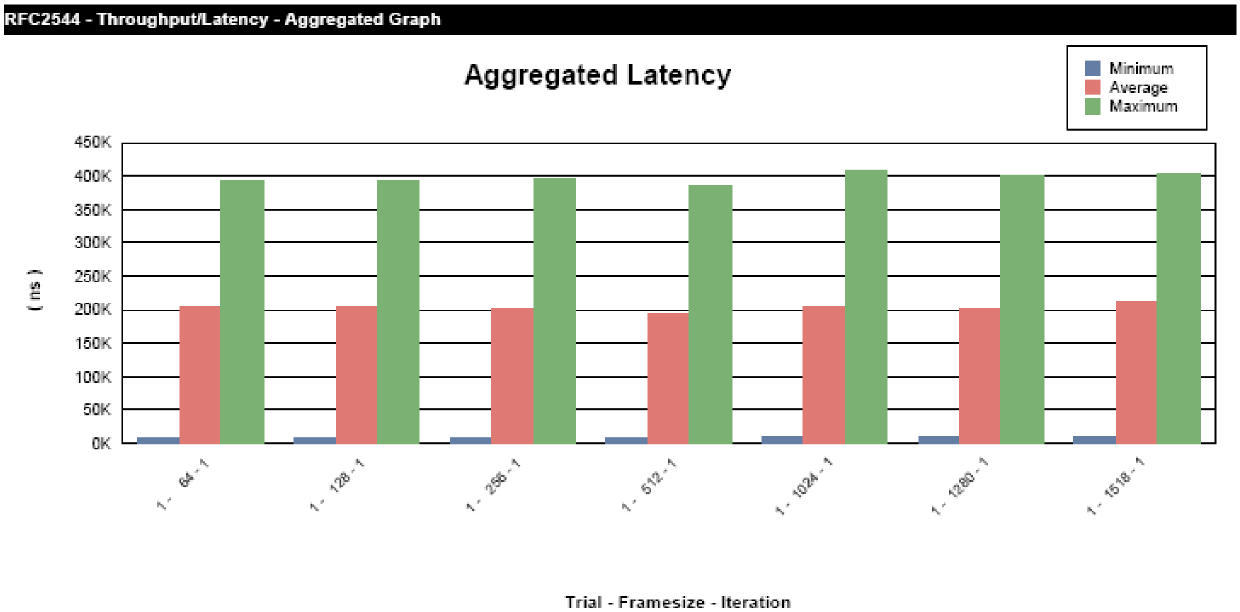


Figure 29. Aggregated Latency Graph in Generated Report

Conclusions

Establishing a latency measurement will depend on many factors and is primarily dependent on the capability of the DUT/SUT and the variables like traffic configuration and forwarding mode (like store and forward or cut through).

Test Case: ULL Measuring Latency over Time and Enabling the Latency Histogram

Overview

Determining the minimum, maximum and average latency is important. However, it is critical to understand if the latency values are changing over time and how many packets were in the maximum of the range. Increasing latency over time could indicate a device is buffering packets which could result in packet drops if the transmit duration is long enough.

Objective

In this test case IxNetwork will be used to configure traffic and enable specific latency measurements including latency over time and a latency histogram.

Setup

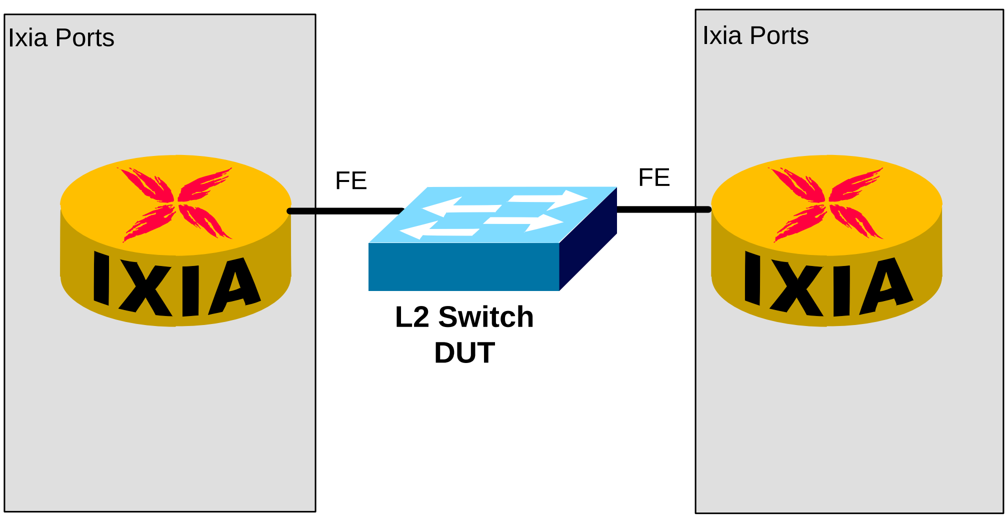


Figure 30. Two 100 Mbp ports connected to a L2 DUT

Step-by-step instructions

1. Launch the **IxNetwork** application, then on the **Overview** view click on the link to "**Click here to configure Ports**".

   Note – Another option is to select "Add Ports" from the Home toolbar.

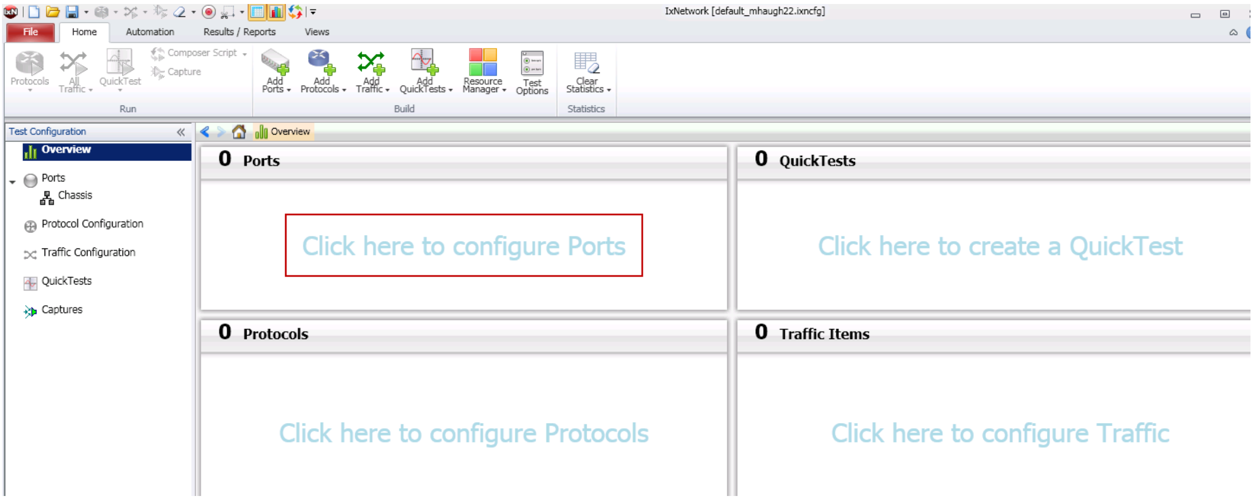


Figure 31. IxNetwork Application Overview screen

2. In the Port Selection dialog, select the chassis to be used in this test (if no chassis has previously been used then click the green + to add a chassis). Next, click on the button to **Connect all checked.**

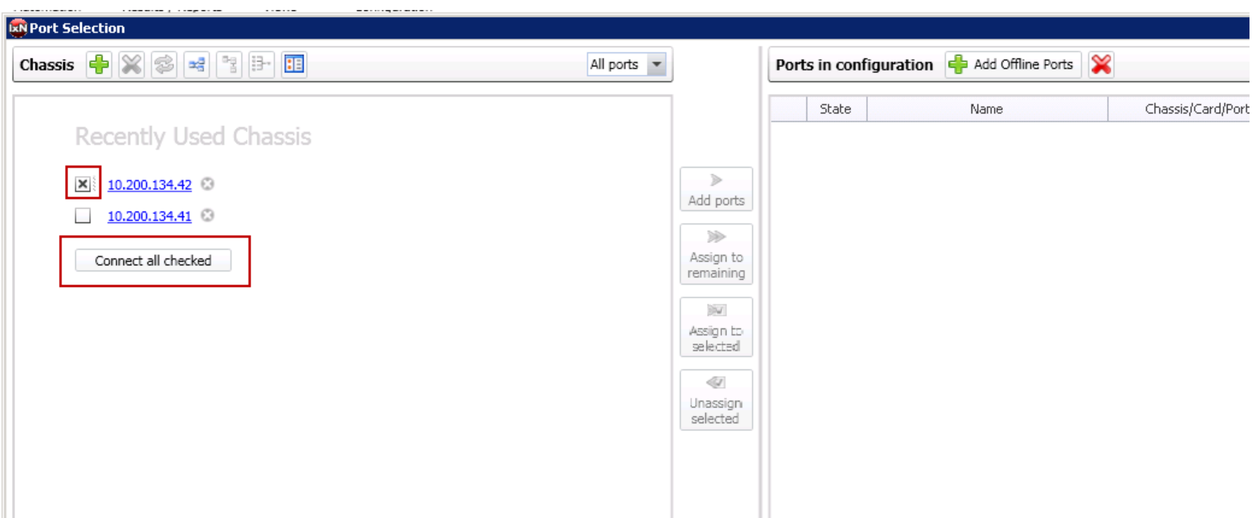


Figure 32. Ports Selection dialog

3. Next, in the Port Section dialog, click on the arrow to expand the card to be used in this test. Then select the ports and click the **Add ports** button. Click **OK** to finish.

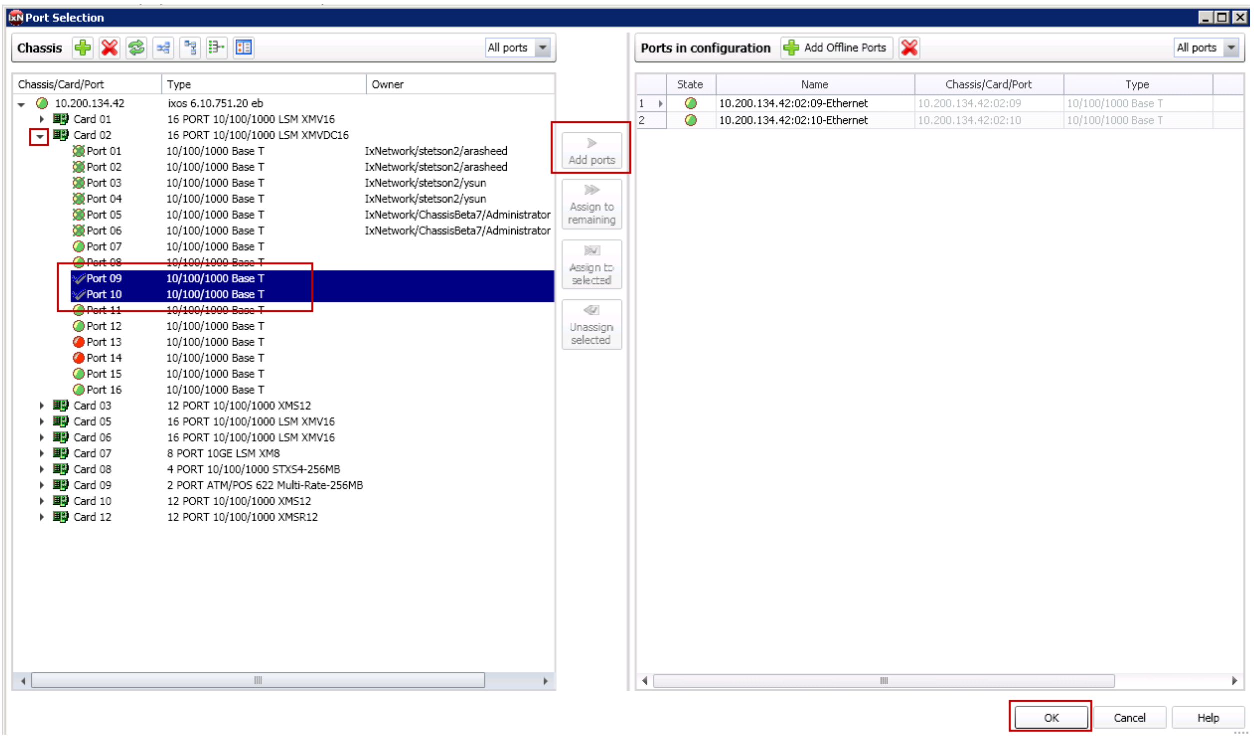


Figure 33. Ports Selection dialog

4. Once finished with the Port Selection dialog, on the **Ports** view of the IxNetwork application verify that the State is up (green) and verify the **Port Statistics** show the expected Speed, Duplex and Link State.

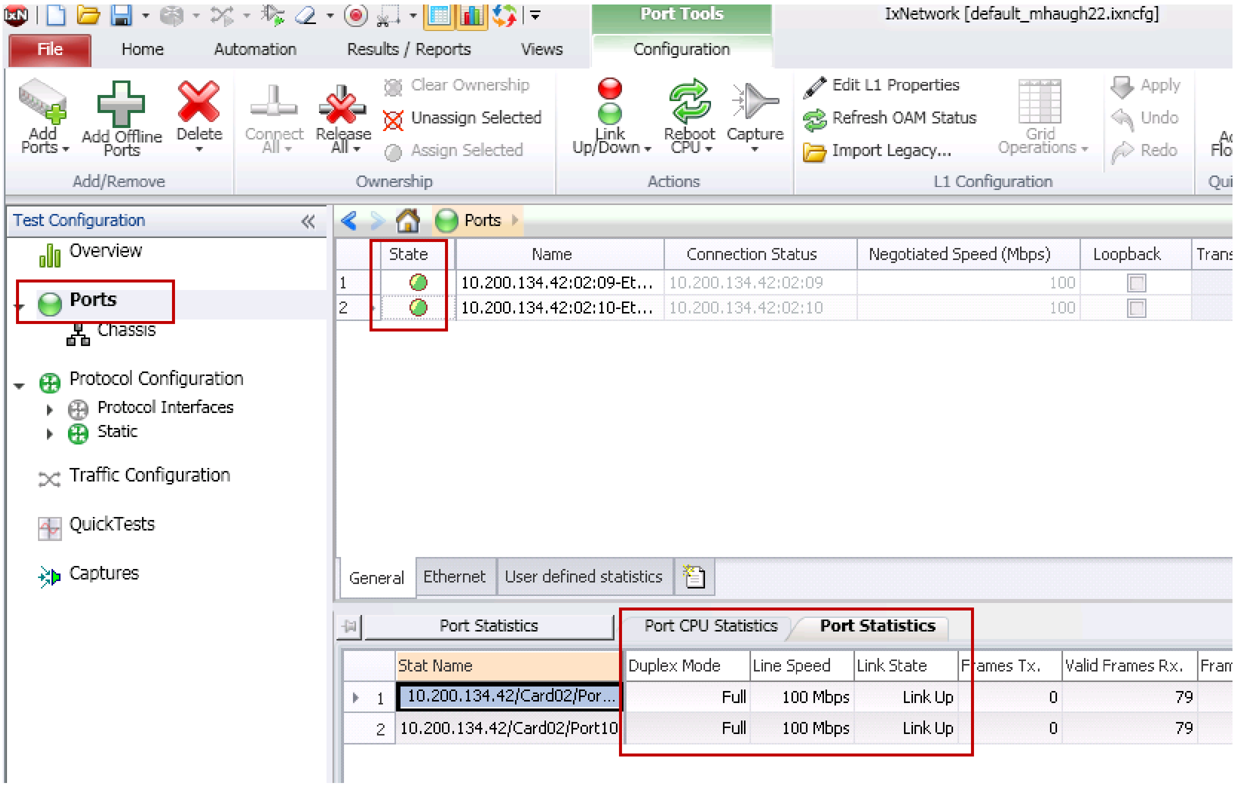


Figure 34. Ports View

5. The next step is to build traffic. First traffic end points should be created, so go to the **Static** view and click on the **LANs** tab since the DUT is a Layer 2 switch. Click the **Add LANs** button on the toolbar.

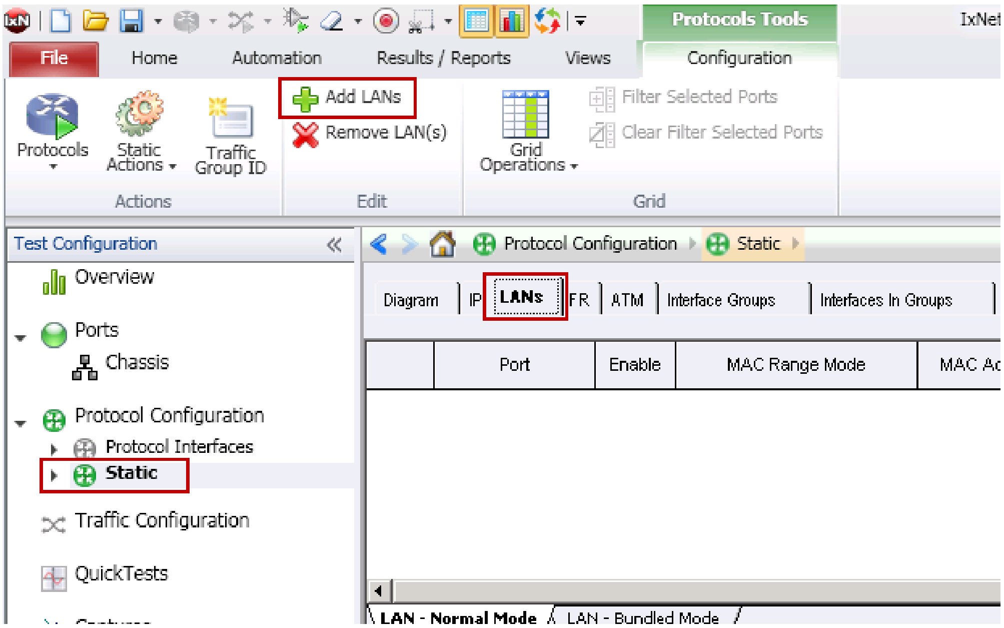


Figure 35. Static LANs Configuration

6. In the **Add Static Lans** pop-up, check the boxes on each port to add 1 per Port. Then click **OK**.

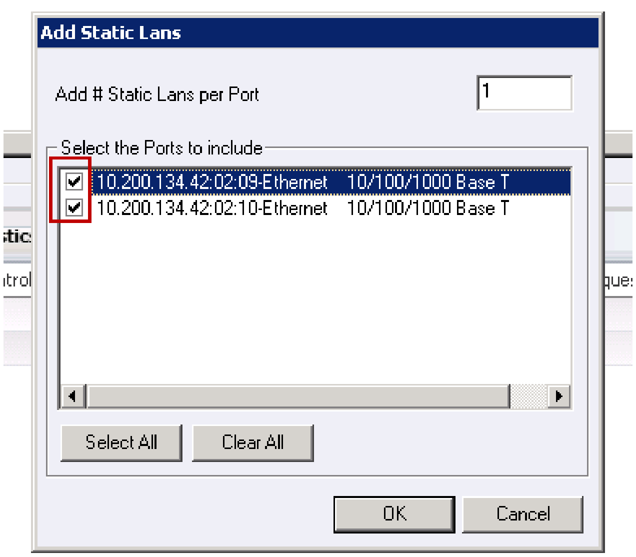


Figure 36. Add Static Lans Wizard

7. Next, configure the MAC addresses for each port and check the box to Enable the LAN.

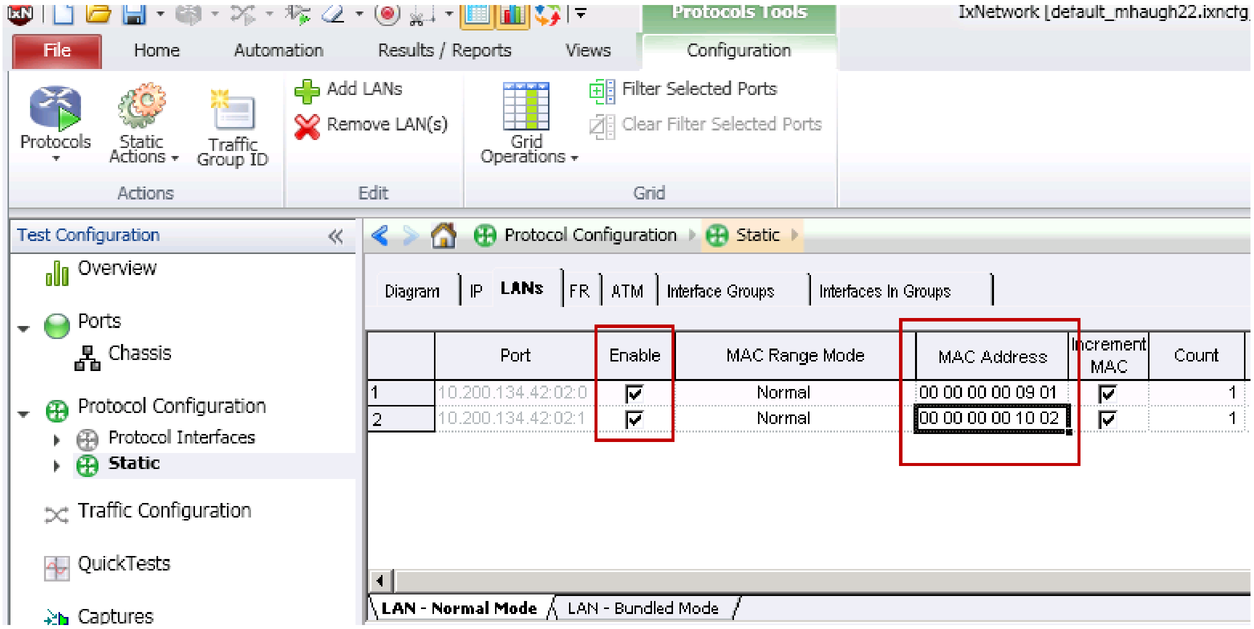


Figure 37. Static LANs Configuration

8. Now navigate to the **Traffic Configuration** view and click on the **Add L2-3 Traffic Items** button.

   Note – another option is to click on the L2-3 Traffic button from the toolbar.

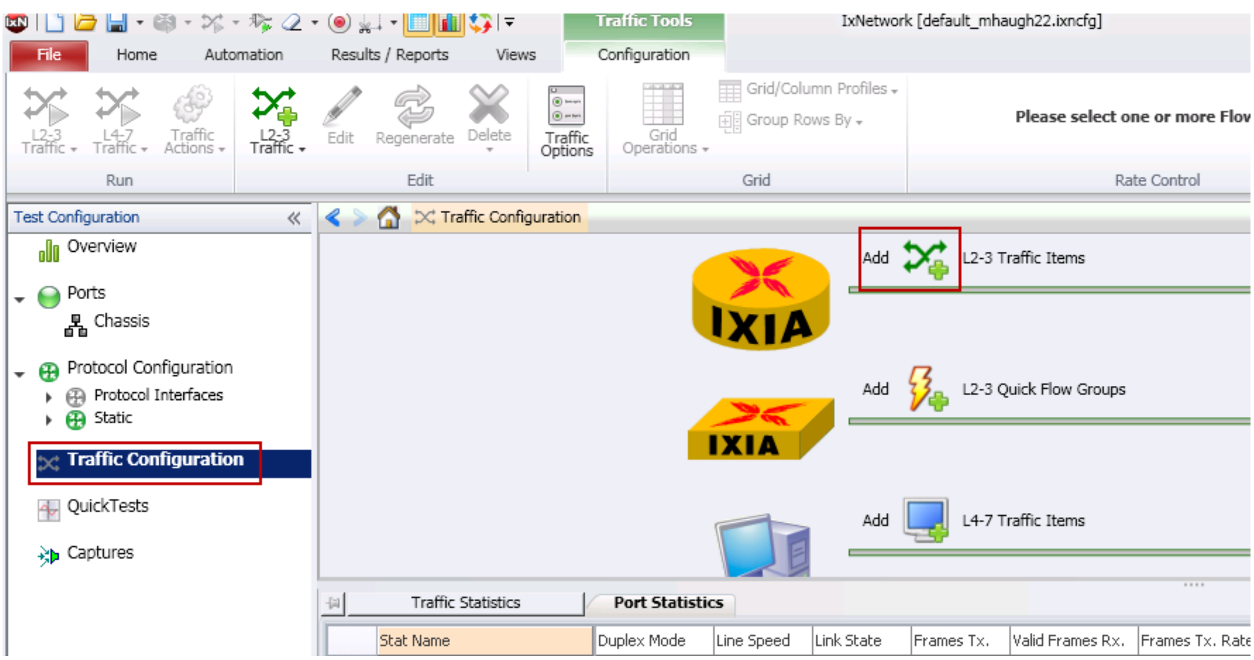


Figure 38. Traffic Configuration

9. In the **Advanced Traffic Wizard** select the Type of Traffic as Ethernet/VLAN (since the DUT is a Layer 2 switch). Check the **Bi-Directional** check box. Select the MAC address endpoints as Source and Destination and click the green down arrow to add the traffic as an Endpoint Set. Next, Click on **Frame Setup** in the navigation bar.

   Note – Packet/QoS and Flow Group Setup are optional to configure for this test.

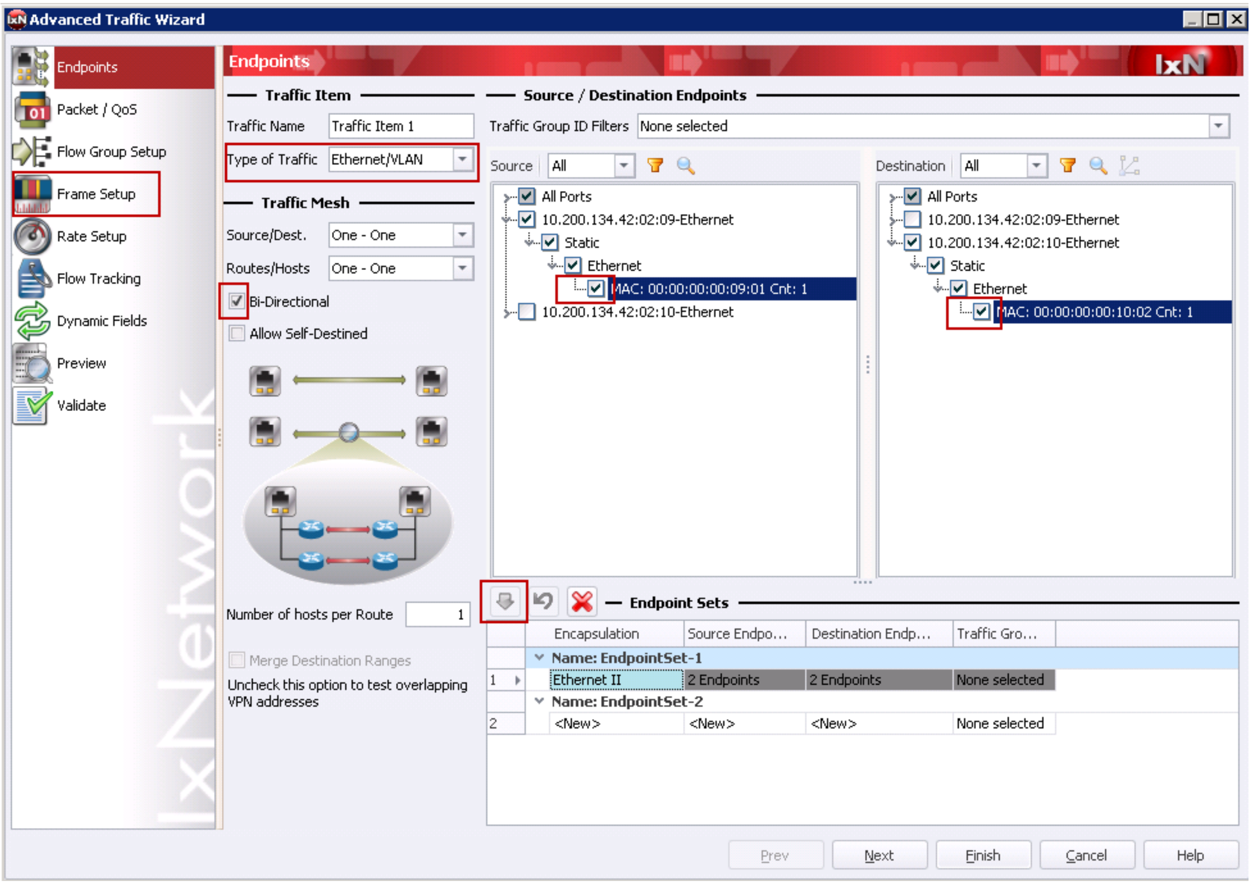


Figure 39. Advanced Traffic Wizard – Endpoints

10. On the **Frame Setup** page, configure a fixed frame size of 512 bytes. Click **Next** to continue to the Rate Setup.

    Note – Frame size is a variable in this test

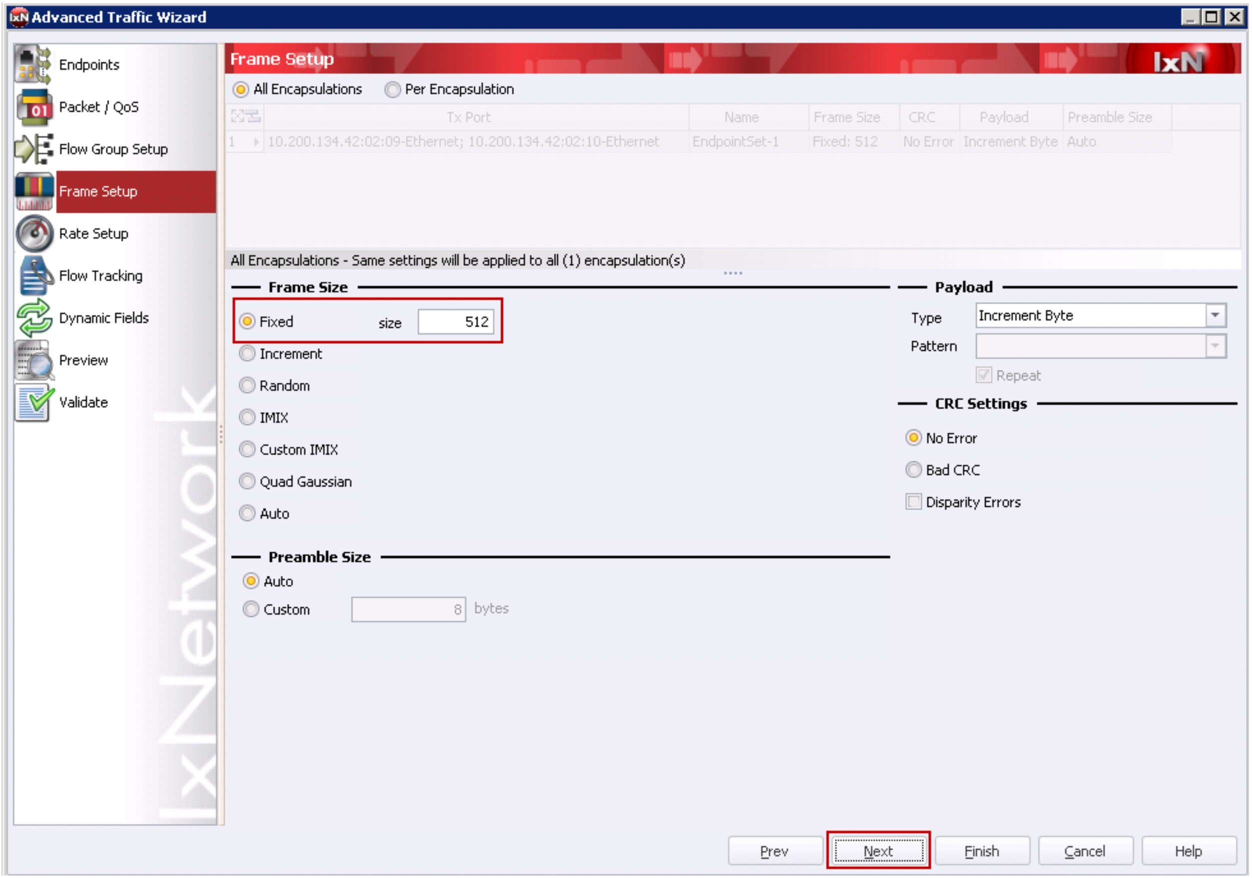


Figure 40. Advanced Traffic Wizard – Frame Setup

11. On the **Rate Setup** page, based on the result of the 2544 test, the **Rate** will be configured at 100% (it is recommended to test at the highest no-drop rate). Configure the Transmission Mode to be **Fixed Duration** for 60 seconds. Click **Next** to move on to the Flow Tracking page.

    Note – Transmit duration is a variable in this test. It is recommended to test for at least 60 seconds to determine the trend of the latency measurement over time. Longer duration test should also be run.

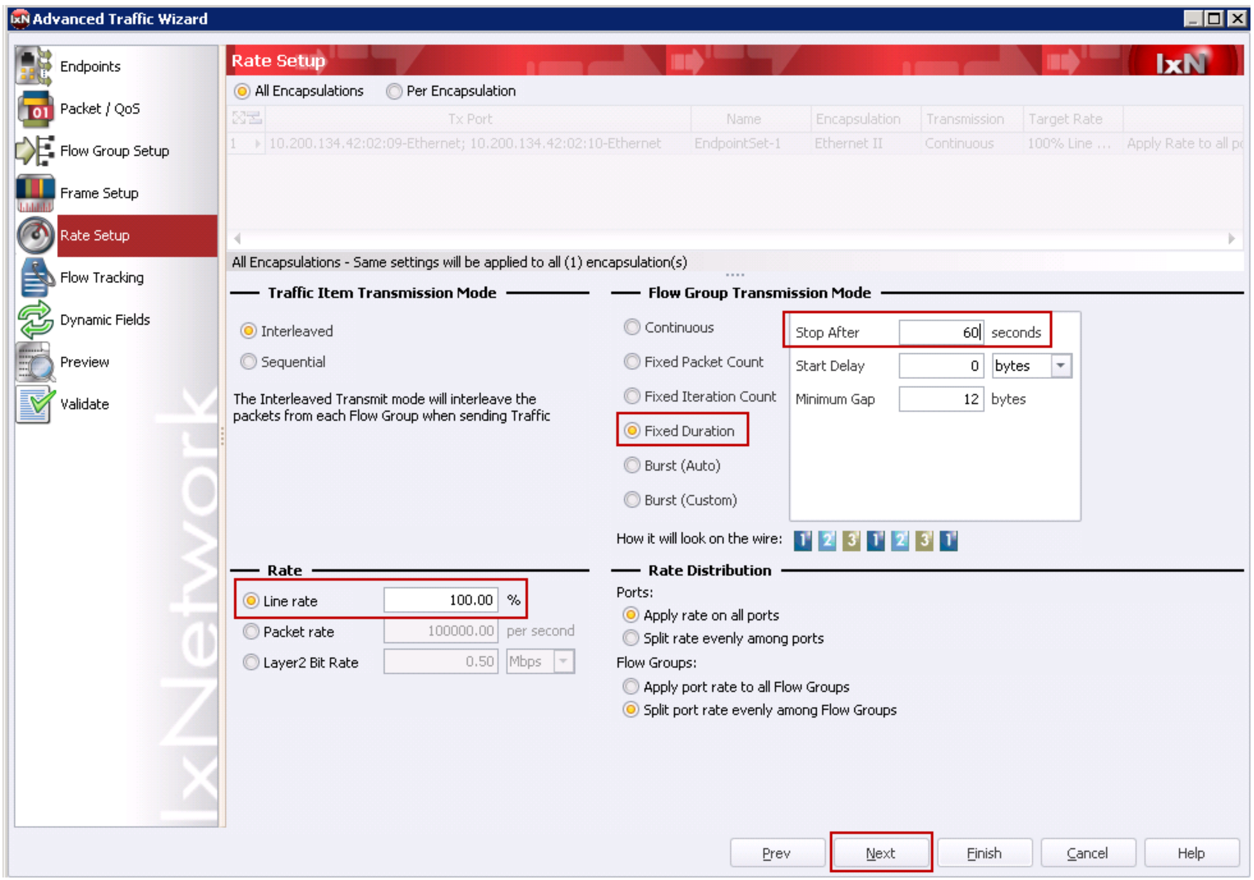


Figure 41. Advanced Traffic Wizard - Rate Setup

12. On the **Flow Tracking** page, select the Track Flows by option, Destination MAC is used in this Layer 2 switch test example. Under Latency Bin Measurement, click the Enable box and configure the bin values. Since the 2544 test indicated a range from 8us to 385us the bins were configured from 10us to 500us. Click **Finish**.

    Note – at least one tracking option must be enabled to get traffic statistics.

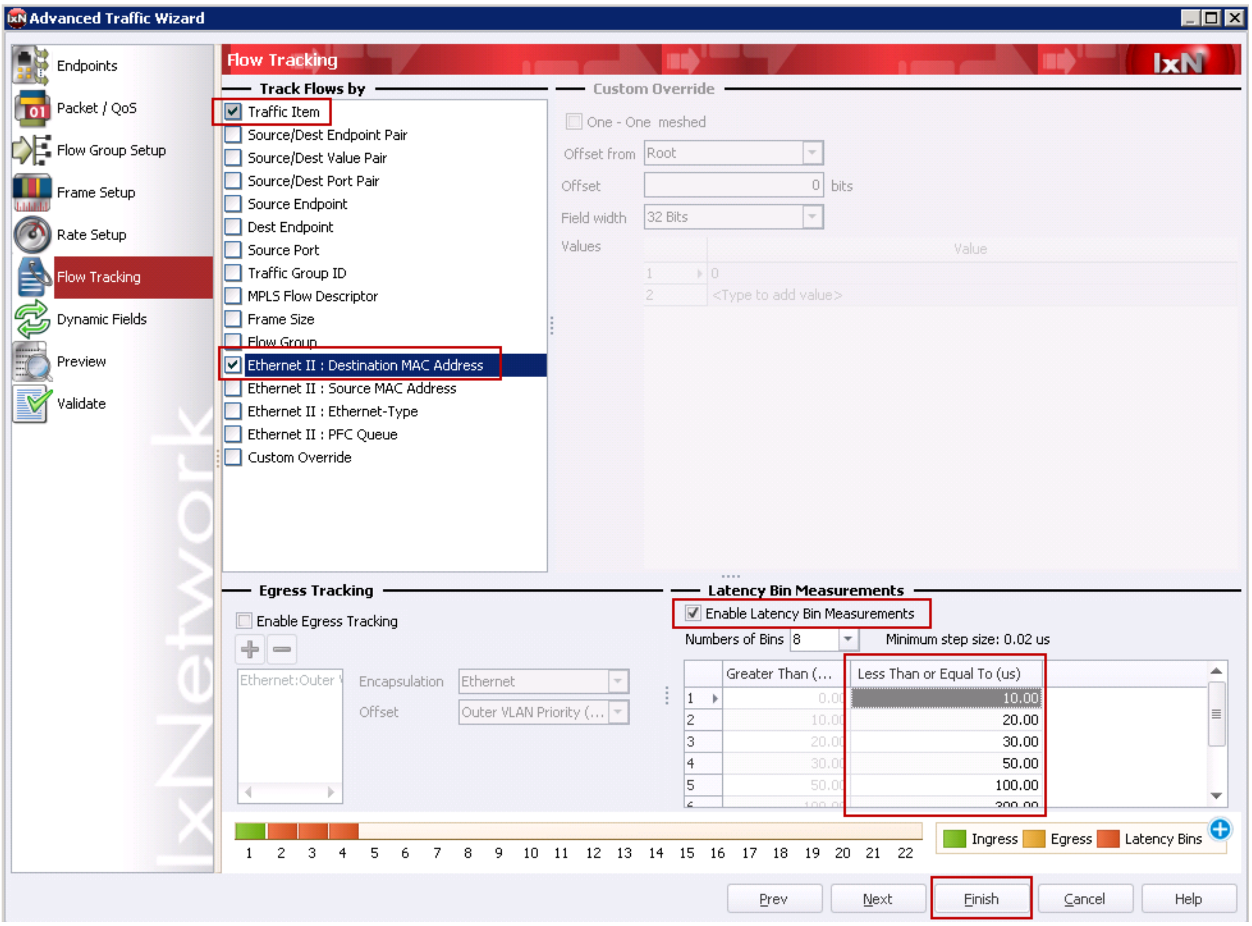


Figure 42. Advanced Traffic Wizard – Flow Tracking

13. Once finished with the traffic wizard, from the Configuration tab toolbar, click the **Apply L2-L3 Traffic** button. This applies the configuration to the hardware.

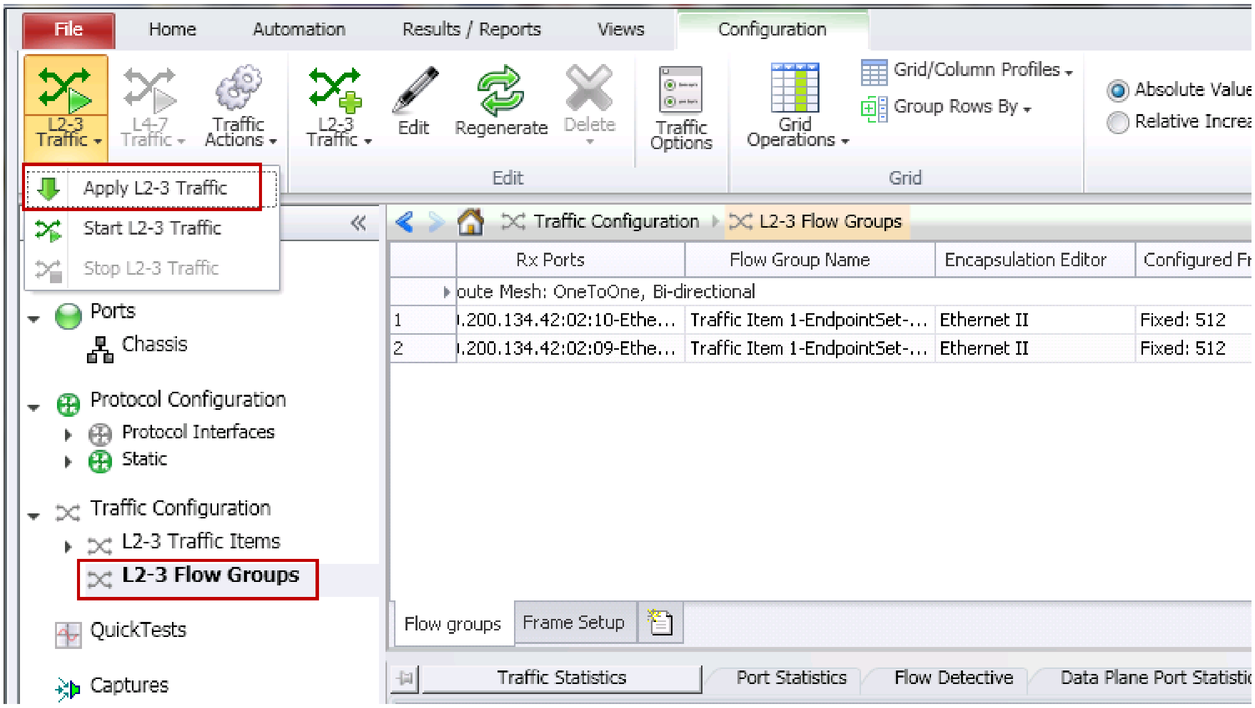


Figure 43. Apply Traffic

14. When testing a Layer 2 switch it is important to send learning frames before a test so that the MAC address table is populated and the DUT will not need to broadcast the frames to perform learning during the test. To send learning frames there is an option under Traffic Actions to **Send Learning Frames**. The frames can be verified in the Port Statistics view.

    Note – It is common to have more Rx than Tx on the Port view since the DUT may be sending frames like discover packets or other protocol packets. These types of packets are not counted in the Traffic Item and Flow statistics.

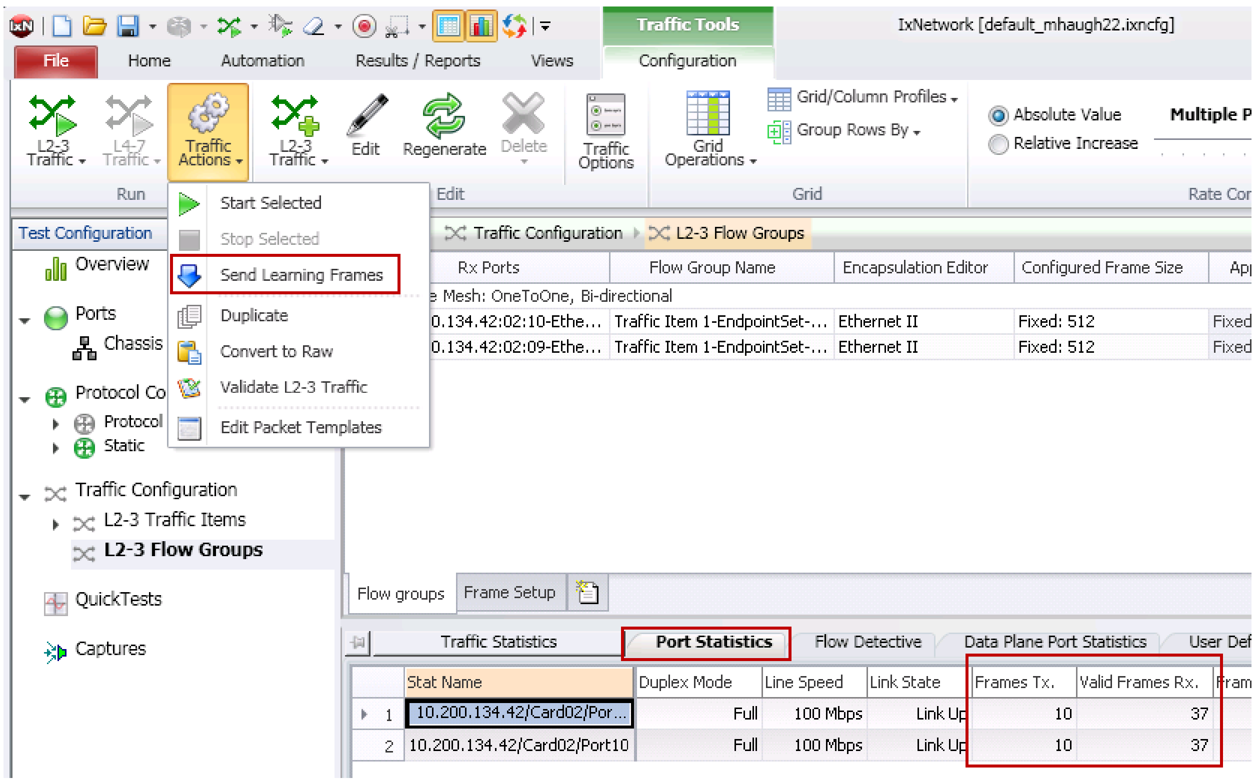


Figure 44. Send Learning Frames

15. Next, to be able to view the Latency Histogram (Rx count per bin), click on the **Traffic Item Statistics** tab. Then, the Statistics Tools toolbar is now visible. Click on the **Customize Traffic View** button. In this dialog remove all the Included Stats by selecting them ad clicking the remove button. Then, click on the Rx Frames per Bin and add the stat and click OK.

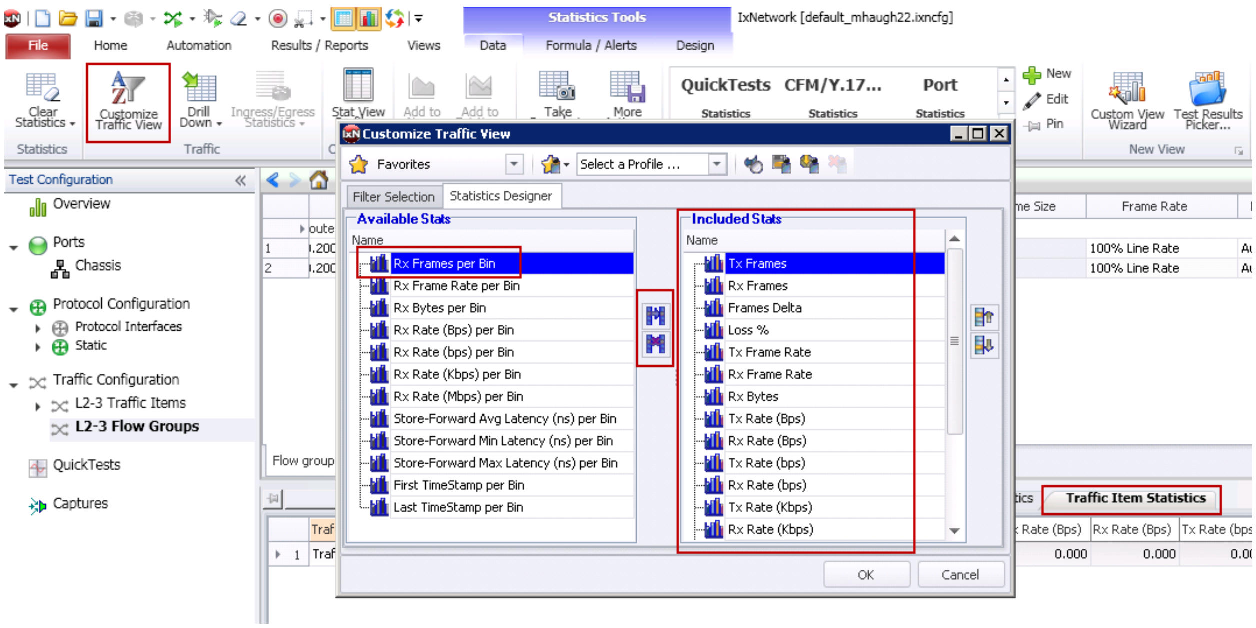


Figure 45. Customize Traffic View

On the **Filter Selection** tab select the port to enable the latency bin measurement on.

Note that the red circle with white x indicates an error. In this case multiple Rx ports cannot be selected, so only one is selected to fix this error.

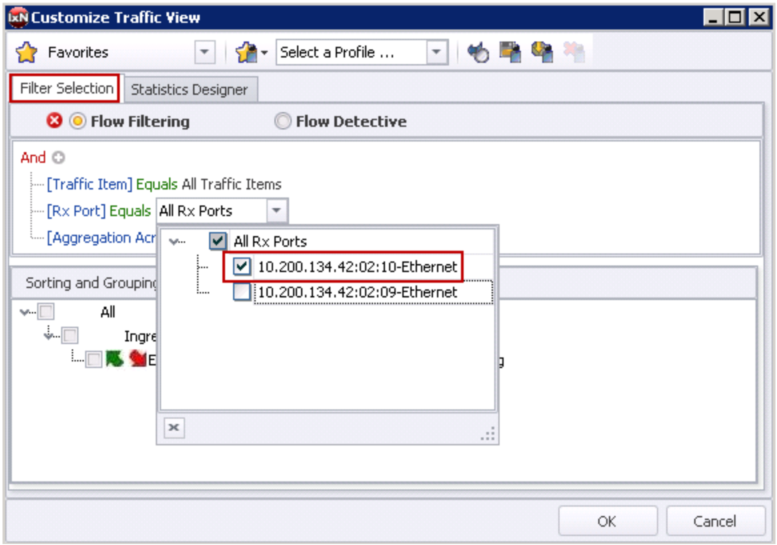


Figure 46. Filter Selection

16. Now, under the **User Defined Statistics** tab the latency bin values are available. Use these statics to determine the performance and behavior of the measured latency. In this example the largest bin continues to increment which could indicate the DUT is buffering frames and latency performance is getting worse over time.

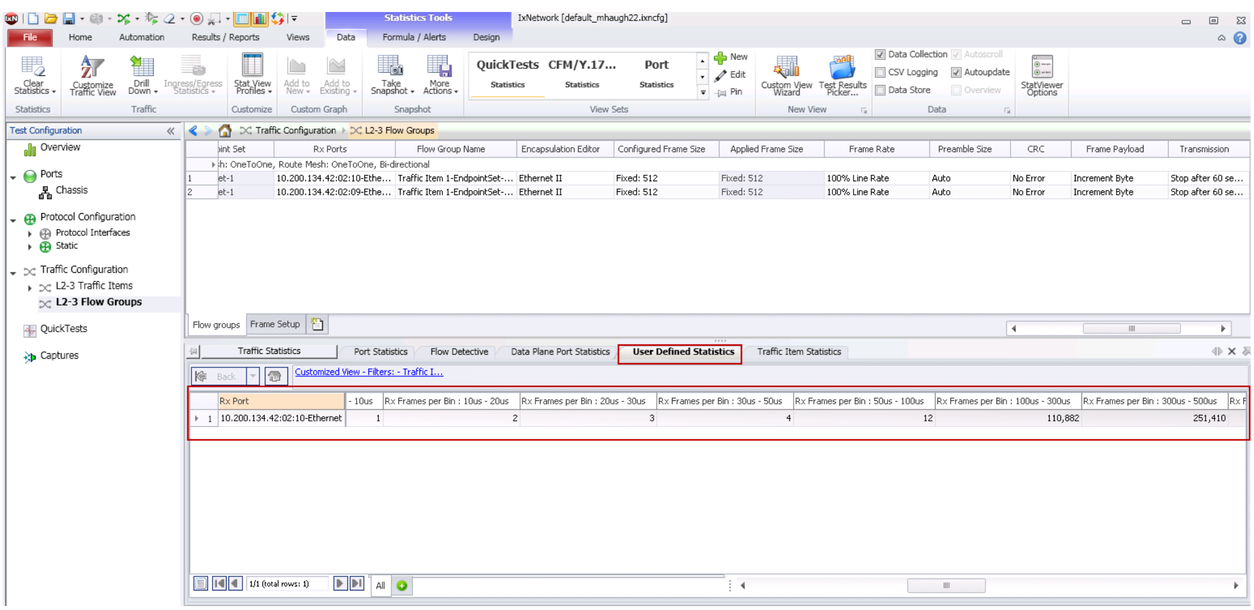


Figure 47. User Defined Statistics

17. Next, to look at latency over time, click on the **Traffic Item Statistics** view; scroll over to the Min, Average and Max latency measurements. Select those cells, right-click and select Add to Custom Graph->New->Time Series

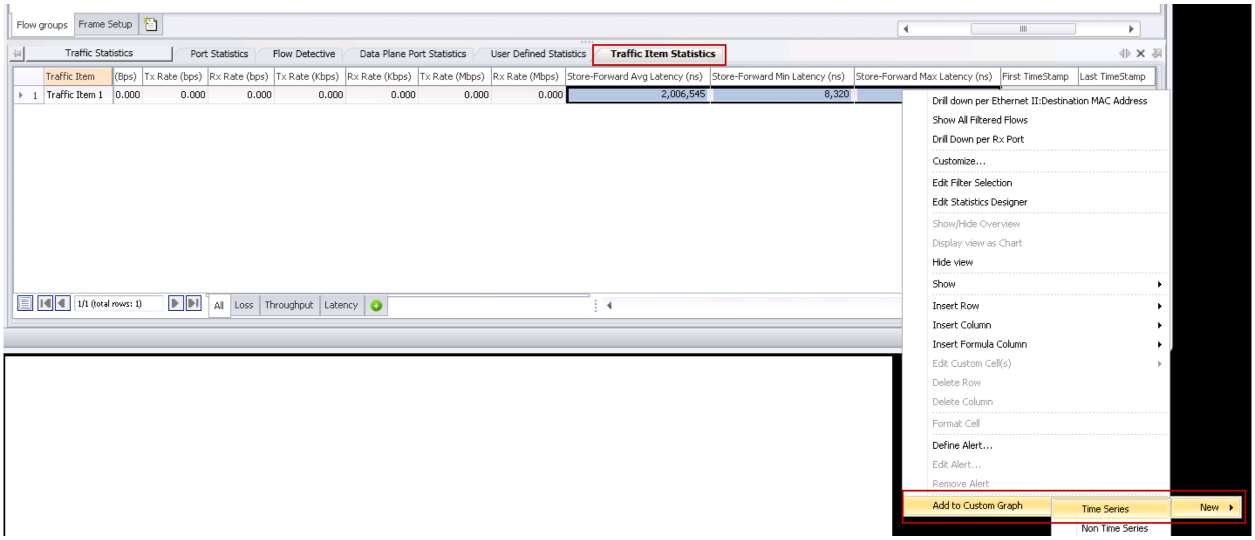


Figure 48. Traffic Item Statistics – Add Time Series Graph

18. Click on the **Custom Graph** tab and from the traffic toolbar icon start traffic using the **Start L2-3 Traffic button**.

Note – again it is observed that the average and maximum latency values are increasing over time.

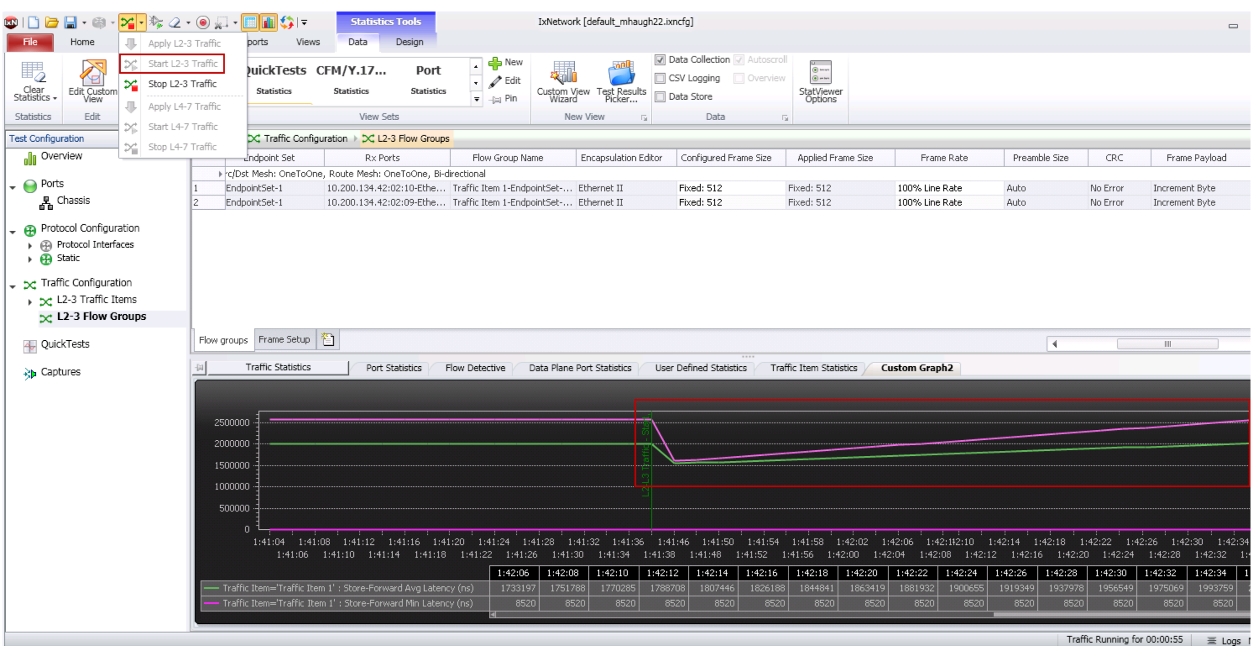


Figure 49. Start Traffic – Custom Graph

19. To enable csv logging of the data click on the **Traffic Statistics** selector button, then right – click on the desired view, in this case Traffic Item statistics and click Properties.

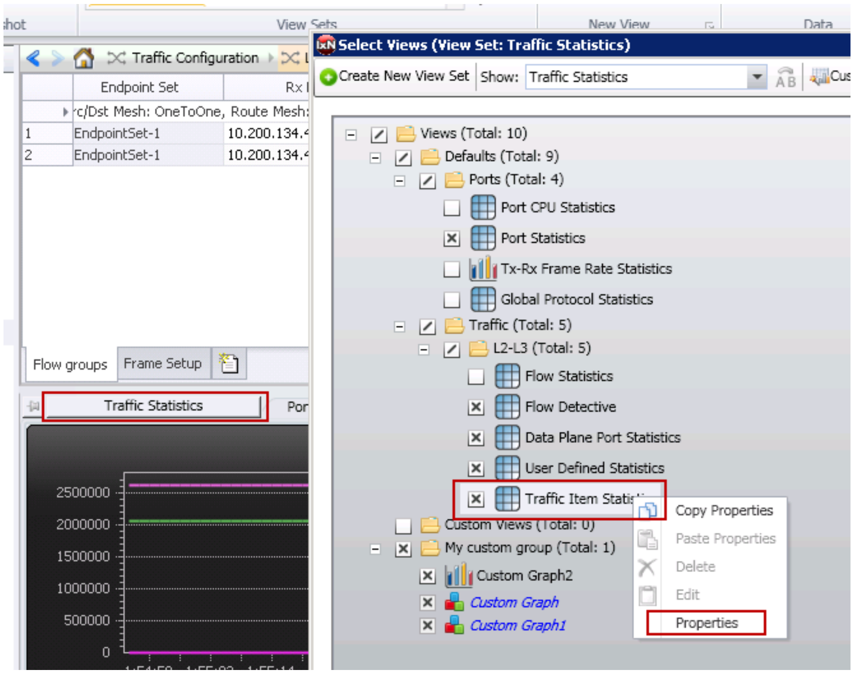


Figure 50. Select Views - Properties

In the **Properties** dialog, click on the **CSV Logging** option in the tree, then click the checkbox to **Enable CSV Logging** and optionally you can configure the name of the file.

Note - the file location is also shown here.

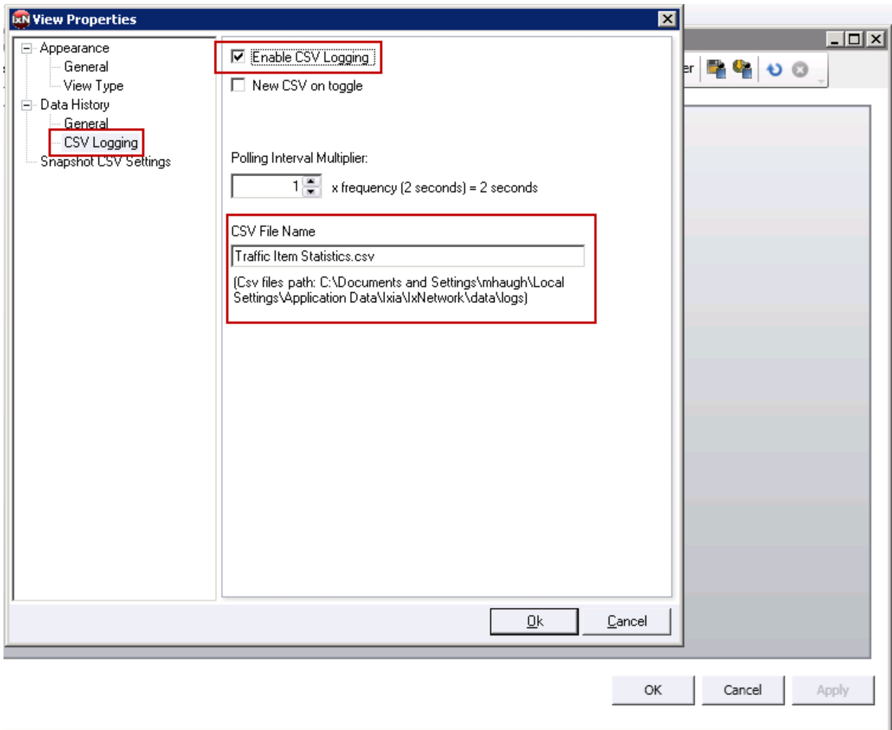


Figure 51. View Properties

20. Navigate to the CSV file on the local machine for further analysis of the latency measurements:

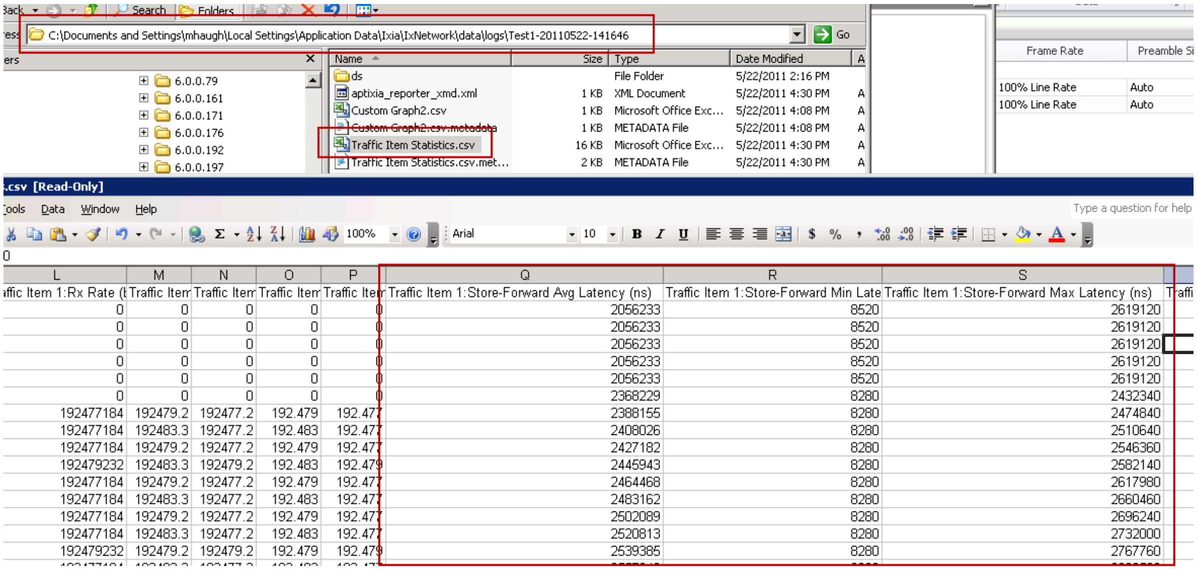


Figure 52. CSV Log file

Test Variables

For latency performance testing, the key is to establish a performance benchmark using the RFC 2544 test methodology, then extend that testing to perform longer duration testing looking at the distribution of the latency measurements and the latency trend over time. Variables for this test include:

- Transmit Duration
- Frame Size
- Traffic Pattern
- Number of ports and flows used in the test

Results Analysis

If the DUT/SUT is performing well the average and maximum latency values should be pretty constant. If these values are increasing over time, this indicates an issue with the DUT/SUT and buffering or another problem may be occurring. If this is the case, try adjusting some of the variables including frame size and rate. Devices typically perform better with larger packets since the packet rate is lower and some devices cannot forward traffic at wire rate, so the rate should be decreased to the highest no-drop value.

Test Case: ULLN Testing a Service during Service Activation or during Maintenance

Overview

After testing in the lab the next phase is service activation testing. To test a live service between two locations will require the test equipment to be synchronized using GPS. This procedure will outline how to establish GPS connectivity, and then use IxNetwork to run performance testing as described in the two previous test cases.

Objective

The test objective is to measure the performance of an Ultra-Low Latency Network service. The latency measurements are expected to be similar to the System Under Test results that were run in the lab with the addition of the network/propagation delay.

Setup

Each location will require an Ixia AFD1 GPS unit and an Ixia chassis (like this XM2):

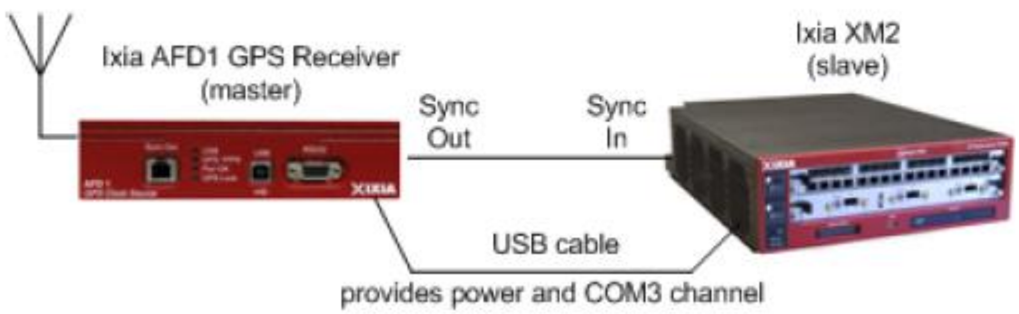


Figure 53. Ixia Chassis with AFD1 GPS Unit

Step-by-step Instructions

1. Using IxExplorer, right click on the chassis and select **Properties:**

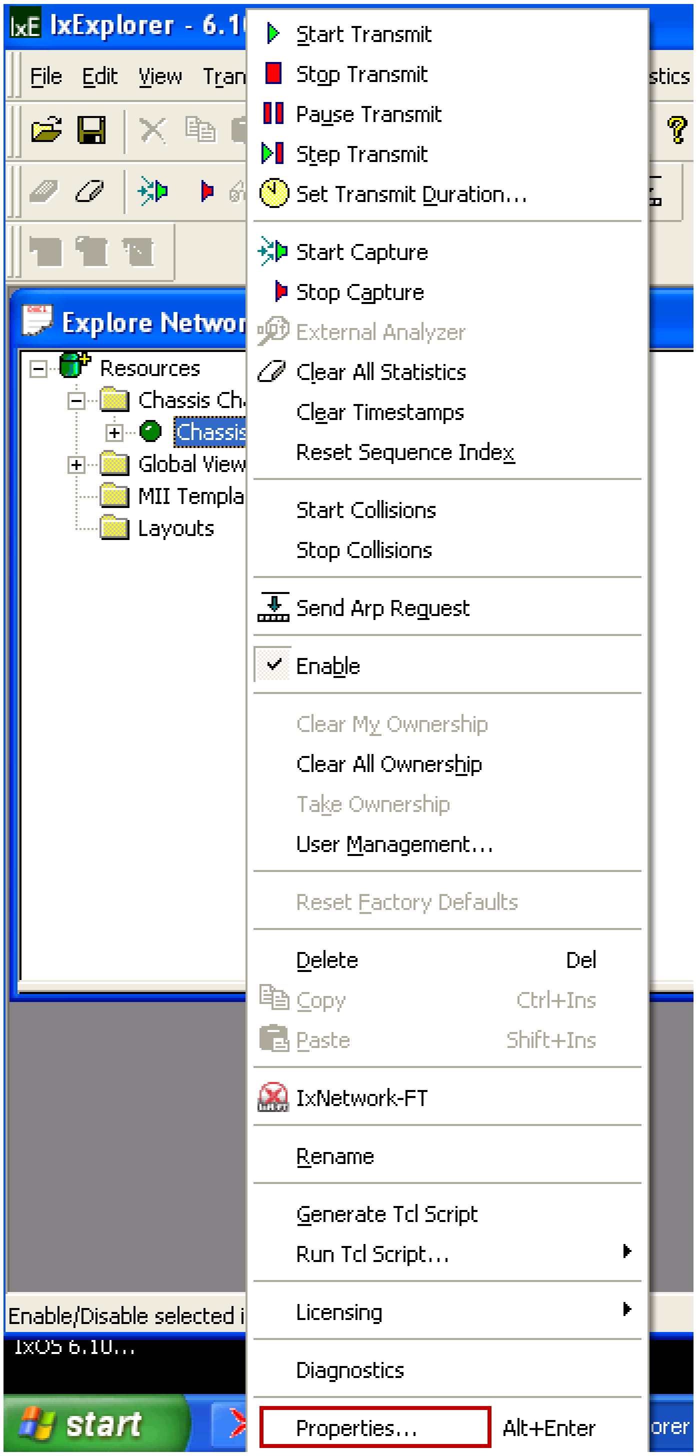


Figure 54. Chassis right-click menu in IxExplorer

2. In the Properties dialog select the **GPS (AFD1)** option. If operating properly the Lock Status should read Locked. Click OK.

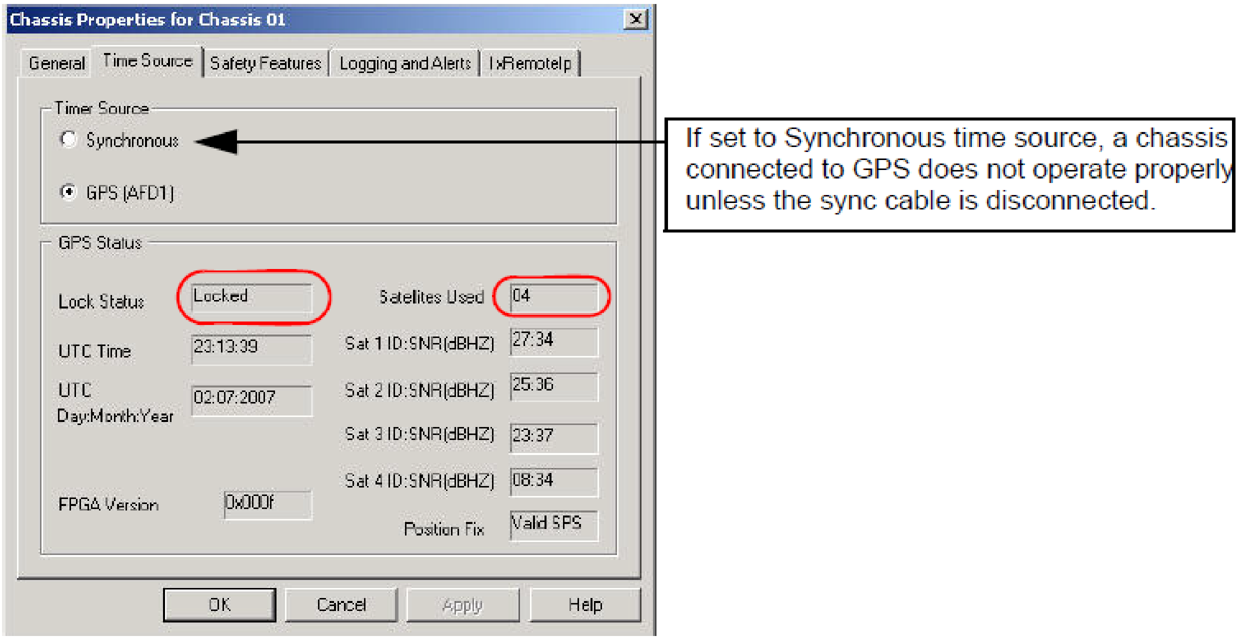


Figure 55. Time Source Configuration

3. Once locked, the IxExplorer GUI will show (GPS Ready) next to the chassis name.

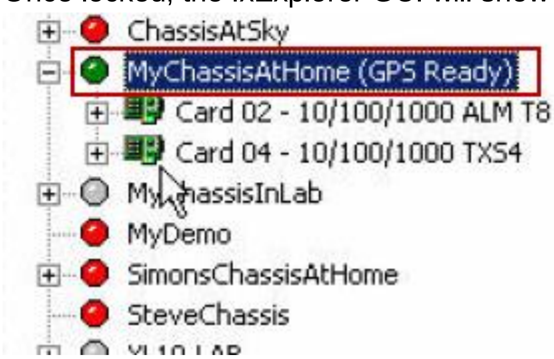


Figure 56. Chassis GPS Ready

4. In IxNetwork, once connected to the chassis, the Chassis view should show the Status as **Connected, Slave**. This should be the case for both chassis used in the test.

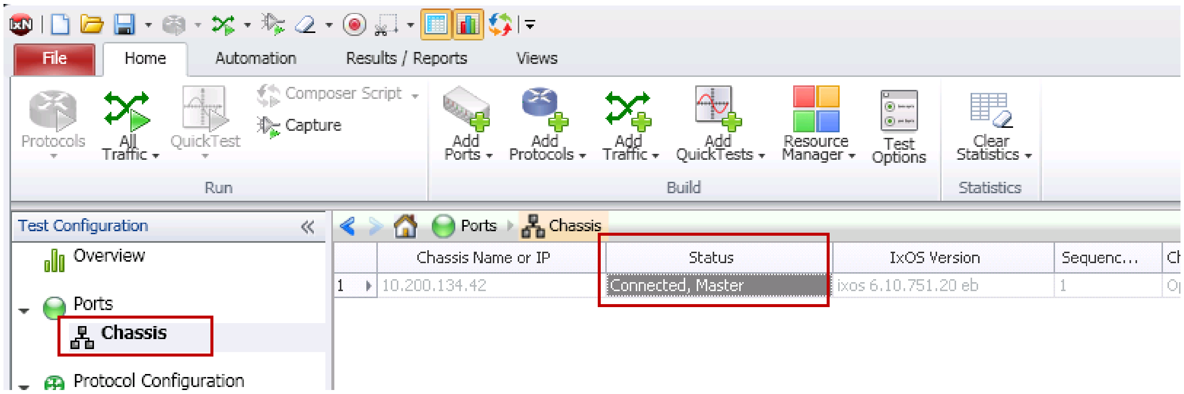


Figure 57. IxNetwork Chassis view

5. Once both/all chassis used in the test are synchronized to GPS then proceed with test cases 1 and 2, running the 2544 test and the latency histogram/latency over time test.

Conclusions

Service activation testing is an important step of service turn-up. Once a service is live and production traffic is running there is limited opportunity to run active testing using test traffic. There is typically a method to monitor performance to ensure that the service level is being delivered to the SLA. There may be periodic maintenance windows which allow running an active test (generating test traffic) to ensure the service is still being delivered at the original performance level.

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