Black Book

Edition 10

Audio Video Bridging

December 2014

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!

Table of 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-four volumes covering 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

Volume 23 – Automotive Ethernet

Volume 24 – Audio Video Bridging

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.

Ixia is committed to helping our customers' network perform at its highest level, so that end users get the best application experience. We hope this Black Book series provides valuable insight into the evolution of our industry, and helps customers deploy applications and network services—in a physical, virtual, or hybrid network configuration.

Bethany Mayer, Ixia President and CEO

Audio Video Bridging

Test Methodologies

This Audio Video Bridging black book provides several examples with detailed steps showing a user how to use Ixia applications and solutions to achieve comprehensive performance testing and validation for Audio Video Bridging.

Introduction

Traditionally, audio/video network used specialized network that could handle the time-sensitive nature of the audio/video traffic. These special networks were analog one-way, single-purpose and point-to-point. Having a dedicated and specialized network for audio/video worked well for a long time. However, there were many drawbacks to this approach. First one being the additional Opex and Capex associated with the specialized networks. The maintenance and support for these specialized networks incurred huge expenditure. Soon, there was need for a generalized network that could scale well and keep up with the demands of bandwidth hungry audio/video applications. Conforming to the standards was another important requirement as it enabled the customers to have a choice among the vendors, and avoid costly upgrades to support higher speeds/bandwidths. Another important requirement was to avoid managing two networks side by side i.e. LAN network for best-effort traffic and specialized network for audio/video applications.

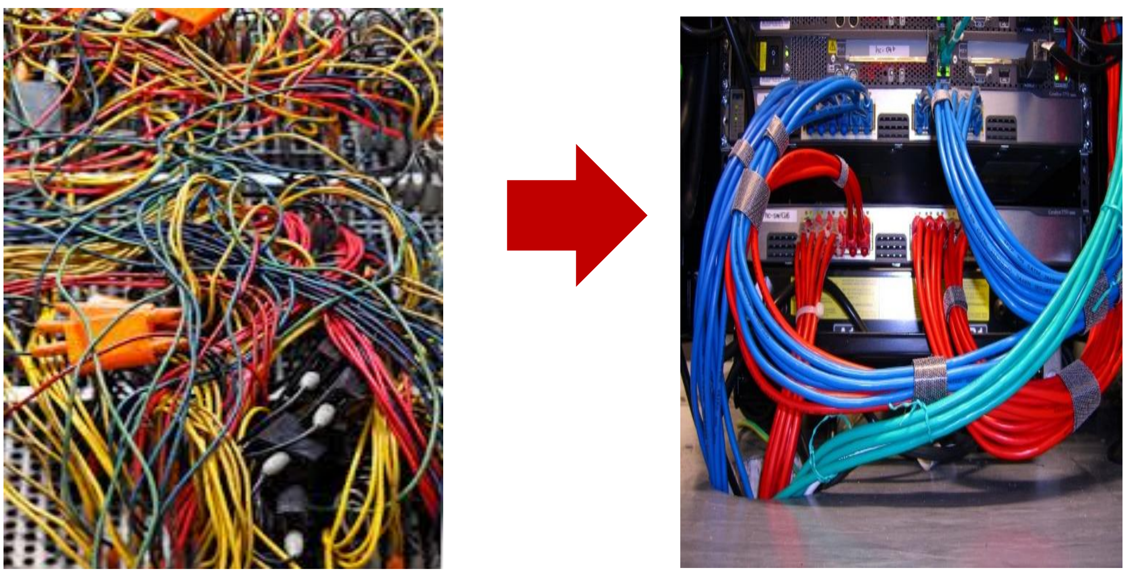


Figure 1- Convergence to Ethernet

Fortunately, Ethernet did meet these requirements. It was simple, standard and widely available. If Ethernet could be made to carry time-sensitive applications then there was a way to converge the LAN and audio-video networks. Convergence to a single network is not a new thing. Traditional Storage networks have converged with the LAN networks with the use of Ethernet and provided similar benefits in terms of savings in Opex and Capex. However, Ethernet did lack some of the features offered by the specialized networks. So IEEE undertook the task of defining standards that enabled Ethernet to provide support for time-sensitive applications. The collection of these standards is commonly referred to as Audio Video Bridging (AVB) standards.

AVB has been finding its application across many industries- Automotive Ethernet, Professional A/V, Home Consumer Electronics and Industrial Ethernet. In the next section, we will focus on AVB for Professional A/V and some of the relevant test cases.

AVB for Professional A/V

Ethernet was meant to carry best-effort traffic and did not provide any guarantees for the QoS or delivery time. While best-effort traffic could be retransmitted and could be dropped, time-sensitive traffic could not be dropped and had a low tolerance for jitter as shown in the image below.

Figure 2 – QoS requirements of Video

Reliability

Video has very strict requirements in terms of loss. For example, if I-frames are lost, then entire picture is lost. Similarly, when audio traffic is sent in real time, it cannot incur any loss as retransmission is not a possibility. In short, delay, loss and jitter affect these time-sensitive applications more than best-effort traffic. Guaranteeing QoS necessitated that the resources to forward the traffic with bounded delay were always available. Another important aspect was a mechanism that confirmed the availability of these resources before transmitting Audio/Video traffic.

The algorithms available to queue and forward the best-effort traffic could not be used for time-sensitive applications. Because AVB frames cannot be dropped, a new algorithm was required that could forward the AVB frames quickly and efficiently. Since time-sensitive traffic also carries highly time-critical traffic such as emergency announcements, the algorithm needed to allow pre-emption of all the other traffic in favor of emergency traffic.

Bounded Delay

Time-sensitive applications like Audio/Video have very stringent requirements in terms of delay and quality. For example, video has to lead the audio so as to avoid lip sync issues, while audio channels must be within a certain window of delay of each other. Hence, Audio/Video applications require both bounded delays and time synchronization among the connected devices. Bounded delay ensures that the Audio/Video content is available to be replayed before a specified time.

Synchronization

Time synchronization among the connected devices ensures that these devices have the same sense of Wall-Clock time. To allow the devices to have the same sense of time, the path delay, queuing delays and clock rates have to be compensated for. The audio/video streams can carry a presentation time that tells the receiving device the time the content should be replayed. This time is referred to as Presentation time. Only when devices have the same sense of time, they can align the replay at the presentation time. Since Audio and Video streams travel from different paths with different sample rates, presentation time allows both contents to be replayed in sync on the receiver.

Bringing Analog and Digital worlds together

Audio video traffic was analog in nature while the various network control for the amplifiers and loudspeakers used the Ethernet control traffic. Using AVB, now Audio Video traffic can also be sent over Ethernet data using digital encoding. Another advantage of this approach is that it eliminates the need for A/C to D/C conversion and vice versa.

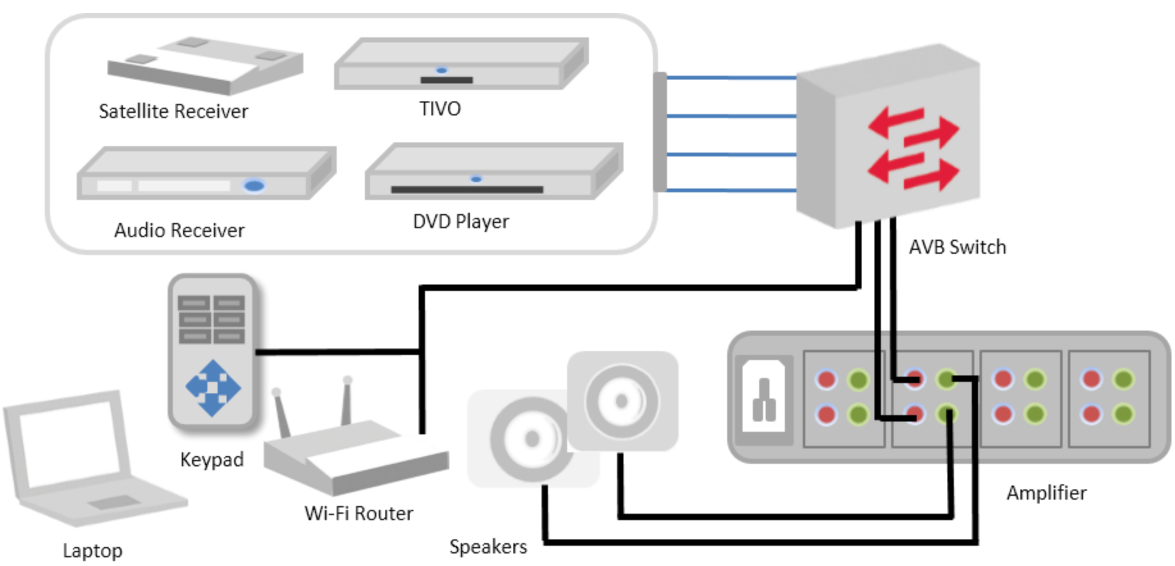


Figure 3 – Networked control of Audio/Video Traffic

Protecting AVB Domain

AVB networks were designed to carry both time-sensitive applications and best-effort traffic. Since the latency and loss requirements of these two traffic vary a great deal, it was important that AVB switches could recognize the presence of non-AVB switches and create AVB boundary on ports.

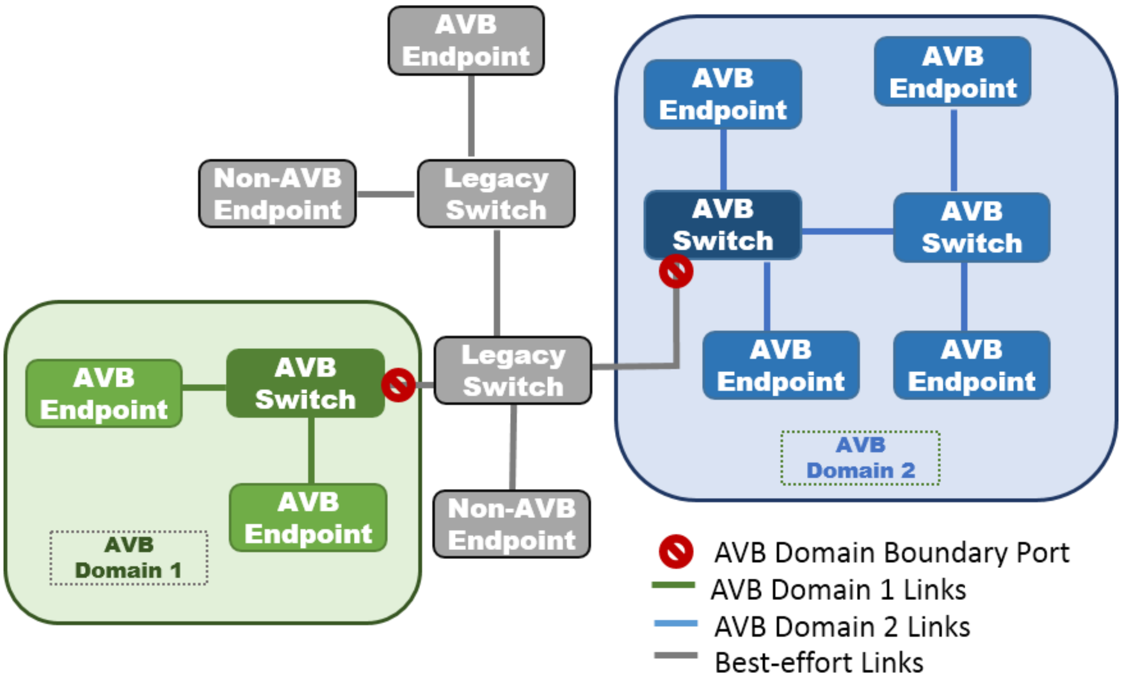


Figure 4 – Protecting AVB Domain

The AVB Domain boundary should extend only to the devices that are capable of meeting the above requirements. If there are non-AVB capable devices between two AVB capable devices, then the AVB capable devices are not included in the AVB domain. This way both AVB and non-AVB traffic can be carried over a LAN network.

AVB Standards Overview

IEEE has defined many standards for AVB. The combination of these standards define the requirements of an AVB network. There are four basic requirements:

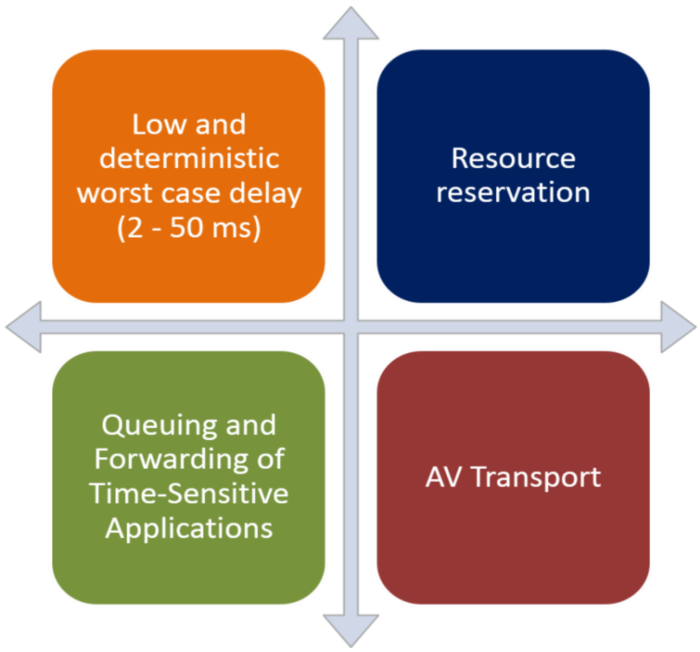


Figure 5 –AVB Fundamental Requirements

Low and Deterministic Delay (2-50 ms)

Ethernet Networks already supports packet based synchronization using protocols like PTP. PTP offered a great deal of accuracy for packetized networks. However the servo machine of the PTP was very complex. So a specialized version of PTP called gPTP was proposed by the standard IEEE 802.1AS. gPTP used peer to peer communication and offered a much simpler state machine. The gPTP protocol is a subset of the PTP protocol. gPTP imposes the use of two step clock and Peer-to-Peer Delay mechanism to synchronize the devices in the network and allows for fast reconfiguration. Using the BMCA algorithm defined in gPTP, AVB systems form a hierarchy of clocks. This way the synchronization is passed from the Grand Master to all the end stations.

Resource Reservation

IEEE 802.1Q Clause 35 defines a new protocol- Stream Reservation Protocol. This protocol enables the resources to be reserved for a time-sensitive application before its transmission. This is a powerful tool as it enables the AVB end-stations to automatically configure a bridged network for required resources without the need of administration.

The SRP has three main components: Talker, Listener and Bridge. The Talker is responsible for advertising the resource reservation message towards the listener. The resource reservation message has the QoS and bandwidth requirements. The reservation message is forwarded by the bridge, which will also add the latency to the accumulated latency so far. The Receiver will register with the stream based on the accumulated latency and send a Ready message towards the Talker. The intermediate bridges will reserve the required resources and forward the Ready to Talker. The Talker can start transmitting the AV content on receiving the Ready message.

Queueing and Forwarding of time-sensitive applications

IEEE 802.1Qat defines a new algorithm Credit-based Shaper (CBS) Algorithm. Audio video contents requires low latency and consumes more bandwidth than the best-effort traffic. As the memory in the bridges in limited, it is important to transmit audio-video traffic without undue delays. The CBS Algorithm spaces out the AVB Traffic Stream frames as far as possible. The algorithm uses the bandwidth reservation information calculated by SRP. The spaced out traffic prevents the formation of long bursts of high priority traffic. The CBS algorithm shapes the AVB traffic such that the bandwidth reservation requirement is met for each AVB traffic stream.

Another function of this new algorithm is to protect AVB traffic from the best-effort traffic, thus the algorithm forms a boundary between AVB and non-AVB domains and re-maps parameters that could be common between AVB and non-AVB traffic.

AV Transport

IEEE 1722 Standard define a layer 2 encapsulation for Audio/Video traffic. The protocol enables timestamps to be embedded along with the data. The timestamps are called presentation timestamps. These presentation timestamps represent the time at which the content has to be replayed at the Listener. The protocol takes advantage of the SRP and gPTP protocols to embed the presentation timestamps and data in the traffic stream.

Testing AVB for Professional A/V Use Cases

Following sections detail the test requirements, test steps for professional Audio Video Bridging use cases and detailed test steps using Ixia equipment and software.

Test AVB Stream Reservation

Objective

Setup control plane reservation for streams with different VLAN priorities (Different VLAN priorities will indicate different class of streams) and check whether DUT is able to reserve the streams belonging to both classes.

Test Prerequisites

- The test tool must be capable of emulating Talker and Listener and to trigger bandwidth reservation using MSRP.
- The test tool must be capable of configuring the properties of a stream such as Traffic Specification, Class and Data parameters.
- The test tool must be capable of displaying the status of reservations in both Talker and Listener emulations.
- The tool must be capable of generating 1722 frames
    - With random length (even exceeding the reserved Bandwidth)
    - At random time moments or in bursts with configurable burst lengths.

Setup

The setup for this test requires at least two test ports which are connected via an AVB Bridge.

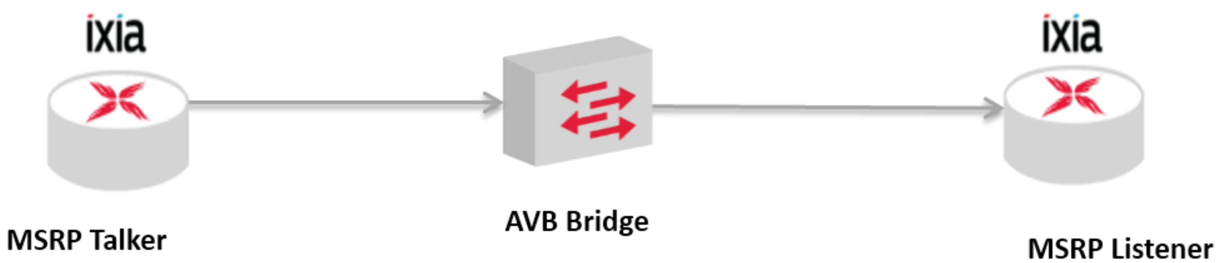


Figure 6 - AVB Stream Reservation

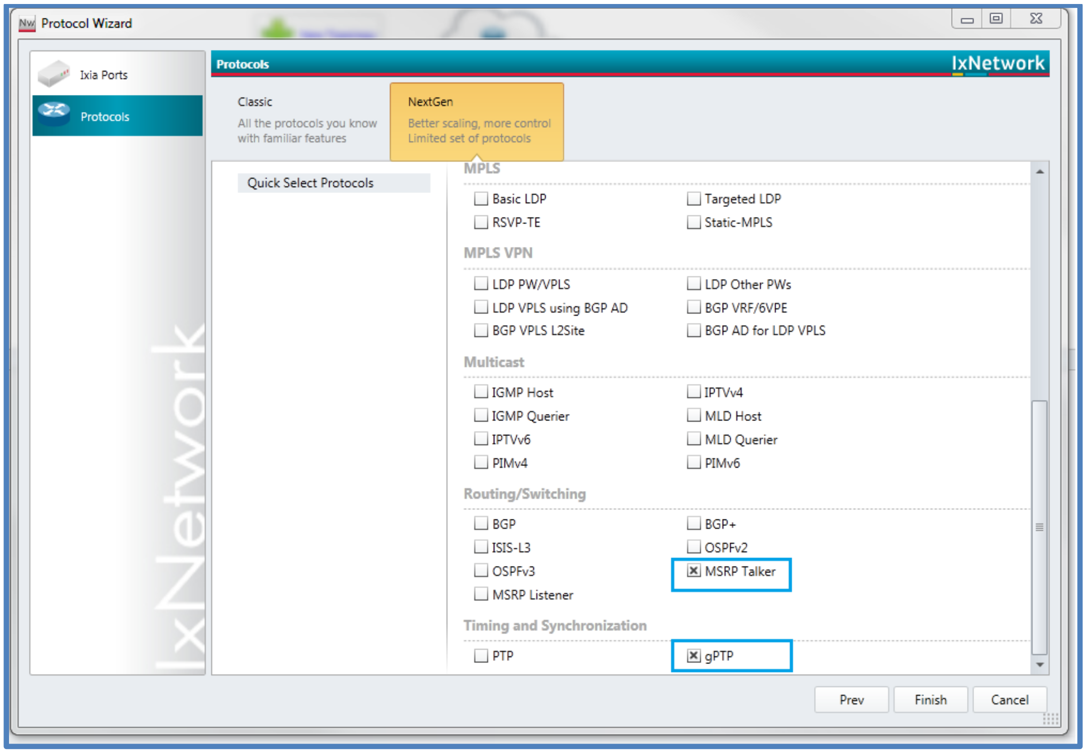
Methodology

- One of the test port simulates a Talker and the other port simulates a Listener.
- The Talker sends reservation requests for two streams belonging to two different classes (VLAN Priority 3 and 2).
- The listener subscribes to both streams advertised from talker side.
- The DUT is expected to allow reservation for streams up to its reservation limit.
- 1722 encapsulated Traffic is sent from the Talker port for the reserved bandwidth.

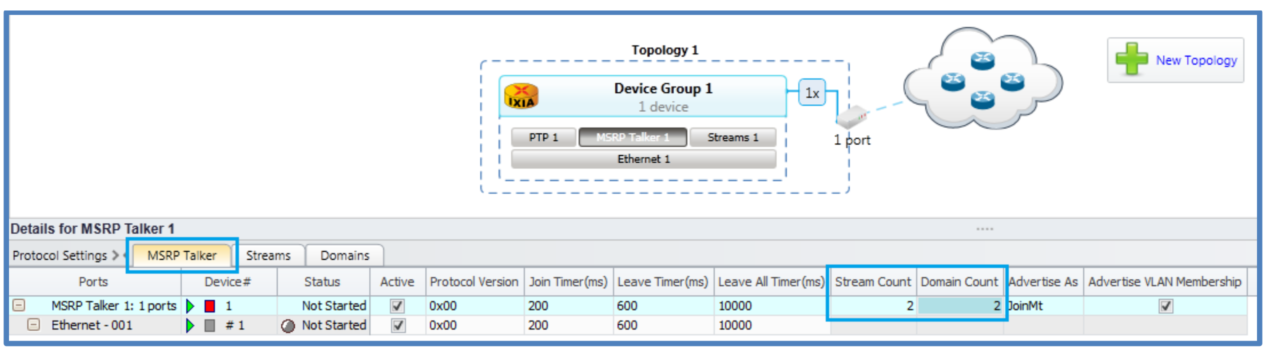
- Verify that the DUT honors the bandwidth reservation for both Class A and Class B traffic for different frame rates.
- Optionally observe the DUT behavior when the traffic exceeds the reserved bandwidth.

Test using IxNetwork

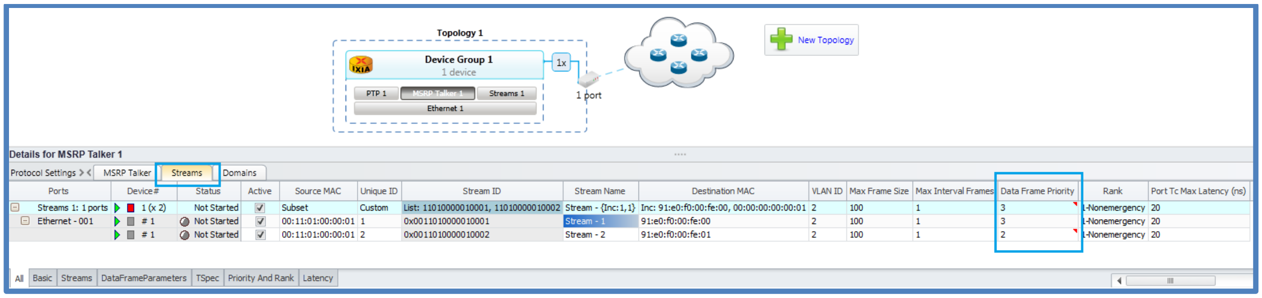
1. Select one Ixia port and add MSRP Talker and gPTP from NextGen Protocol Wizard.



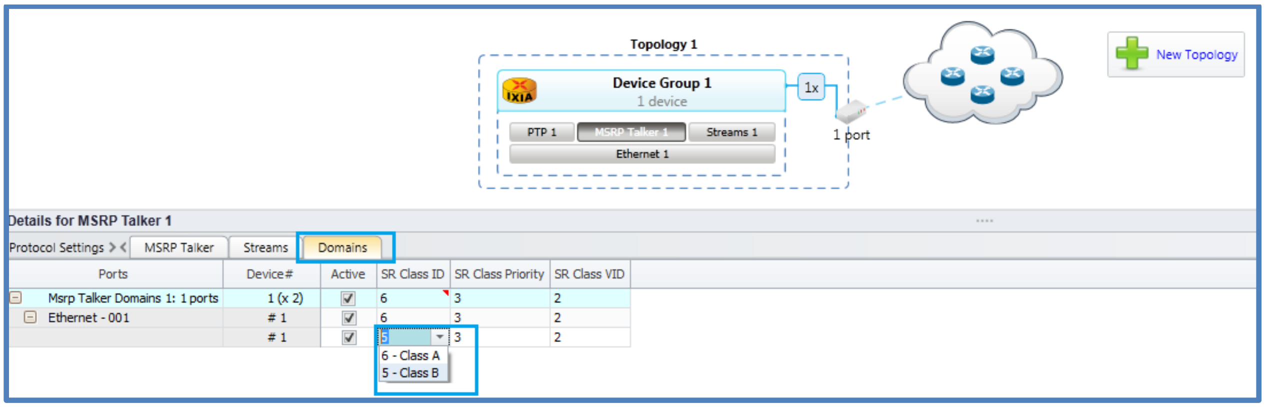
2. In The MSRP Talker configuration grid change the Stream Count to 2.



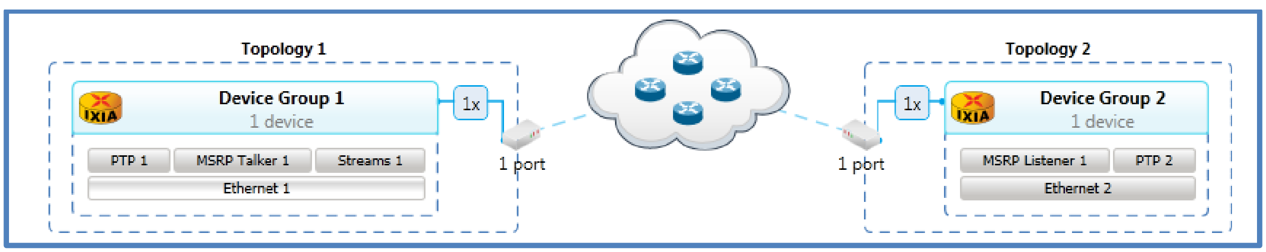
3. In the Streams configuration Tab change the stream related parameters. Configure different priorities for the two streams. This will indicate that the two streams belong to different classes.



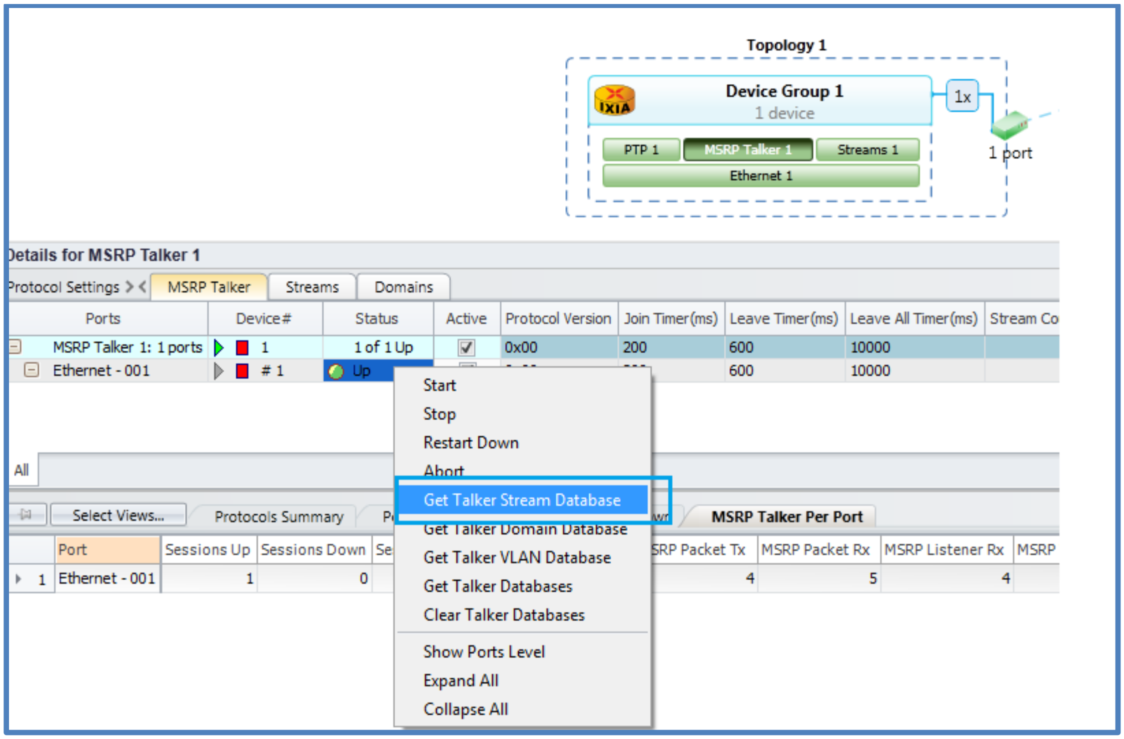
4. Configure 2 domains – one as class A and another as class B since we have configured two streams belonging to two different priorities.



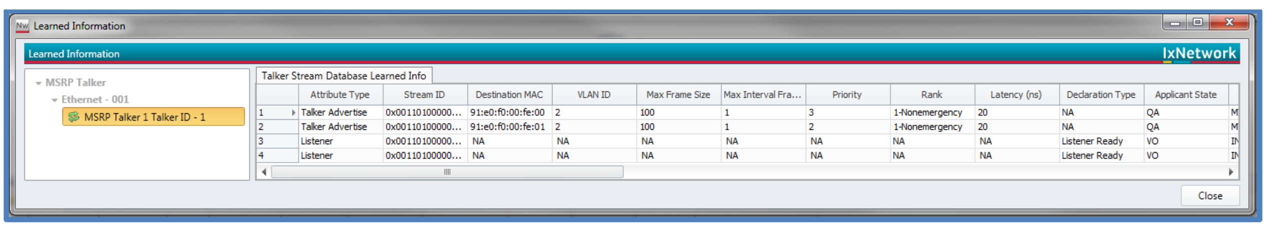
5. Select other Ixia port and add MSRP Listener and gPTP from NextGen Protocol Wizard. The ixia listener is preconfigured to subscribe to all streams that it receives advertisement of. Change the role of gPTP to Master at either Listener or the Talker side.



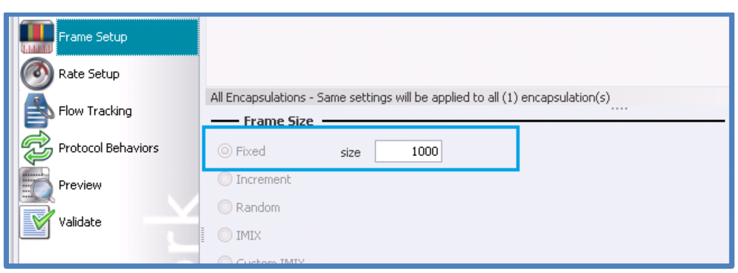
6. At this stage start all protocols in IxNetwork and check the colors come green in the scenario.
7. Check the Learned Stream database to for the reservation status.



8. The stream database will show all details of the attributes exchanged. From this database view the status of reservation for each stream can be checked our along with the reason for failure. For example the stream id for which talker has received Listener attribute with Declaration Type set to “Listen Ready”, will have proper BW reserved by the AVB Switch.

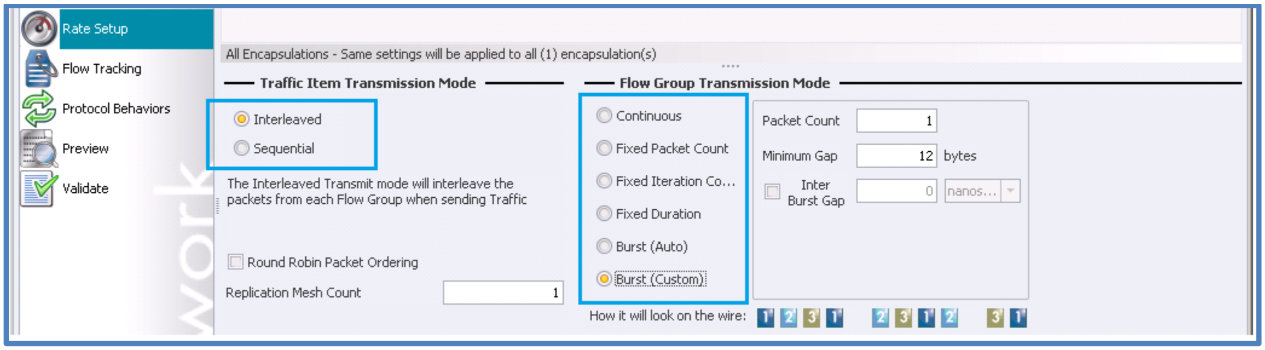


9. The frame size can be changed for a 1722 traffic from the traffic wizard.



10. To change the way traffic is sent from the source port one needs to change the parameters in the rate setup in traffic wizard. For example, to send AVB traffic in bursts, select the “Burst” option in the Flow Group Transmission mode and configure the Packet count and inter burst gap. The interleaved mode will send the packets in an interleaved

manner from each flow groups – i.e. for each streams if each stream is configured as a separate flow group. In the sequential mode it will send all packets from one flow group before moving to the other.



Observable Results

1. By observing the learned database and the control plane statistics, it can be verified whether DUT reserves bandwidth according to the AVB standards.
2. By observing the Loss/Latency etc. parameter, it can be verified whether DUT complies with the traffic forwarding expectations.
3. By increasing number of Talkers/Listeners/Streams, it can be verified whether the DUT is able to achieve expected scale.

Test Synchronization

Objective

Identify IEEE 1588/802.1AS frames based on destination address, extract protocol specific information from the fields, and show statistics regarding extracted fields.

Test Prerequisites

- The test tool must be able to emulate gPTP Grand Master and Slave.
- The test tool must be able to run BMCA and setup a clock hierarchy in AVB domain.
- The test tool MUST allow to advertise different Grand Master properties.

Setup

This test requires one or two ports Ixia ports connected to the DUT.

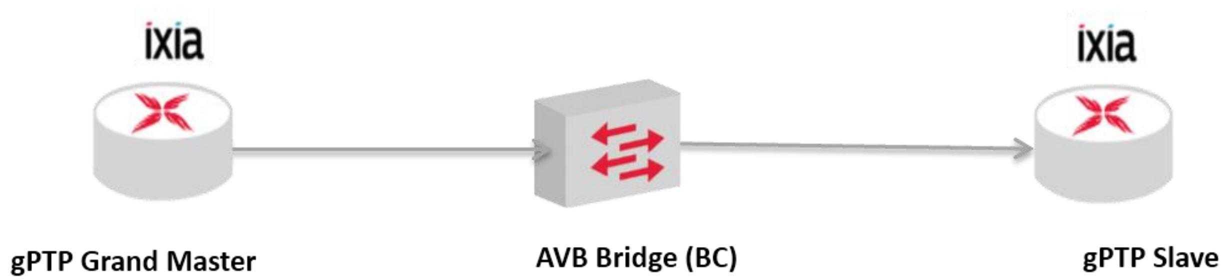


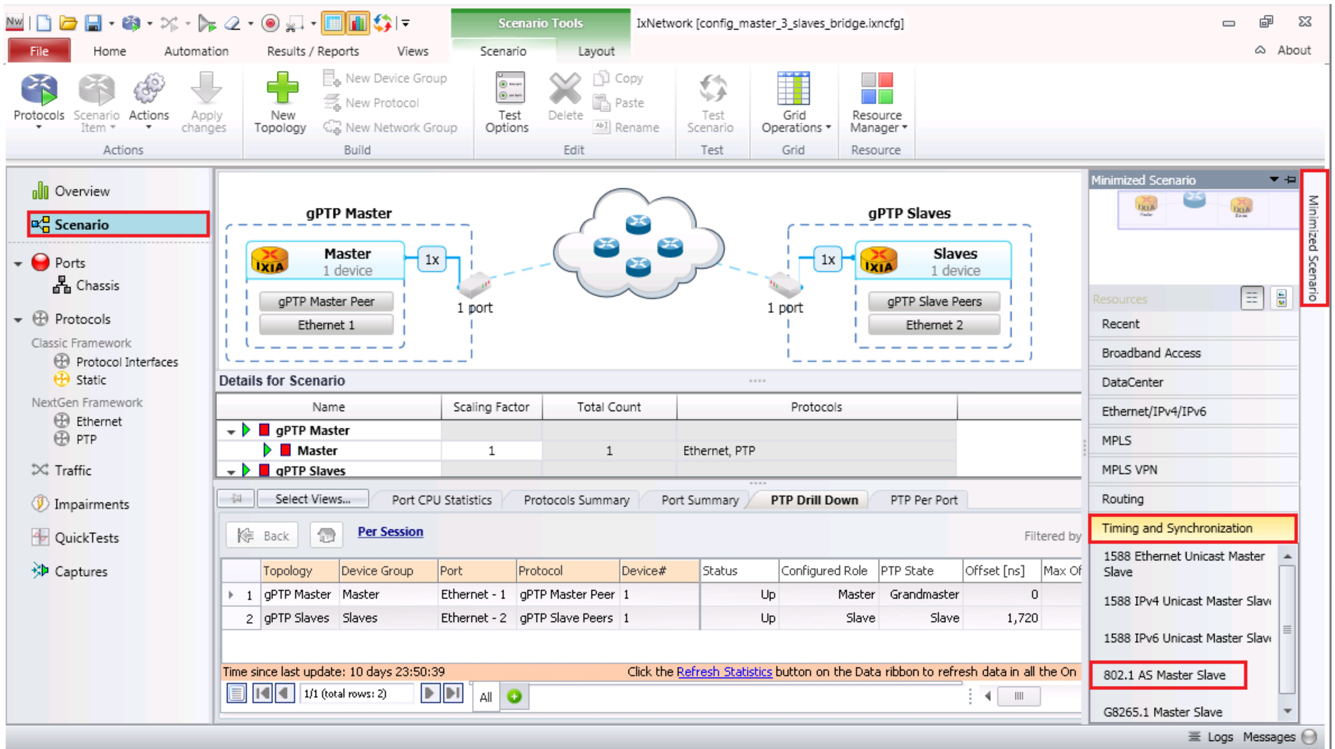
Figure 7 - Synchronization

Methodology

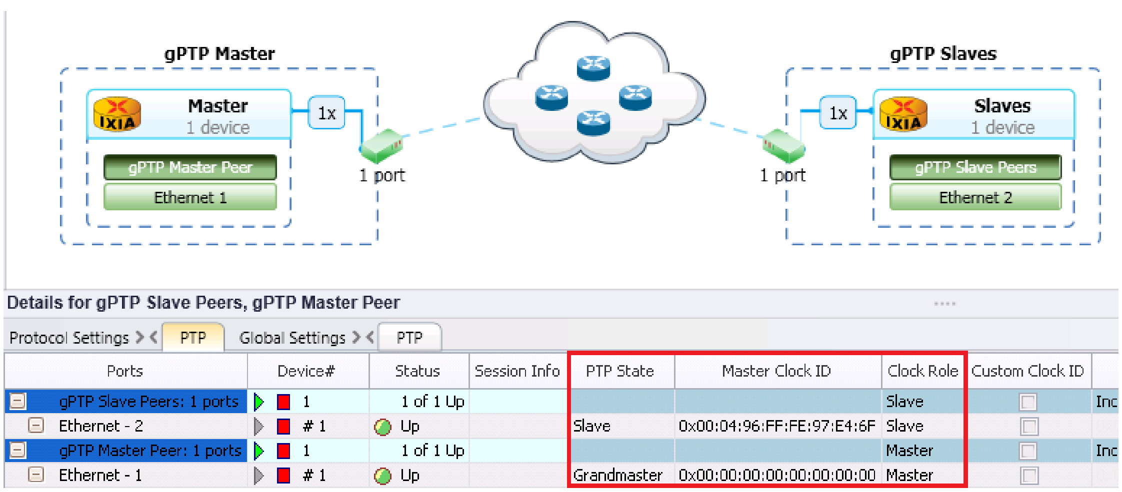
- Configure master clock on one of the test ports and emulate slave on the other test port.
- The DUT receives the synchronization information on the master from the master port and forwards it to the slave port
- The Slave clock emulated on test port will run the BMCA and should select the DUT port connected to it as Master.
- Verify the message exchange between the test ports and DUT.
- Repeat the above test for various Sync message rates.

Test using IxNetwork

1. Generate a gPTP scenario described above by dragging the “802.1AS Master Slave” predefined resource from Minimized Scenario toolbar available in the Scenario view.



2. Go the Ports view and assign ports from the chassis connected to the DUT.
3. Start master session by starting the gPTP Master.
4. Let the DUT synchronize for a few seconds and then start the Slave session.
5. Check that the BMCA is negotiated properly by verifying that the emulated sessions are in correct state (Grandmaster for the Master port and Slave for the Slave port). This can be verified by looking at the Master Clock ID Column.



6. Go to PTP per Port statistics and check that the message counters for correct messages types are increasing as expected (Announce messages should not be received on the Grandmaster port after BMCA negotiation), based on the selected profile. Check that the message rates received on the emulation ports are the ones configures on the DUT.

Select Views... | Port CPU Statistics | Protocols Summary | Port Summary | PTP Drill Down | **PTP Per Port**

	Port	Sync Messages Received Rate	FollowUp Messages Received Rate	PDelayReq Messages Received Rate	PDelayResp Messages Received Rate
1	Ethernet - 1	0	0	1	1
2	Ethernet - 2	9	8	1	1

7. Go the PTP Drilldown and check the Path Delay statistic – it should have a similar value to what the DUT is currently calculating. Offset values should also be relatively low (20—40ns).

Select Views... | Port CPU Statistics | Protocols Summary | Port Summary | **PTP Drill Down** | PTP Per Port

Back | **Per Session** | Filte

	Topology	Device Group	Port	Protocol	Device#	Status	Configured Role	PTP State	Offset [ns]	Max Offset [ns]	Min Offset [ns]	Avg Offset [ns]	Path Delay [ns]
1	gPTP Master	Master	Ethernet - 1	gPTP Master Peer	1	Up	Master	Grandmaster	0	0	0	0	298
2	gPTP Slaves	Slaves	Ethernet - 2	gPTP Slave Peers	1	Up	Slave	Slave	4	1,720	-1,732	0	300

8. Experiment with different Sync packet rates on the Grandmaster and monitor Slave offset stability. Big variations in offset are seen in the example below when the Sync rate is lower on the Grandmaster (4pps) than the one configured on the DUT (8pps), indicating that Syntonization is not performed properly. Also, spikes in offset can be observed when rates are equal that are not seen when the rate on the Grandmaster is larger than the one on the slave.

Select Views... | Port CPU Statistics | Protocols Summary | Port Summary | **PTP Drill Down** | PTP Per Port

Back | **Per Session** | Filtered by All

	Topology	Device Group	Port	Protocol	Device#	Status	Configured Role	PTP State	Offset [ns]	Max Offset [ns]	Min Offset [ns]	Avg Offset [ns]	Path Delay [ns]
1	gPTP Master	Master	Ethernet - 1	gPTP Master Peer	1	Up	Master	Grandmaster	0	0	0	0	308
2	gPTP Slaves	Slaves	Ethernet - 2	gPTP Slave Peers	1	Up	Slave	Slave	-1,628	1,873	-1,930	0	280

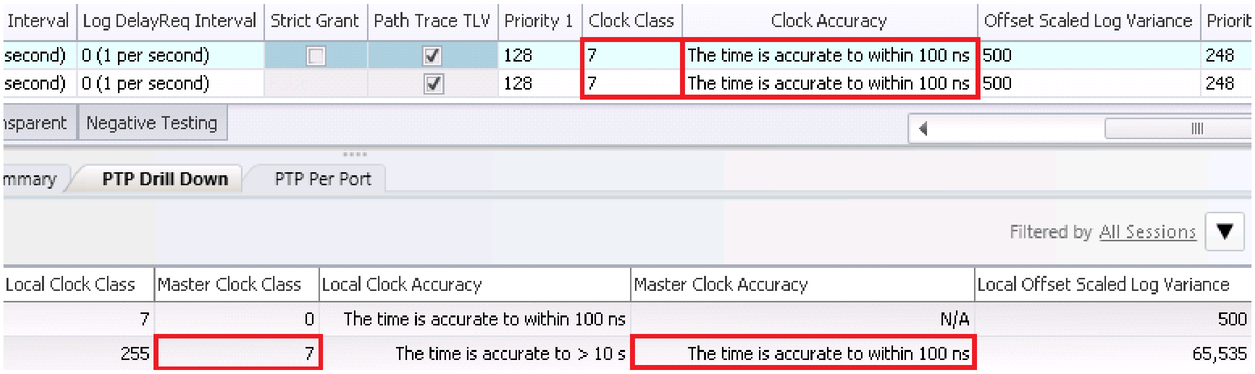
Again verify that BMCA has been properly negotiated by checking that the bridge inserts its own Clock ID in Source Port Identity of messages, and the Clock ID configured in the Master emulation in the Grandmaster information of Announce messages.

	Topology	Device Group	Port	Protocol	Device#	Port Identity	Master Port Identity	Grandmaster Port Identity
1	gPTP Master	Master	Ethernet - 1	gPTP Master Peer	1	00:13:00:ff:fe:00:00:01	00:00:00:00:00:00:00:00	00:00:00:00:00:00:00:00
2	gPTP Slaves	Slaves	Ethernet - 2	gPTP Slave Peers	1	00:13:01:ff:fe:00:00:01	00:04:96:ff:fe:97:e4:6f	00:13:00:ff:fe:00:00:01

9. Verify that all PTP characteristics, such as Clock Class and Clock Accuracy are taken by the DUT through BMCA from the Grandmaster and advertised to the Slave clock.

Protocol	Device#	Local Clock Class	Master Clock Class	Local Clock Accuracy	Master Clock Accuracy	Local Offset Scaled Log Variance
gPTP Master Peer	1	6	0	The time is accurate to within 1 us	N/A	0
gPTP Slave Peers	1	255	6	The time is accurate to > 10 s	The time is accurate to within 1 us	65,535

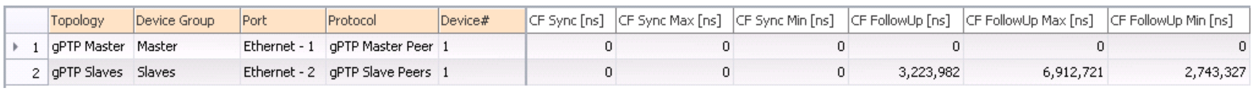
10. Change these values on the fly on the Grandmaster and see that they propagate to the Slave



Interval	Log DelayReq Interval	Strict Grant	Path Trace TLV	Priority 1	Clock Class	Clock Accuracy	Offset Scaled Log Variance	Priorit
second)	0 (1 per second)	☐	☑	128	7	The time is accurate to within 100 ns	500	248
second)	0 (1 per second)		☑	128	7	The time is accurate to within 100 ns	500	248

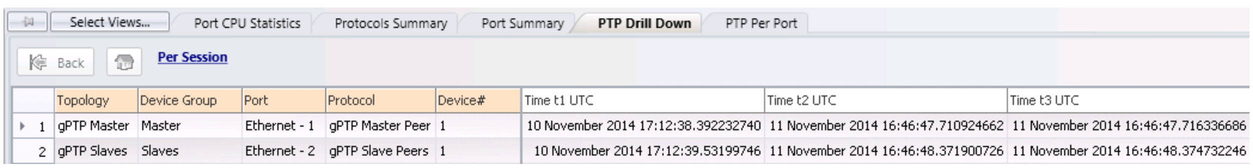
Local Clock Class	Master Clock Class	Local Clock Accuracy	Master Clock Accuracy	Local Offset Scaled Log Variance
7	0	The time is accurate to within 100 ns	N/A	500
255	7	The time is accurate to > 10 s	The time is accurate to within 100 ns	65,535

11. Monitor the variation of FollowUp Correction Field values when using different rates



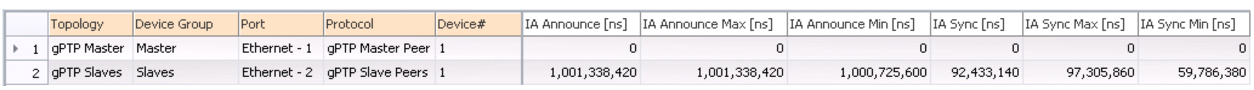
	Topology	Device Group	Port	Protocol	Device#	CF Sync [ns]	CF Sync Max [ns]	CF Sync Min [ns]	CF FollowUp [ns]	CF FollowUp Max [ns]	CF FollowUp Min [ns]
1	gPTP Master	Master	Ethernet - 1	gPTP Master Peer	1	0	0	0	0	0	0
2	gPTP Slaves	Slaves	Ethernet - 2	gPTP Slave Peers	1	0	0	0	3,223,982	6,912,721	2,743,327

12. Check if the bridge is properly propagating UTC time from the Grandmaster to the Slave



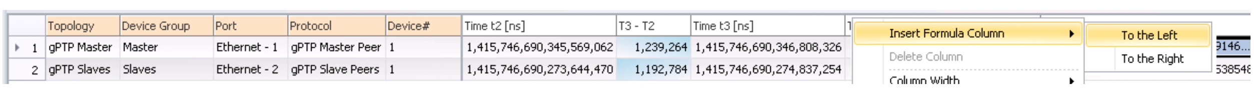
	Topology	Device Group	Port	Protocol	Device#	Time t1 UTC	Time t2 UTC	Time t3 UTC
1	gPTP Master	Master	Ethernet - 1	gPTP Master Peer	1	10 November 2014 17:12:38.392232740	11 November 2014 16:46:47.710924662	11 November 2014 16:46:47.716336686
2	gPTP Slaves	Slaves	Ethernet - 2	gPTP Slave Peers	1	10 November 2014 17:12:39.53199746	11 November 2014 16:46:48.371900726	11 November 2014 16:46:48.374732246

13. Check the stability of the rates configured on the DUT by inspecting the inter-arrival time of different message types on the Slave (Announce/Sync) and Grandmaster port (PdelayReq)



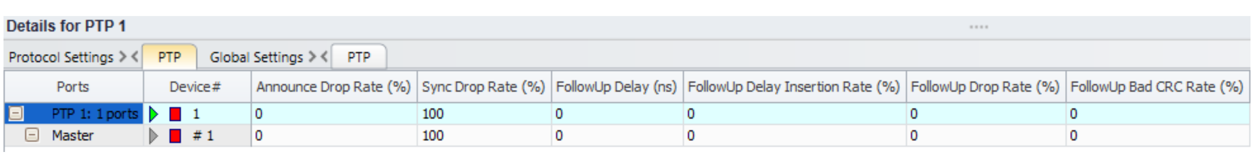
	Topology	Device Group	Port	Protocol	Device#	IA Announce [ns]	IA Announce Max [ns]	IA Announce Min [ns]	IA Sync [ns]	IA Sync Max [ns]	IA Sync Min [ns]
1	gPTP Master	Master	Ethernet - 1	gPTP Master Peer	1	0	0	0	0	0	0
2	gPTP Slaves	Slaves	Ethernet - 2	gPTP Slave Peers	1	1,001,338,420	1,001,338,420	1,000,725,600	92,433,140	97,305,860	59,786,380

14. Check that the PDelay turn-around time is under 10ms (complies with 802.1AS chapter B.2.3). To verify simply add a formula column “T3-T2” with the formula "Time t3 [ns]" - "Time t2 [ns]"

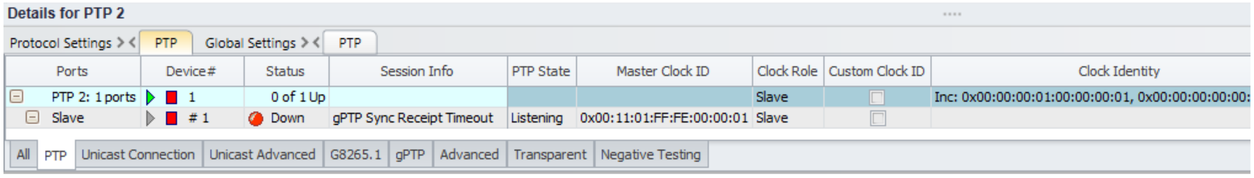


	Topology	Device Group	Port	Protocol	Device#	Time t2 [ns]	T3 - T2	Time t3 [ns]
1	gPTP Master	Master	Ethernet - 1	gPTP Master Peer	1	1,415,746,690,345,569,062	1,239,264	1,415,746,690,346,808,326
2	gPTP Slaves	Slaves	Ethernet - 2	gPTP Slave Peers	1	1,415,746,690,273,644,470	1,192,784	1,415,746,690,274,837,254

15. Verify that when a loss of Sync messages occurs (emulated through the Negative testing tab) the DUT goes into Sync Receipt Timeout state, state that should be propagated to the Slave session. This can be checked in the Session Info and PTP State columns of the Slave session.



Ports	Device#	Announce Drop Rate (%)	Sync Drop Rate (%)	FollowUp Delay (ns)	FollowUp Delay Insertion Rate (%)	FollowUp Drop Rate (%)	FollowUp Bad CRC Rate (%)
PTP 1: 1 ports	1	0	100	0	0	0	0
Master	# 1	0	100	0	0	0	0



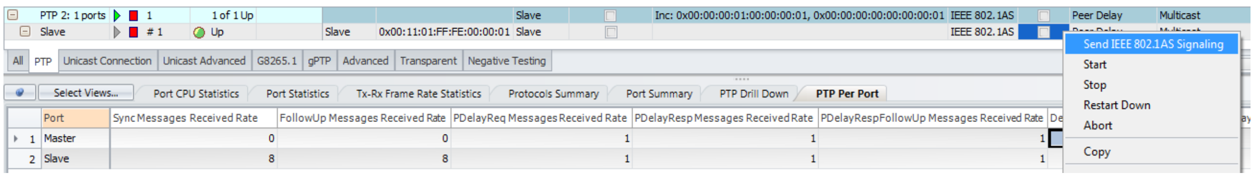
Details for PTP 2

Protocol Settings > < PTP | Global Settings > < PTP

	Ports	Device#	Status	Session Info	PTP State	Master Clock ID	Clock Role	Custom Clock ID	Clock Identity
⊟	PTP 2: 1 ports	1	0 of 1 Up				Slave	☐	Inc: 0x00:00:00:01:00:00:00:01, 0x00:00:00:00:00:
⊟	Slave	# 1	Down	gPTP Sync Receipt Timeout	Listening	0x00:11:01:FF:FE:00:00:01	Slave	☐	

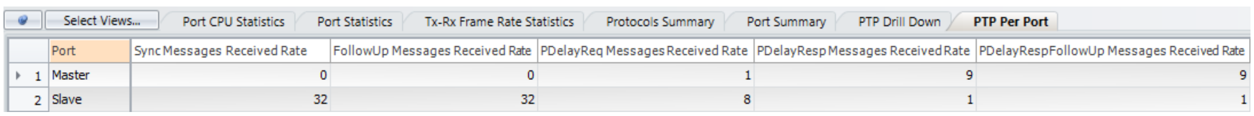
All | PTP | Unicast Connection | Unicast Advanced | G8265.1 | gPTP | Advanced | Transparent | Negative Testing

16. Check that DUT complies with gPTP specific signaling messages by requesting different rates from the Slave session. In the example below a 32 pps Sync rate and 8 pps PDelayReq was requested, and it can be immediately seen in the Per Port rate window that the DUT complied



⊟	PTP 2: 1 ports	1	1 of 1 Up			Slave	☐	Inc: 0x00:00:00:01:00:00:00:01, 0x00:00:00:00:00:00:00:01	IEEE 802.1AS	☐	Peer Delay	Multicast
⊟	Slave	# 1	Up	Slave	0x00:11:01:FF:FE:00:00:01	Slave	☐		IEEE 802.1AS	☐		

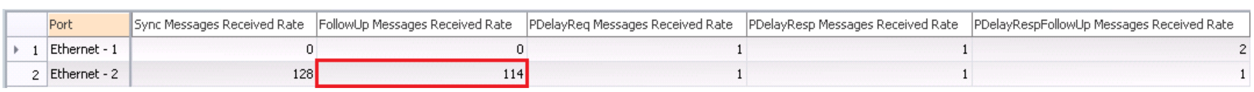
	Port	Sync Messages Received Rate	FollowUp Messages Received Rate	PDelayReq Messages Received Rate	PDelayResp Messages Received Rate	PDelayRespFollowUp Messages Received Rate
1	Master	0	0	1	1	1
2	Slave	8	8	1	1	1



Select Views... | Port CPU Statistics | Port Statistics | Tx-Rx Frame Rate Statistics | Protocols Summary | Port Summary | PTP Drill Down | PTP Per Port

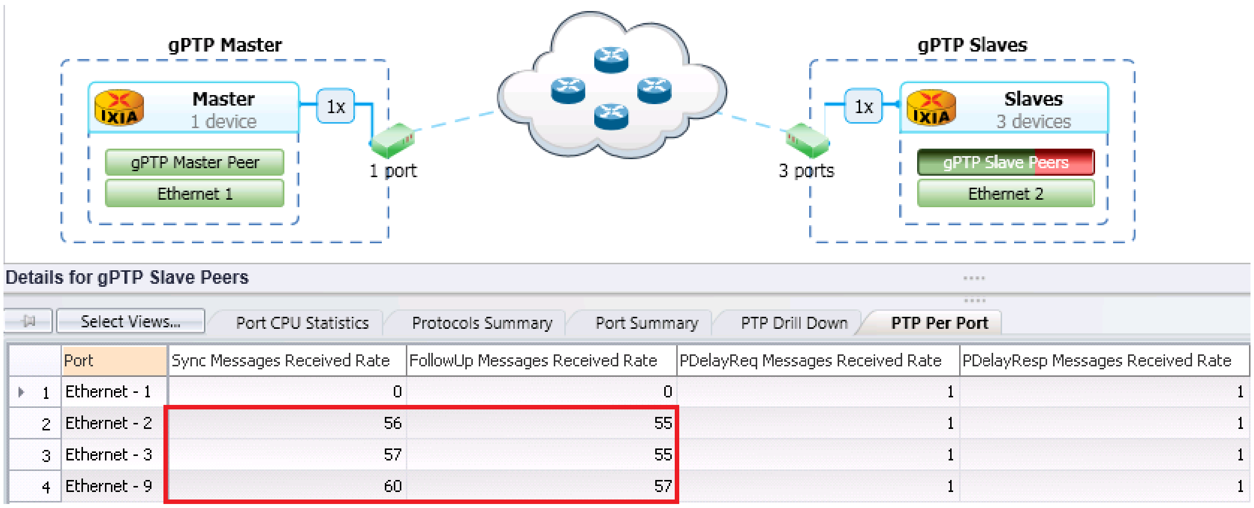
	Port	Sync Messages Received Rate	FollowUp Messages Received Rate	PDelayReq Messages Received Rate	PDelayResp Messages Received Rate	PDelayRespFollowUp Messages Received Rate
1	Master	0	0	1	9	9
2	Slave	32	32	8	1	1

17. Test performance by checking what packet rate the DUT can sustain for multiple message types. In the example below it can be seen that from 128 pps and up message rates can no longer be sustained by the DUT, because the FollowUp rate varies to that point that the Slave begins to flap between Slave and Sync Receipt Timeout state

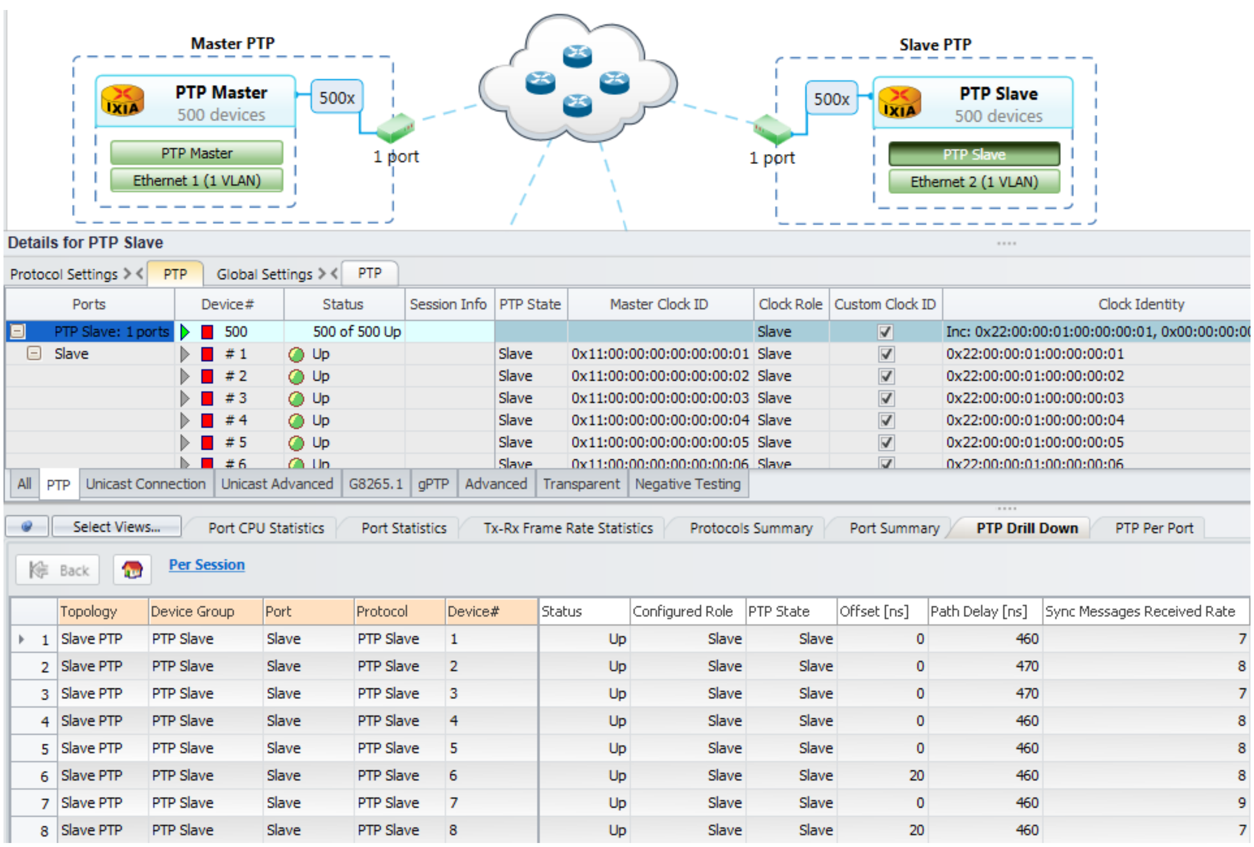


	Port	Sync Messages Received Rate	FollowUp Messages Received Rate	PDelayReq Messages Received Rate	PDelayResp Messages Received Rate	PDelayRespFollowUp Messages Received Rate
1	Ethernet - 1	0	0	1	1	2
2	Ethernet - 2	128	114	1	1	1

18. Test scalability by checking what rates can be sustained when communicating Synchronization information on different rates on multiple ports at the same time, by simply connecting multiple ports from the DUT to the IxNetwork Slave DG. In the example below we connected two more ports to the DUT, and requested from all 3 slaves a Sync message rate of 64 pps. Even though this rate can be sustained for 1 session, for 3 sessions the actual received rate is much lower and sessions flap between Sync Receipt Timeout and Slave state, as can be seen in the figure below.



19. Test scalability can also be checked by initiating multiple sessions on the same port, over VLANs (the 802.1AS prohibits the use of VLANs for gPTP by does mention that logical point to point connections can traverse a shared medium).
20. The Request Response mechanism available in standard 1588 a scalability test with multiple sessions on the same port can be ran directly and is supported by IxNetwork.



Observable Results

1. Experiment with different Sync packet rates on the Grandmaster and monitor Slave offset stability.
2. Verify that all PTP characteristics, such as Clock Class and Clock Accuracy are taken by the DUT through BMCA from the Grandmaster and advertised to the Slave clock. Change these values on the fly on the Grandmaster and see that they propagate to the Slave.
3. Monitor the variation of FollowUp Correction Field values when using different rates
4. Check the stability of the rates configured on the DUT by inspecting the inter-arrival time of different message types on the Slave (Announce/Sync) and Grandmaster port (PdelayReq).
5. Verify that when a loss of Sync messages occurs (emulated through the Negative testing tab) the DUT goes into Sync Receipt Timeout state.
6. Check that DUT complies with gPTP specific signaling messages by requesting different rates from the Slave session.

Test AVB Stream Transmission and Bandwidth Reservation

Objective

Reserve bandwidth for AVB streams and send both AVB traffic and non-AVB unreserved traffic through the DUT. Check that, when in congestion, DUT is able to forward reserved AVB traffic within permitted latency of AVB domain.

Test Prerequisites

- The test tool must be able to configure both AVB and non-AVB devices.
- The tool must be capable of measuring and checking that an AVB stream respects the reserved bandwidth.

Setup

The setup for this test requires at least three test ports which are connected via the AVB Bridge.

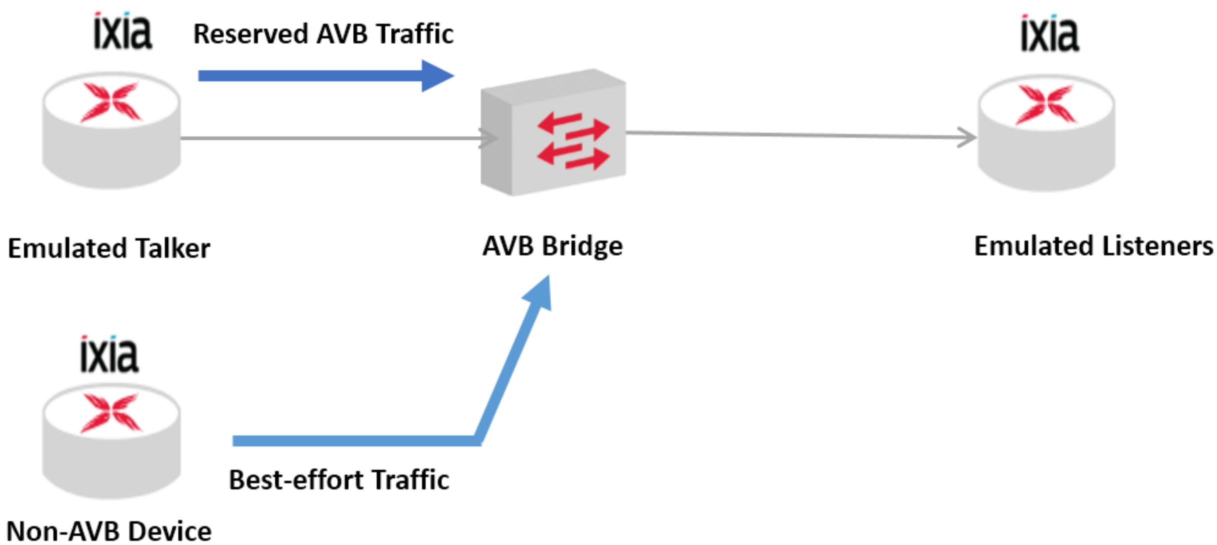


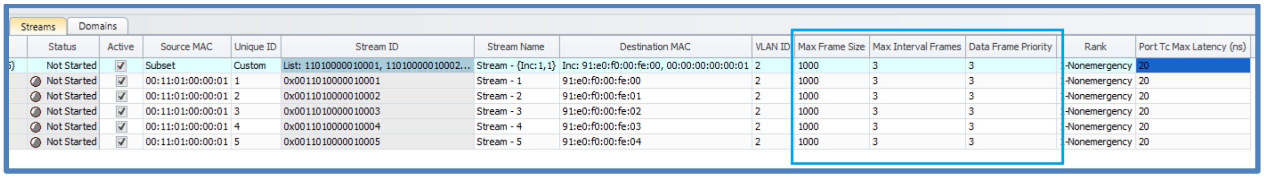
Figure 8 - AVB Stream Transmission and Bandwidth Reservation

Methodology

- The source port simulates one Talker and the destination port simulates one Listener.
- There is another source port which is a Non-AVB device.
- The non-AVB source port will send unreserved traffic through the DUT and the AVB port will send reserved traffic and thereby create congestion.
- The DUT should be able to forward the reserved AVB traffic.
- As per the 802.1Qat specification DUT should only reserve up to 75% of the available bandwidth. For example, if the DUT has a 1 Gig link, 750 Mbps can be reserved.

Test using IxNetwork

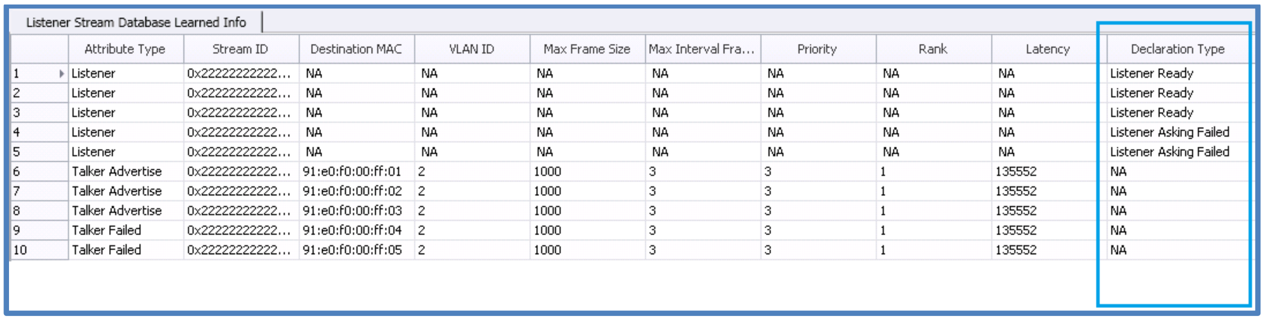
1. Configure 5 streams of 200 Mbps each by changing Stream configurations in the following manner:



Streams | Domains

	Status	Active	Source MAC	Unique ID	Stream ID	Stream Name	Destination MAC	VLAN ID	Max Frame Size	Max Interval Frames	Data Frame Priority	Rank	Port Tc Max Latency (ns)
5)	Not Started	☑	Subset	Custom	List: 110100000010001, 110100000010002...	Stream - {Inc:1,1}	Inc: 91:e0:f0:00:fe:00, 00:00:00:00:00:01	2	1000	3	3	-Nonemergency	20
	Not Started	☑	00:11:01:00:00:01	1	0x0011010000010001	Stream - 1	91:e0:f0:00:fe:00	2	1000	3	3	-Nonemergency	20
	Not Started	☑	00:11:01:00:00:01	2	0x0011010000010002	Stream - 2	91:e0:f0:00:fe:01	2	1000	3	3	-Nonemergency	20
	Not Started	☑	00:11:01:00:00:01	3	0x0011010000010003	Stream - 3	91:e0:f0:00:fe:02	2	1000	3	3	-Nonemergency	20
	Not Started	☑	00:11:01:00:00:01	4	0x0011010000010004	Stream - 4	91:e0:f0:00:fe:03	2	1000	3	3	-Nonemergency	20
	Not Started	☑	00:11:01:00:00:01	5	0x0011010000010005	Stream - 5	91:e0:f0:00:fe:04	2	1000	3	3	-Nonemergency	20

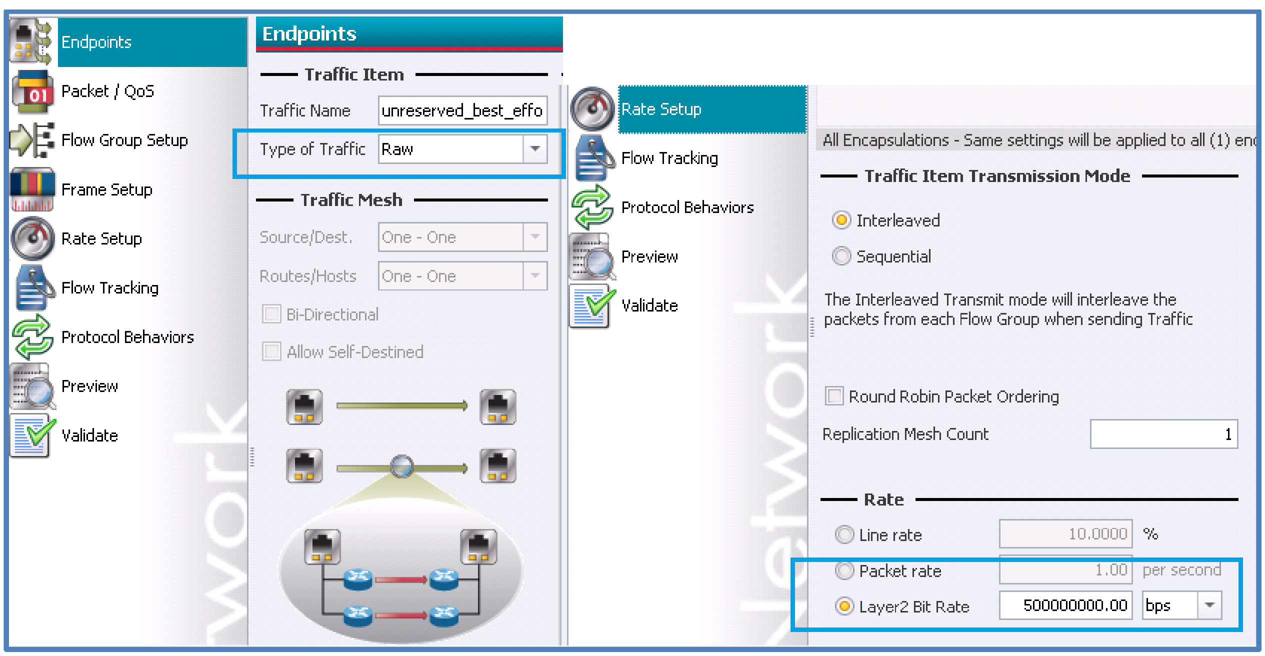
2. Verify that reservation of 3 streams (600 Mbps) will be allowed by the DUT and reservation of 2 streams will fail. Check the Listener Stream database Info to verify that.



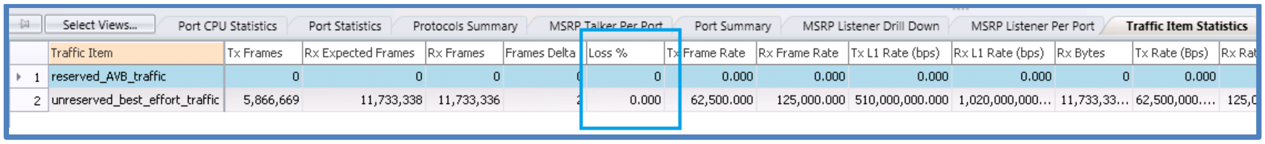
Listener Stream Database Learned Info

	Attribute Type	Stream ID	Destination MAC	VLAN ID	Max Frame Size	Max Interval Fra...	Priority	Rank	Latency	Declaration Type
1	Listener	0x22222222222...	NA	NA	NA	NA	NA	NA	NA	Listener Ready
2	Listener	0x22222222222...	NA	NA	NA	NA	NA	NA	NA	Listener Ready
3	Listener	0x22222222222...	NA	NA	NA	NA	NA	NA	NA	Listener Ready
4	Listener	0x22222222222...	NA	NA	NA	NA	NA	NA	NA	Listener Asking Failed
5	Listener	0x22222222222...	NA	NA	NA	NA	NA	NA	NA	Listener Asking Failed
6	Talker Advertise	0x22222222222...	91:e0:f0:00:ff:01	2	1000	3	3	1	135552	NA
7	Talker Advertise	0x22222222222...	91:e0:f0:00:ff:02	2	1000	3	3	1	135552	NA
8	Talker Advertise	0x22222222222...	91:e0:f0:00:ff:03	2	1000	3	3	1	135552	NA
9	Talker Failed	0x22222222222...	91:e0:f0:00:ff:04	2	1000	3	3	1	135552	NA
10	Talker Failed	0x22222222222...	91:e0:f0:00:ff:05	2	1000	3	3	1	135552	NA

3. Now start 500 Mbps of Non-AVB Unreserved traffic from Talker port to Destination port. Expectation will be that the traffic will get through since the DUT is not loaded at this time.

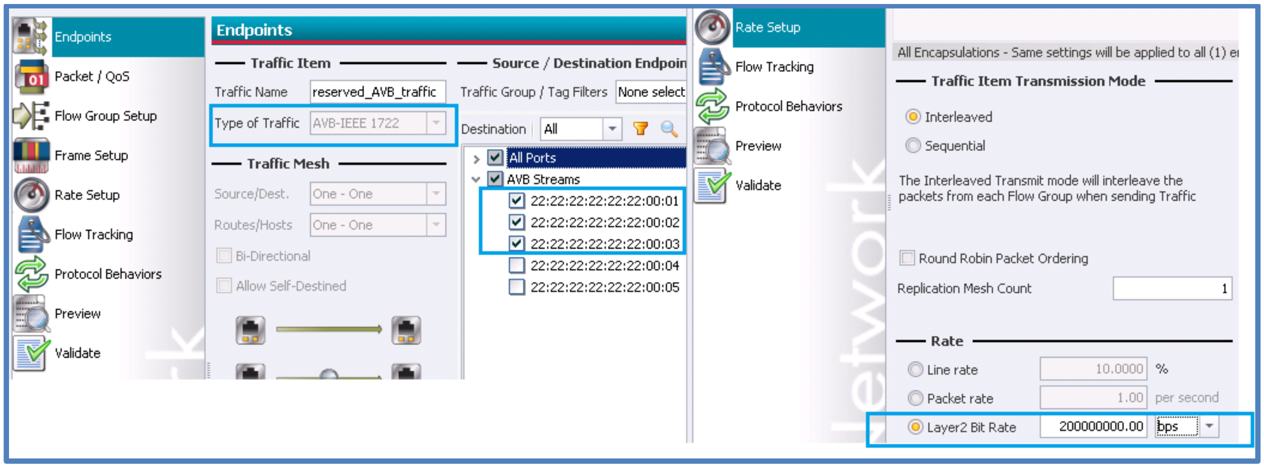


4. Verify from traffic item statistics that there is no loss for the unreserved traffic.

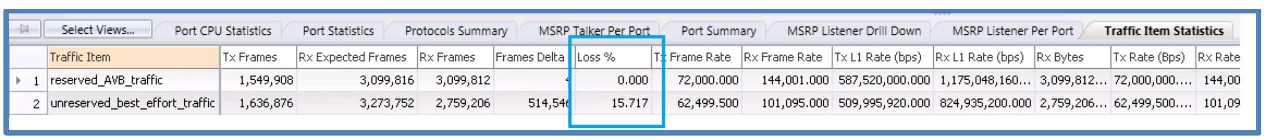


	Traffic Item	Tx Frames	Rx Expected Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate	Tx L1 Rate (bps)	Rx L1 Rate (bps)	Rx Bytes	Tx Rate (Bps)
1	reserved_AVB_traffic	0	0	0		0	0.000	0.000	0.000	0.000	0	0.000
2	unreserved_best_effort_traffic	5,866,669	11,733,338	11,733,336	2	0.000	62,500.000	125,000.000	510,000,000.000	1,020,000,000...	11,733,33...	62,500,000....

5. Now configure 600 Mbps of Reserved traffic for the AVB streams that is already reserved.

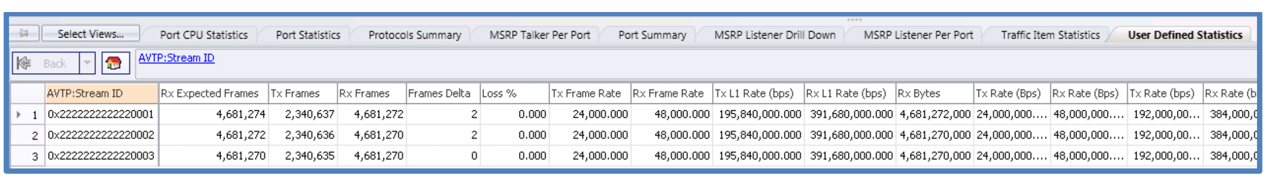


6. After starting the reserved traffic, expectation is that DUT will give higher priority to the reserved traffic since there is a congestion now. Check from traffic statistics that reserved traffic is going through with no loss whereas un-reserved traffic is incurring loss.



	Traffic Item	Tx Frames	Rx Expected Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate	Tx L1 Rate (bps)	Rx L1 Rate (bps)	Rx Bytes	Tx Rate (Bps)	Rx Rate
1	reserved_AVB_traffic	1,549,908	3,099,816	3,099,812	4	0.000	72,000.000	144,001.000	587,520,000.000	1,175,048,160...	3,099,812...	72,000,000....	144,00
2	unreserved_best_effort_traffic	1,636,876	3,273,752	2,759,206	514,54	15.717	62,499.500	101,095.000	509,995,920.000	824,935,200.000	2,759,206...	62,499,500....	101,09

7. Further, per stream drill down view will show per stream traffic statistics.



	AVTP:Stream ID	Rx Expected Frames	Tx Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate	Tx L1 Rate (bps)	Rx L1 Rate (bps)	Rx Bytes	Tx Rate (Bps)	Rx Rate (Bps)	Tx Rate (bps)	Rx Rate (b
1	0x2222222222220001	4,681,274	2,340,637	4,681,272	2	0.000	24,000.000	48,000.000	195,840,000.000	391,680,000.000	4,681,272,000	24,000,000....	48,000,000....	192,000,00...	384,000,0
2	0x2222222222220002	4,681,272	2,340,636	4,681,270	2	0.000	24,000.000	48,000.000	195,840,000.000	391,680,000.000	4,681,270,000	24,000,000....	48,000,000....	192,000,00...	384,000,0
3	0x2222222222220003	4,681,270	2,340,635	4,681,270	0	0.000	24,000.000	48,000.000	195,840,000.000	391,680,000.000	4,681,270,000	24,000,000....	48,000,000....	192,000,00...	384,000,0

Observable Results

1. By observing the loss percentage and receive latency in the traffic statistics, it can be verified whether DUT complies with the AVB standards.
2. The same test can be repeated with varying frame size and frame rate to check performance of DUT.

Verify Handling of Emergency Traffic

Objective

The objective of this test is to verify that DUT is able to pre-empt normal traffic in favor of emergency traffic. The emergency traffic frame size and rate is varied to check that DUT is always responding to the emergency traffic in standard compliant behavior.

Test Prerequisites

- The test tool must be capable of emulating MSRP Talker and Listener endpoints.
- The test tool must be able to configure AVB streams for both emergency and non-emergency traffic.
- The tool must be capable of measuring the loss and latency of AVB stream carrying emergency and non-emergency traffic independently.

Setup

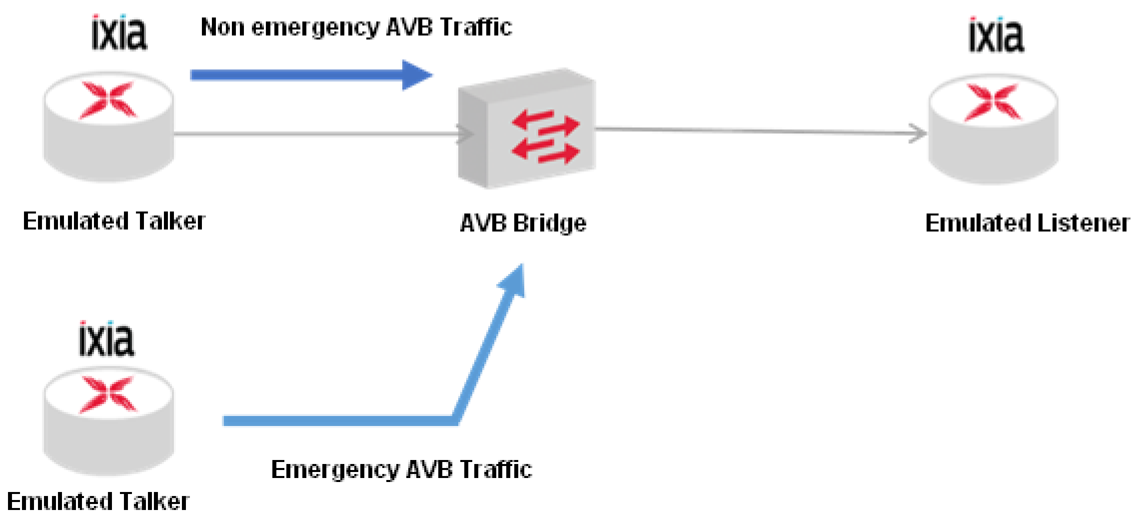


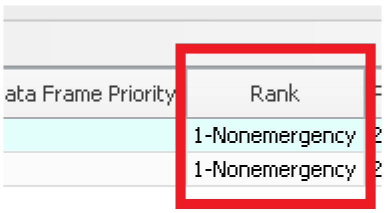
Figure 9 - Verify handling of emergency traffic

Methodology

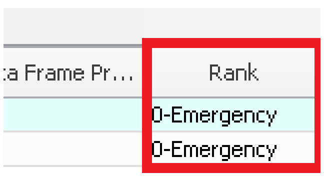
- Configure Ixia Talker on two ports(one for sending non-emergency and another one for sending emergency) and Ixia Listener on another port
- Bring up the SRP and gPTP control plane against the DUT
- Make one stream reservation for normal AVB traffic and another stream reservation for emergency traffic.
- Configure separate traffic items for normal AVB traffic and emergency traffic
- Start the traffic.
- Change the frame size/rate for normal and emergency traffic and check the DUT behavior.
- Start and stop the traffic item for emergency traffic and check the DUT behavior

Test using IxNetwork

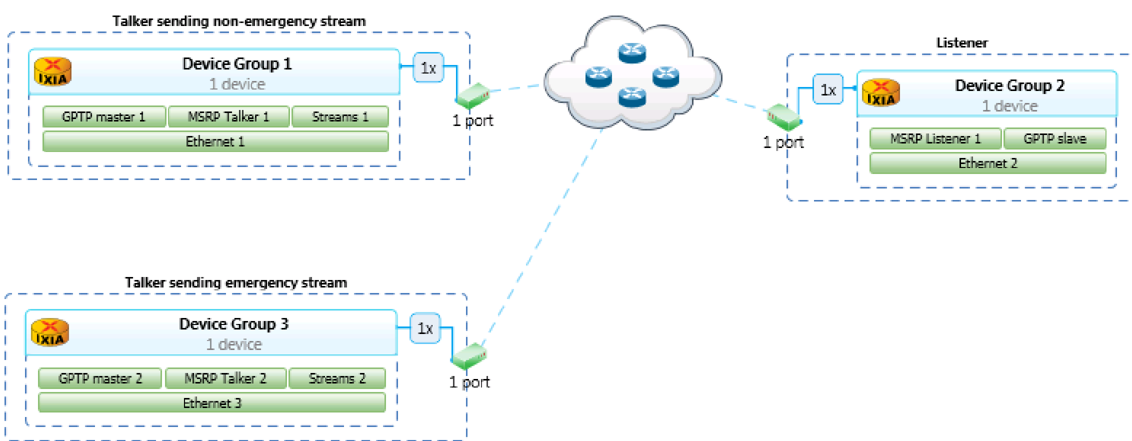
1. Configure Talker 1 for sending Non-Emergency stream, Talker 2 for sending Emergency stream, Listener 1 for subscribing Emergency and Non-Emergency streams.
2. Configure 1 Non-Emergency AVB stream for Talker 1 with 750 Mbps (75% of link speed) of 1 Gbps link. Use the Streams tab and the Rank field to be set to 1 for this.



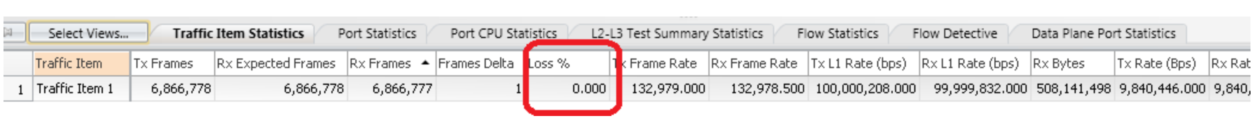
3. Configure 1 Emergency AVB stream for Talker 2 with 750Mbps (75% of link speed) of 1 Gbps link. Use the Streams tab and the Rank field to be set to 0 for this.



4. Bring up the control plane and verify that the protocols are up.



5. Send non-emergency traffic from Talker 1 and verify that there is no loss for the packets received by Listener 1.

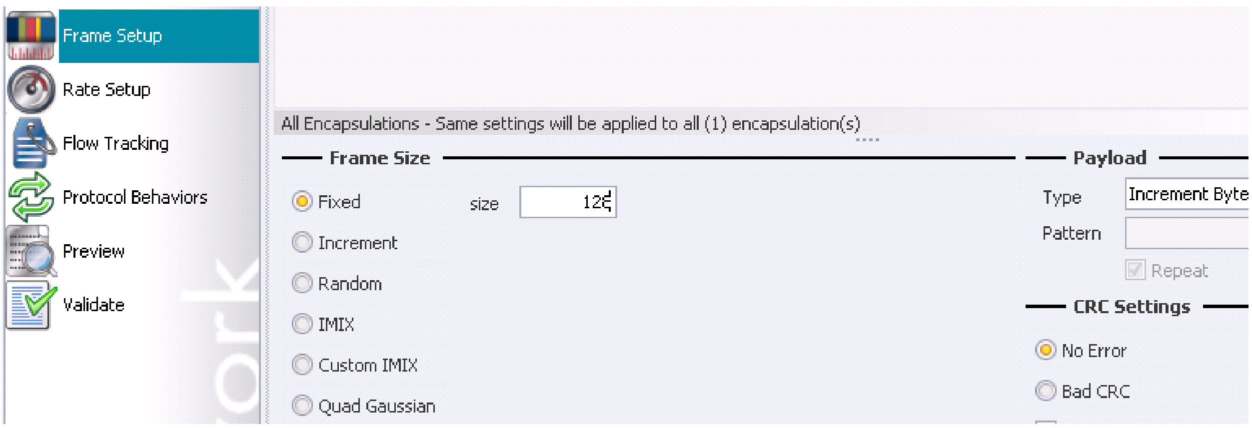


	Traffic Item	Tx Frames	Rx Expected Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate	Tx L1 Rate (bps)	Rx L1 Rate (bps)	Rx Bytes	Tx Rate (Bps)	Rx Rat
1	Traffic Item 1	6,866,778	6,866,778	6,866,777	1	0.000	132,979.000	132,978.500	100,000,208.000	99,999,832.000	508,141,498	9,840,446.000	9,840,

6. Send emergency traffic flows from Talker 2 simultaneously while non-emergency traffic flows, and verify that there will be no packet loss for emergency traffic(Talker 2 to Listener 1) but packet loss will be there for non-emergency traffic(Talker 1 to Listener 1).

Traffic Item	Tx Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate	T
Traffic Item 1	2,920,962	0	2,920,962	100.000	148,809.500	0.000	
Traffic Item 2	2,920,962	2,920,962	0	0.000	148,809.500	148,809.500	

7. Vary the Frame size of the non-emergency and emergency traffic and verify that the DUT behavior remains the same. There will be no packet loss for emergency traffic but packet loss will be there for non-emergency traffic.



Observable Results

By observing the loss percentage and receive latency in the traffic statistics, it can be verified whether DUT gives preference to emergency AVB traffic over non-emergency AVB traffic.

Testing AVB Traffic QoS in Presence of Bursty/Continuous Best-Effort Traffic

Objective

The objective of this test is to verify that credit based shaper algorithm running on DUT egress port will meet the shaping requirements for both AVB and Non-AVB traffic.

Test Prerequisites

- The test tool must be capable of emulating MSRP Talker and Listener endpoints.
- The test tool must be capable of sending Best Effort traffic in different modes – bursty, continuous etc.
- The test tool must be able to configure AVB streams
- The tool must be capable of measuring the loss and latency of AVB traffic and non-AVB traffic independently.

Setup

The setup for this test requires at least three test ports which are connected via the AVB Bridge.

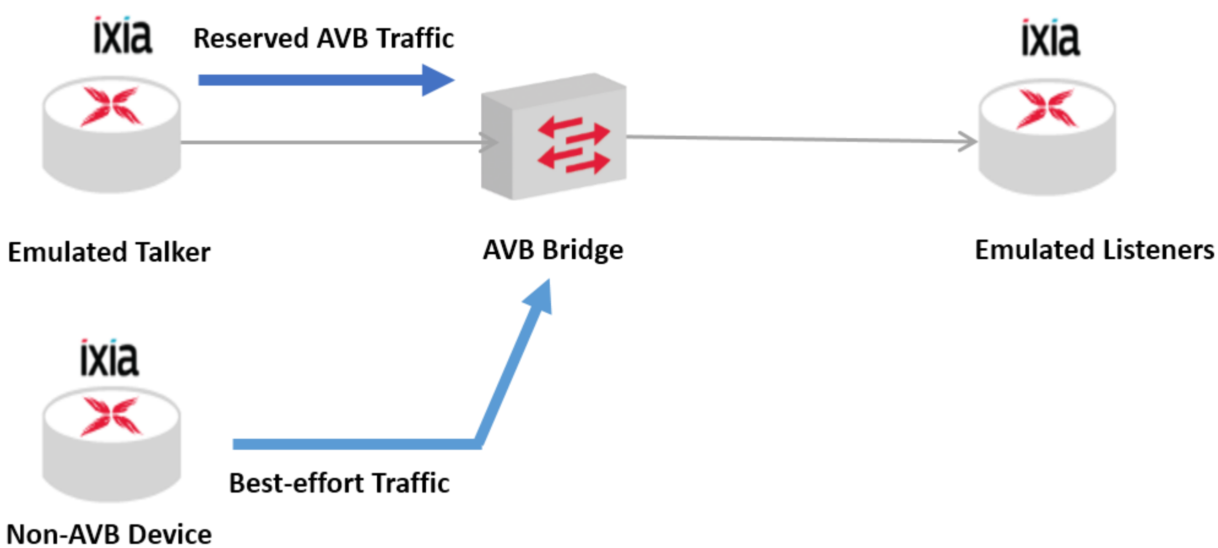


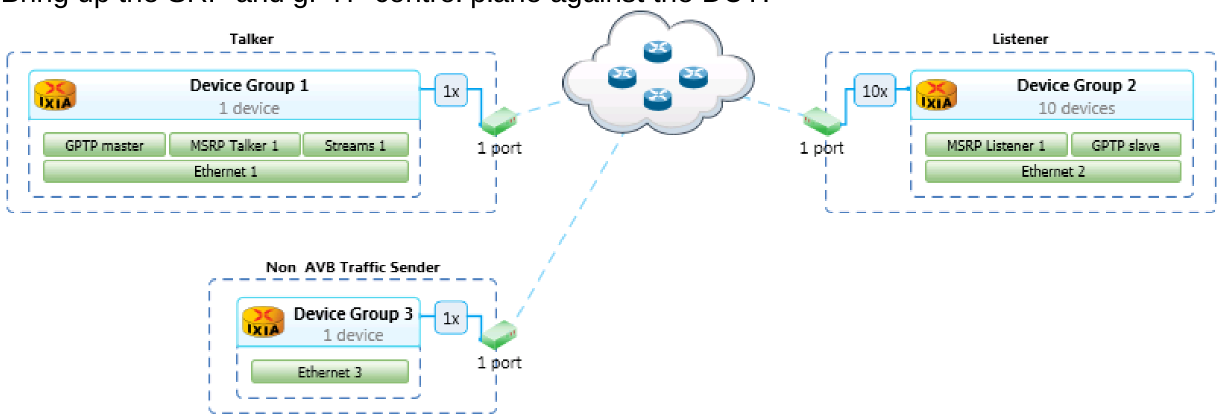
Figure 10 - Test AVB traffic QoS

Methodology

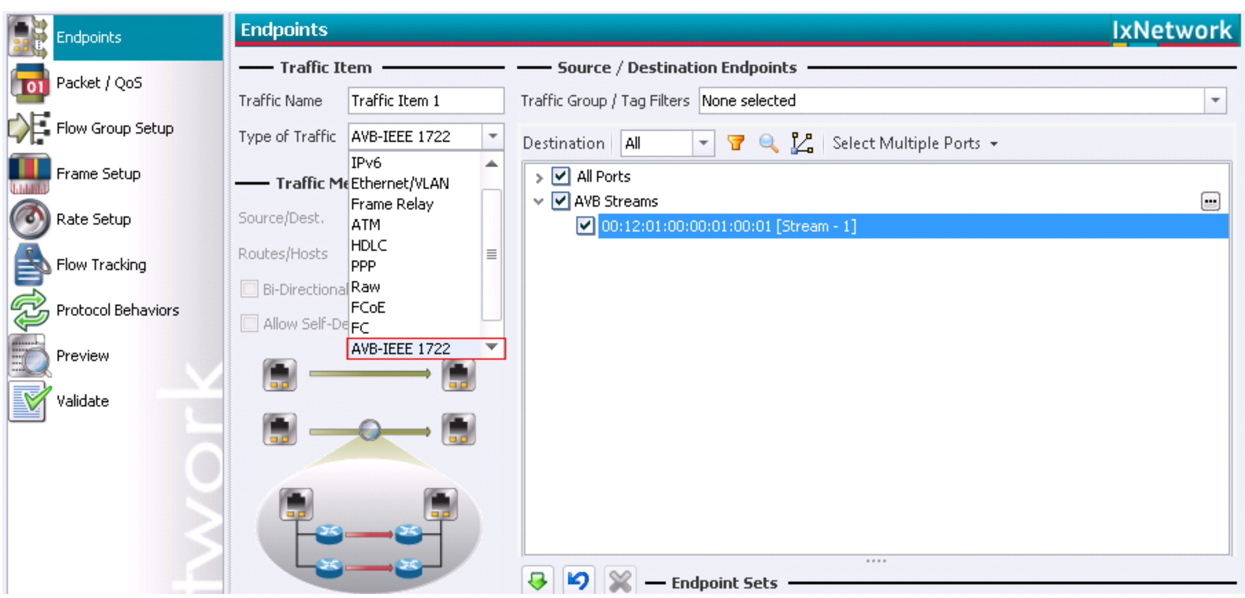
- Configure Ixia Talker on one port and Ixia Listener on another port
- Configure one more port for sending Non AVB traffic
- Bring up the SRP and gPTP control plane against the DUT
- Configure both AVB and non-AVB traffic.
- Start the traffic.
- Stop the traffic and set the mode of non-AVB traffic to bursty.
- Start the traffic and verify that the credit based shaper is able to shape the best-effort traffic.

Test Using IxNetwork

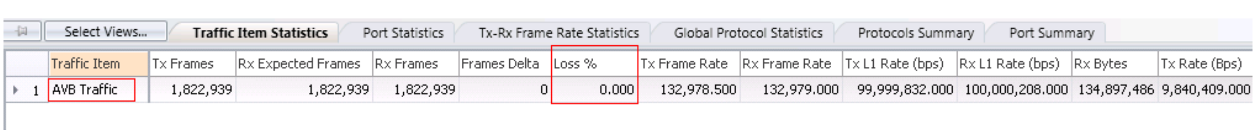
1. Configure Ixia Talker on one port and Ixia Listener on another port. Configure one more port for sending Non-AVB traffic.
2. Bring up the SRP and gPTP control plane against the DUT.



3. Configure AVB traffic to be sent from Talker to Listener with 750 Mbps (reserving 75% of 1 Gbps link speed)

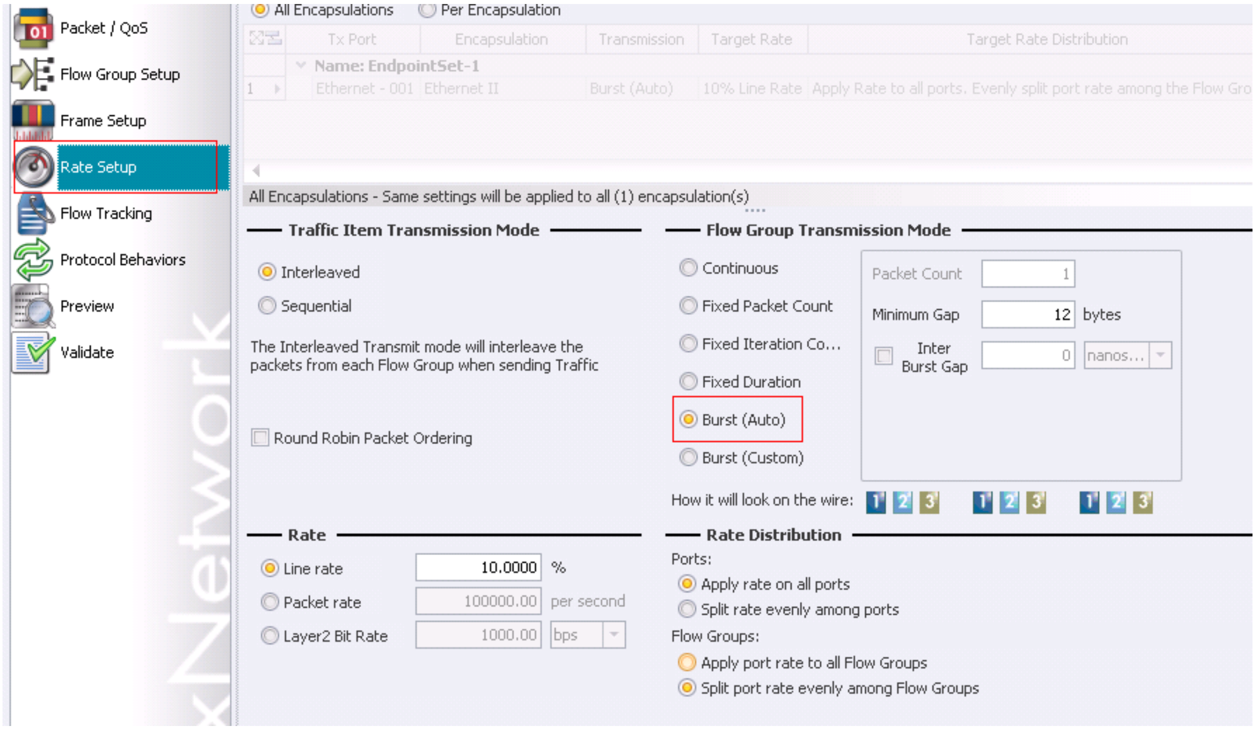


4. Send AVB traffic and verify that there is no loss.

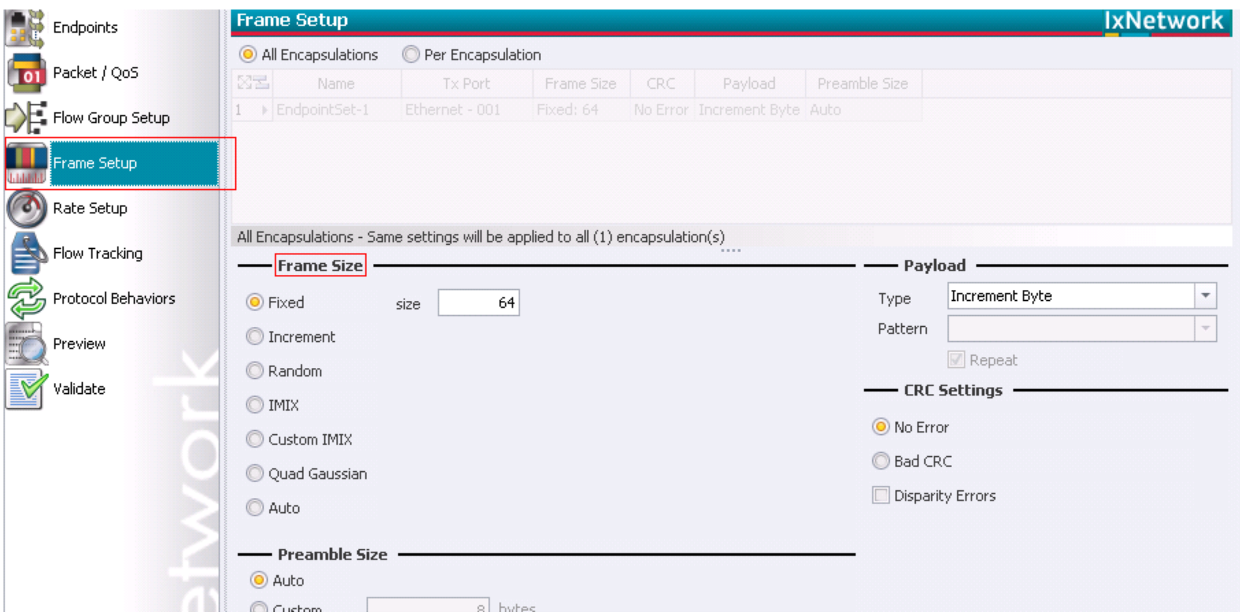


	Traffic Item	Tx Frames	Rx Expected Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate	Tx L1 Rate (bps)	Rx L1 Rate (bps)	Rx Bytes	Tx Rate (Bps)
1	AVB Traffic	1,822,939	1,822,939	1,822,939	0	0.000	132,978.500	132,979.000	99,999,832.000	100,000,208.000	134,897,486	9,840,409.000

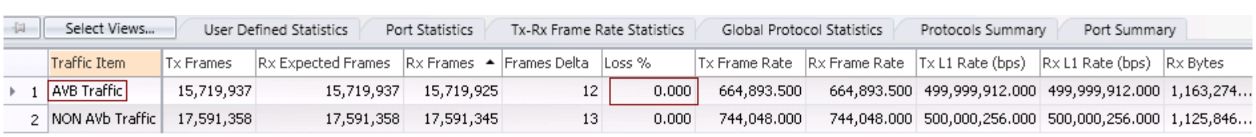
5. Configure Non-AVB traffic and set the mode to bursty and ensure that non-AVB traffic consumes 25% BW or more.



6. Configure packet size from Frame Setup and test for both large and small packet size.

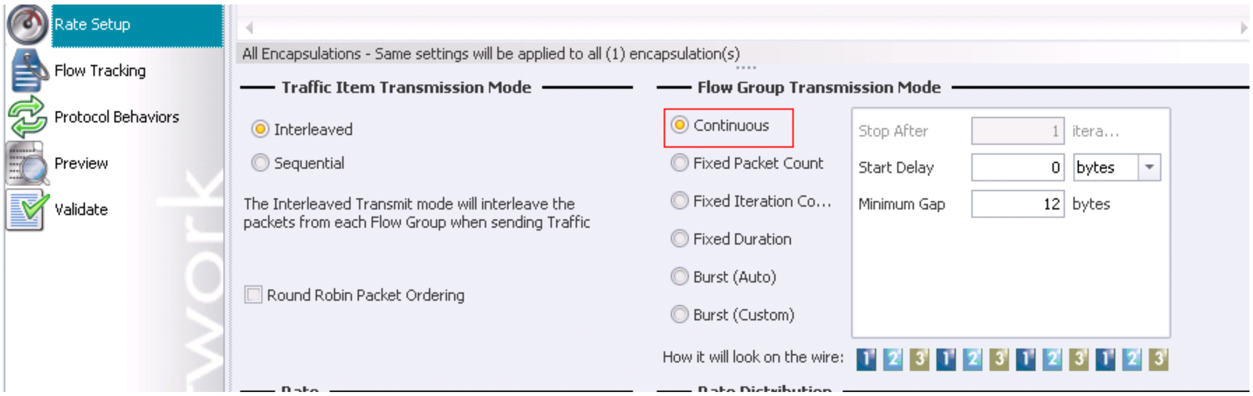


7. Send AVB traffic and non AVB traffic simultaneously from Port 1 and Port 2 and verify that the AVB traffic is not impacted by non AVB traffic.

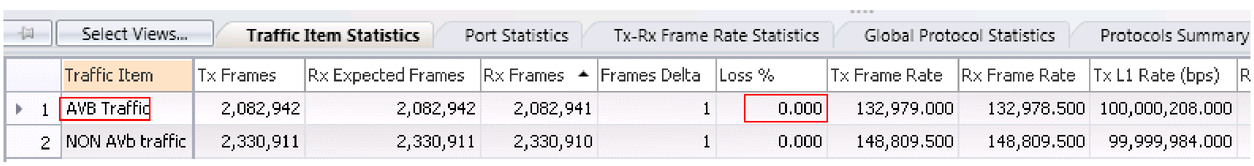


	Traffic Item	Tx Frames	Rx Expected Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate	Tx L1 Rate (bps)	Rx L1 Rate (bps)	Rx Bytes
1	AVB Traffic	15,719,937	15,719,937	15,719,925	12	0.000	664,893.500	664,893.500	499,999,912.000	499,999,912.000	1,163,274...
2	NON AVb Traffic	17,591,358	17,591,358	17,591,345	13	0.000	744,048.000	744,048.000	500,000,256.000	500,000,256.000	1,125,846...

8. Stop the AVB and non AVB traffic.
9. Configure Non AVB traffic and set the mode to continuous.



10. Configure packet size from Frame Setup and ensure that non-AVB traffic consumes 25% BW or more. Test for both large and small packet size.
11. Send AVB traffic and Non AVB traffic simultaneously and check that the AVB traffic is not impacted by non AVB traffic.



	Traffic Item	Tx Frames	Rx Expected Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate	Tx L1 Rate (bps)
1	AVB Traffic	2,082,942	2,082,942	2,082,941	1	0.000	132,979.000	132,978.500	100,000,208.000
2	NON AVb traffic	2,330,911	2,330,911	2,330,910	1	0.000	148,809.500	148,809.500	99,999,984.000

Observable Results

1. By observing the loss percentage and receive latency in the traffic statistics, it can be verified that the QOS of AVB traffic is not impacted by non AVB Traffic.
2. QOS parameters of AVB streams must not degrade, irrespective of the switch is handling larger buffers or higher packet switching, for the non AVB traffic.

Priority Re-Mapping for Best-Effort Traffic

Objective

The objective of this test is to find that the DUT will set the AVB domain boundaries on its ports and the best-effort traffic received on an AVB boundary port will be forwarded with remapped priority in the AVB domain.

Test Prerequisites

- The test tool must be capable of emulating MSRP Talker and Listener endpoints.
- The test tool must be capable of sending Best Effort traffic.
- The test tool must be able to configure AVB streams
- The tool must be capable of measuring the loss and latency of AVB traffic and non-AVB traffic independently.
- The tool must be capable of checking both ingress and egress VLAN priority simultaneously.

Setup

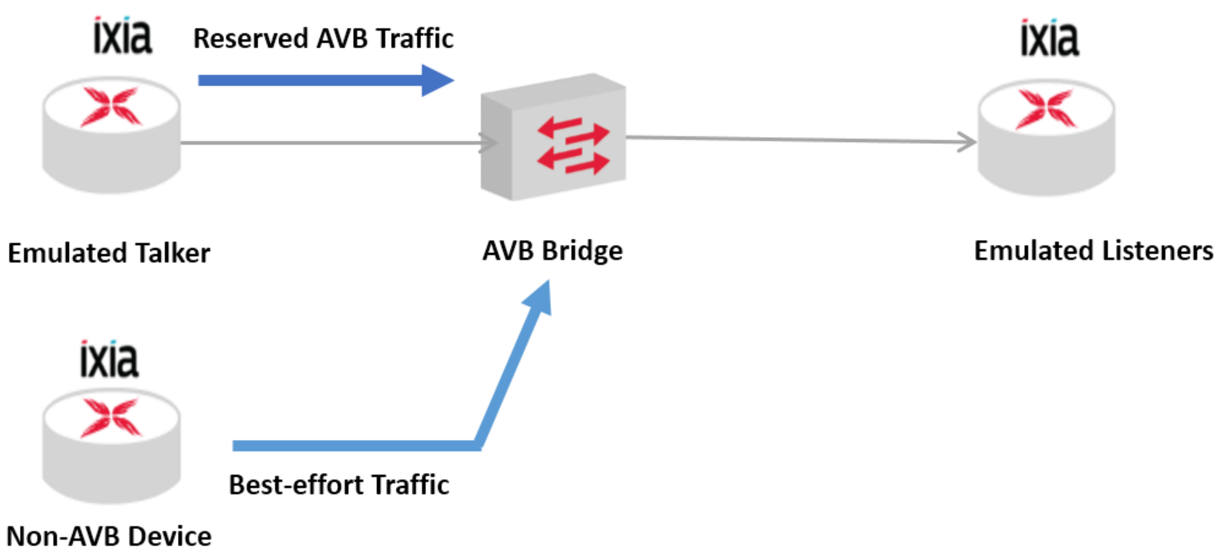


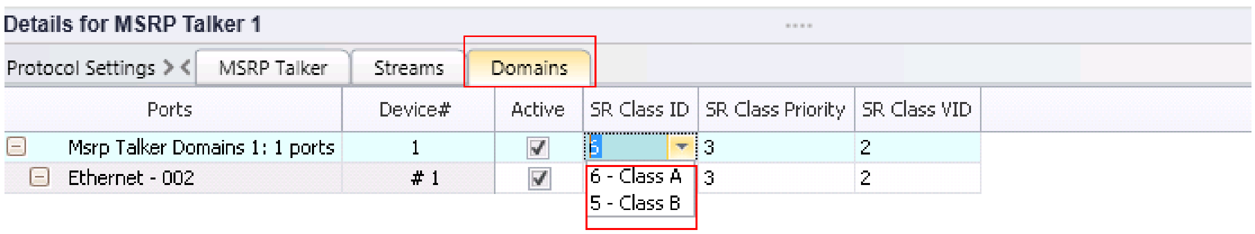
Figure 11 - Priority re-mapping for best-effort traffic

Methodology

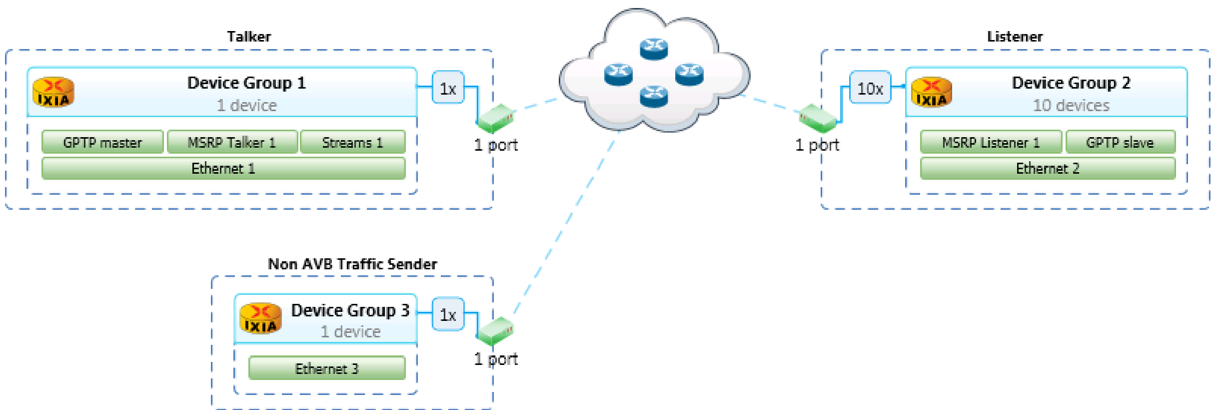
- Configure Ixia Talker on one port and Ixia Listener on another port
- Configure another port for sending non-AVB traffic
- Bring up the SRP and gPTP control plane against the DUT
- Configure AVB traffic on one Ixia Talker Port for SR Class A and SR class B
- Configure non-AVB traffic on another Ixia Port, configure two flows - one with priority 2 and another with Priority 3
- Verify that Non-AVB traffic priority is remapped to 0 (as per 802.1Qav standard)

Test using IxNetwork

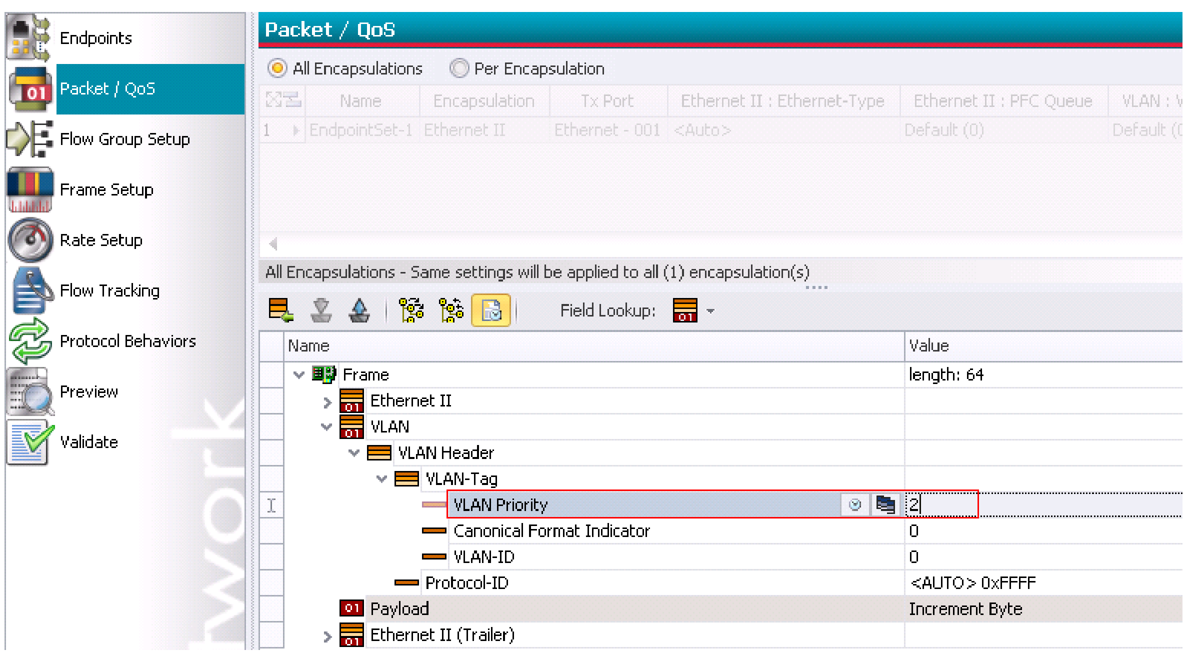
1. Configure Ixia Talker on one port and Ixia Listener on another port. Configure one more port for sending non AVB traffic.
2. Configure AVB traffic on Ixia Talker Port for SR Class A and SR class B



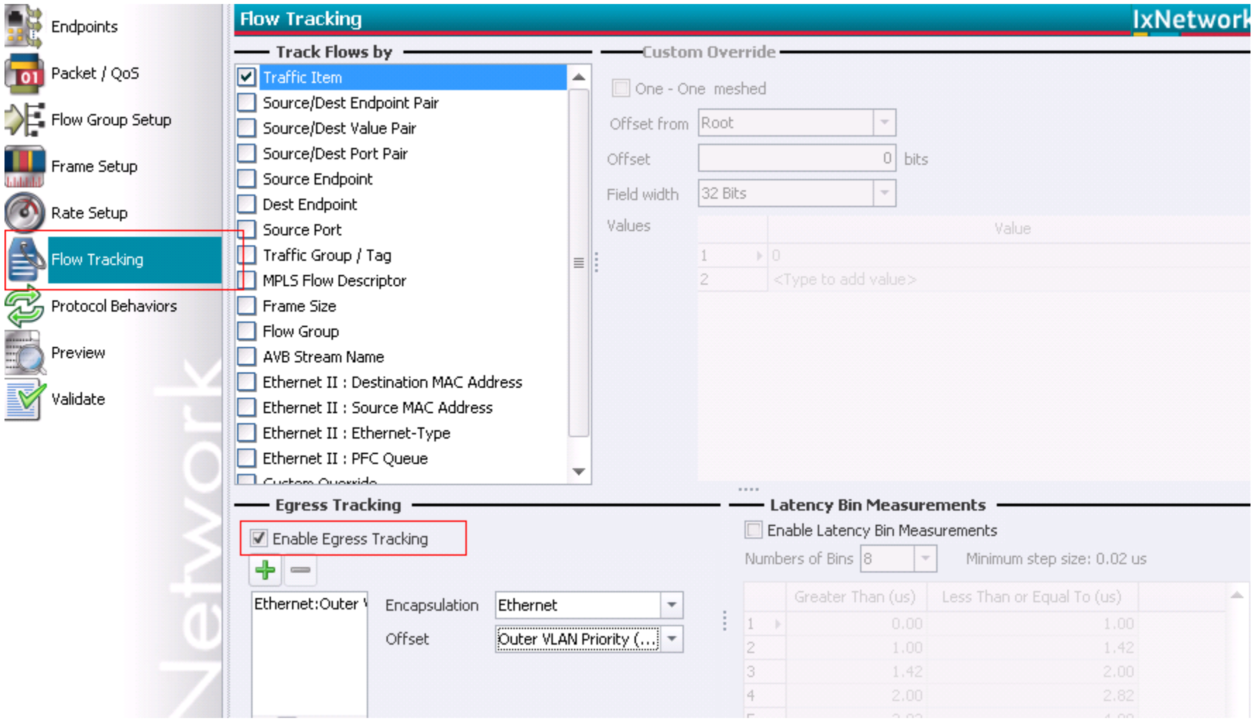
3. Bring up the MSRP and gPTP control plane against the DUT. Ensure that it is up.



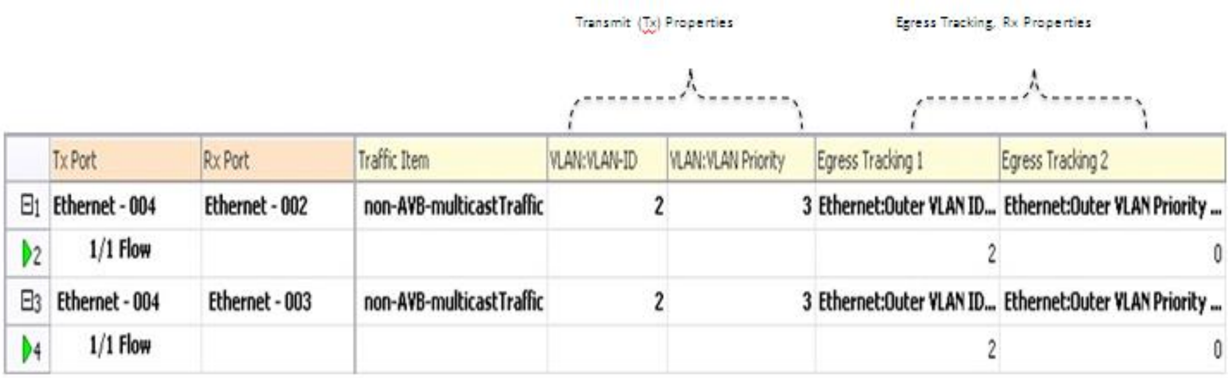
4. Configure non-AVB traffic on another Ixia Port, configure two flows - one with priority 2 and another with Priority 3 in Traffic Wizard.



5. Enable egress tracking on VLAN priority on the traffic parameters.



6. Verify that Non-AVB traffic priority is remapped to 0 (as per 802.1Qav standard).



	Tx Port	Rx Port	Traffic Item	VLAN:VLAN-ID	VLAN:VLAN Priority	Egress Tracking 1	Egress Tracking 2
1	Ethernet - 004	Ethernet - 002	non-AVB-multicastTraffic	2	3	Ethernet:Outer VLAN ID...	Ethernet:Outer VLAN Priority ...
2	1/1 Flow					2	0
3	Ethernet - 004	Ethernet - 003	non-AVB-multicastTraffic	2	3	Ethernet:Outer VLAN ID...	Ethernet:Outer VLAN Priority ...
4	1/1 Flow					2	0

Observable Results

1. By observing the test result it can be verified that DUT triggers Priority Rewrite is to protect AVB-Traffic.
2. With varying load of non-AVB traffic, priority rewrite processing must not impact AVB traffic QOS.
3. Priority rewrite is not affected by the nature of the traffic (busty, steady, line rate).

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