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Expires in: November 2002

# Methodology for IP Multicast Benchmarking
<draft-ietf-bmwg-mcastm-09.txt>

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## Abstract

The purpose of this draft is to describe methodology specific to the benchmarking of multicast IP forwarding devices. It builds upon the tenets set forth in RFC 2544, RFC 2432 and other IETF Benchmarking Methodology Working Group (BMWG) efforts. This document seeks to extend these efforts to the multicast paradigm.

The BMWG produces two major classes of documents: Benchmarking Terminology documents and Benchmarking Methodology documents. The Terminology documents present the benchmarks and other related terms. The Methodology documents define the procedures required to collect the benchmarks cited in the corresponding Terminology

documents.

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## 1. Introduction

This document defines a specific set of tests that vendors can use to measure and report the performance characteristics and forwarding capabilities of network devices that support IP multicast protocols. The results of these tests will provide the user comparable data from different vendors with which to evaluate these devices.

A previous document, " Terminology for IP Multicast Benchmarking" (RFC 2432), defined many of the terms that are used in this document. The terminology document should be consulted before attempting to make use of this document.

This methodology will focus on one source to many destinations, although many of the tests described may be extended to use multiple source to multiple destination IP multicast communication.

## 2. Key Words to Reflect Requirements

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119. RFC 2119 defines the use of these key words to help make the intent of standards track documents as clear as possible. While this document uses these keywords, this document is not a standards track document.

## 3. Test set up

The set of methodologies presented in this draft are for single ingress, multiple egress scenarios as exemplified by Figures 1 and 2. Methodologies for multiple ingress, multiple egress scenarios are beyond the scope of this document.

Figure 1 shows a typical setup for an IP multicast test, with one source to multiple destinations.

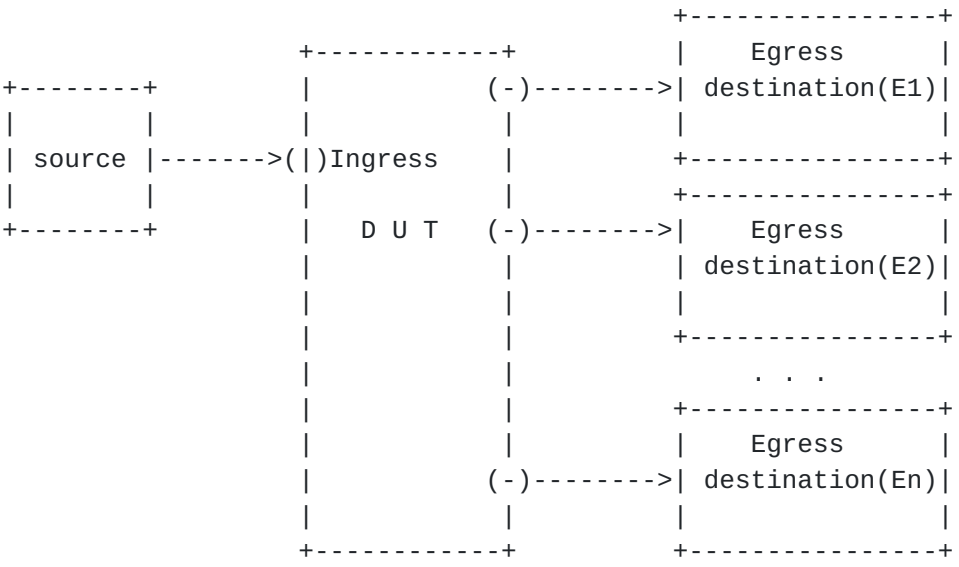



Figure 1

If the multicast metrics are to be taken across multiple devices forming a System Under Test (SUT), then test packets are offered to a single ingress interface on a device of the SUT, subsequently routed across the SUT topology, and finally forwarded to the test apparatus' packet-receiving components by the test egress interface(s) of devices in the SUT. Figure 2 offers an example SUT test topology. If a SUT is tested, the details of the test topology MUST be disclosed with the corresponding test results.

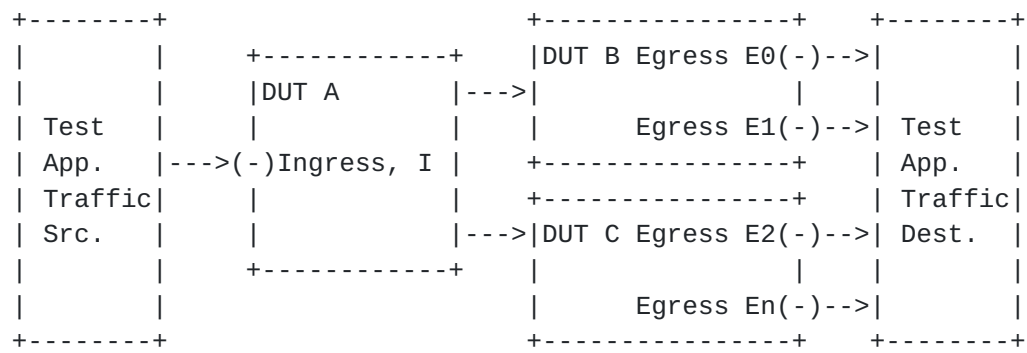



Figure 2

Generally, the destination ports first join the desired number of multicast groups by sending IGMP Join Group messages to the DUT/SUT. To verify that all destination ports successfully joined

the appropriate groups, the source port MUST transmit IP multicast frames destined for these groups. The destination ports MAY send IGMP Leave Group messages after the transmission of IP Multicast frames to clear the IGMP table of the DUT/SUT.

In addition, test equipment MUST validate the correct and proper forwarding actions of the devices they test in order to ensure the receipt of only the frames that are involved in the test.

## 3.1. Test Considerations

The procedures outlined below are written without regard for specific physical layer or link layer protocols. The methodology further assumes a uniform medium topology. Issues regarding mixed transmission media, such as speed mismatch, headers differences, etc., are not specifically addressed. Flow control, QoS and other traffic-affecting mechanisms MUST be disabled. Modifications to the specified collection procedures might need to be made to accommodate the transmission media actually tested. These accommodations MUST be presented with the test results.

An actual flow of test traffic may be required to prime related mechanisms, (e.g., process RPF events, build device caches, etc.) to optimally forward subsequent traffic. Therefore, before an initial, measured forwarding test trial, the test apparatus MUST generate test traffic utilizing the same addressing characteristics to the DUT/SUT that will subsequently be used to measure the DUT/SUT response. The test monitor should ensure the correct forwarding of traffic by the DUT/SUT. The priming action need only be repeated to keep the associated information current.

### 3.1.1. IGMP Support

Each of the destination ports should support and be able to test all IGMP versions 1, 2 and 3. The minimum requirement, however, is IGMP version 2.

Each destination port should be able to respond to IGMP queries during the test.

Each destination port should also send LEAVE (running IGMP version 2) after each test.

### 3.1.2. Group Addresses

It is intended that the collection of benchmarks prescribed in this document be executed in an isolated lab environment. That is to say, the test traffic offered the tested devices MUST NOT traverse a live internet, intranet, or other user-oriented network.

Assuming the above, there is no restriction to the use of multicast addresses to compose the test traffic other than those assignments imposed by IANA. The IANA assignments MUST be regarded for operational consistency. For multicast address assignments see:

http://www.iana.org/assignments/multicast-addresses

It should be noted that address selection need not be restricted to Administratively Scoped IP Multicast addresses.

### 3.1.3. Frame Sizes

Each test SHOULD be run with different Multicast Frame Sizes. The recommended frame sizes are 64, 128, 256, 512, 1024, 1280, and 1518 byte frames.

### 3.1.4. TTL

The source frames should have a TTL value large enough to accommodate the DUT/SUT.

### 3.1.5. Trial Duration

The duration of the test portion of each trial SHOULD be at least 30 seconds. This parameter MUST be included as part of the results reporting for each methodology.

## 3.2. Layer 2 Support

Each of the destination ports should support GARP/GMRP protocols to join groups on Layer 2 DUTs/SUTs.

# 4. Forwarding and Throughput

This section contains the description of the tests that are related to the characterization of the packet forwarding of a DUT/SUT in a multicast environment. Some metrics extend the concept of throughput presented in RFC 1242. The notion of Forwarding Rate is cited in RFC 2285.

## 4.1. Mixed Class Throughput

Objective

To determine the throughput of a DUT/SUT when both unicast class frames and multicast class frames are offered simultaneously to a fixed number of ports as defined in RFC 2432.

Procedure

Multicast and unicast traffic are mixed together in the same aggregated traffic stream in order to simulate the non-homogenous networking environment. The DUT/SUT MUST learn the appropriate unicast IP addresses, either by sending ARP frames from each unicast address, sending a RIP packet or by assigning static entries into the DUT/SUT address table.

The relationship between the intended load [Ma91] of multicast class frames vs. unicast class frames MUST be specified:

a) As an independent rate for unicast class and multicast class of traffic OR
b) As an aggregate rate comprised of a ratio of multicast class to unicast class of traffic.

The offered load per each DUT/SUT port MUST not exceed the maximum bandwidth capacity of any configured receive DUT/SUT ports.

All DUT/SUT ports configured to receive multicast traffic MUST join all configured multicast groups prior to transmitting test frames. Joining a group is accomplished by sending an IGMP Join Group messages. All DUT/SUT ports configured to receive unicast traffic MUST send learning frames prior to transmitting test frames (see section 3 for more information).

Unicast traffic distribution can either be non-meshed or meshed [Ma98] as specified in RFC2544 or RFC2289. A minimum of one unicast transmit port MUST be configured to transmit unicast traffic to a DUT/SUT port that is configured to receive unicast and multicast traffic.

Multicast traffic distribution MUST be configured to transmit traffic in a one-to-many mesh [Ma98] configuration. A minimum of one multicast transmit port MUST be configured to transmit multicast traffic to a DUT/SUT port that is configured to receive multicast traffic.

Throughput measurement is defined in RFC1242 [Br91]. A search algorithm MUST be utilized to determine the maximum offered frame rate with a zero frame loss rate.

Result

Parameters to be measured MUST include the aggregate offered load, number of multicast frames offered, number of unicast frames offered, number multicast frames received, number of unicast frames

received and transmit duration of offered frames.

### 4.2. Scaled Group Forwarding Matrix

Objective

To determine Forwarding Rate as a function of tested multicast groups for a fixed number of tested DUT/SUT ports.

Procedure

Multicast traffic is sent at a fixed percent of maximum offered load with a fixed number of receive ports of the tester at a fixed frame length.

On each iteration, the receive ports SHOULD incrementally join 10 multicast groups until a user defined maximum number of groups is reached.

Results

Parameters to be measured MUST include the offered load and forwarding rate as a function of the total number of multicast groups, for each test iteration.

The nature of the traffic stream contributing to the result MUST be reported, specifically number of source and destination ports within the multicast group. In addition, all other reporting parameters of the scaled group forwarding matrix methodology MUST be reflected in the results report, such as the transmitted packet size(s) and offered load of the packet stream for each source port.

Result reports MUST include the following parameters for each iteration: the number of frames offered, number of frames received per each group, number of multicast groups and forwarding rate, in frames per second, and transmit duration of offered frames. Constructing a table that contains the forwarding rate vs. number of groups is desirable.

### 4.3. Aggregated Multicast Throughput

Objective

To determine the maximum rate at which none of the offered frames to be forwarded through N destination interfaces of the same multicast group is dropped.

Procedure

Multicast traffic is sent at a fixed percent of maximum offered load with a fixed number of groups at a fixed frame length for a

fixed duration of time.

The initial number of receive ports of the tester will join the group(s) and the sender will transmit to the same groups after a certain delay (a few seconds).

If any frame loss is detected, one receive port MUST leave the group(s) and the sender will transmit again. Continue in this iterative fashion until either there are no ports left joined to the multicast group(s) OR 0% frame loss is achieved.

Results

Parameters to be measured MUST include the maximum offered load at which no frame loss occurred (as defined by RFC 2544)

The nature of the traffic stream contributing to the result MUST be reported. All required reporting parameters of aggregated throughput MUST be reflected in the results report, such as the initial number of receive ports, the final number of receive ports, total number of multicast group addresses, the transmitted packet size(s), offered load of the packet stream and transmit duration of offered frames.

Constructing a table from the measurements might be useful in illustrating the effect of modifying the number of active egress ports on the tested system.

## 4.4. Encapsulation/Decapsulation (Tunneling) Throughput

This sub-section provides the description of tests that help in obtaining throughput measurements when a DUT/SUT or a set of DUTs are acting as tunnel endpoints

### 4.4.1. Encapsulation Throughput

Objective

To determine the maximum rate at which frames offered a DUT/SUT are encapsulated and correctly forwarded by the DUT/SUT without loss.

Procedure

Traffic is sent through a DUT/SUT that has been configured to encapsulate the frames. Traffic is received on a test port prior to decapsulation and throughput is calculated based on RFC2544.

Results

Parameters to be measured SHOULD include the measured throughput per tunnel.

The nature of the traffic stream contributing to the result MUST be reported. All required reporting parameters of encapsulation throughput MUST be reflected in the results report, such as the transmitted packet size(s), offered load of the packet stream and transmit duration of offered frames.

### 4.4.2. Decapsulation Throughput

Objective

To determine the maximum rate at which frames offered a DUT/SUT are decapsulated and correctly forwarded by the DUT/SUT without loss.

Procedure

Encapsulated traffic is sent through a DUT/SUT that has been configured to decapsulate the frames. Traffic is received on a test port after decapsulation and throughput is calculated based on RFC2544.

Results

Parameters to be measured SHOULD include the measured throughput per tunnel.

The nature of the traffic stream contributing to the result MUST be reported. All required reporting parameters of decapsulation throughput MUST be reflected in the results report, such as the transmitted packet size(s), offered load of the packet stream and transmit duration of offered frames.

### 4.4.3. Re-encapsulation Throughput

Objective

To determine the maximum rate at which frames of one encapsulated format offered a DUT/SUT are converted to another encapsulated format and correctly forwarded by the DUT/SUT without loss.

Procedure

Traffic is sent through a DUT/SUT that has been configured to encapsulate frames into one format, then re-encapsulate the frames into another format. Traffic is received on a test port after all decapsulation is complete and throughput is calculated based on RFC2544.

Results

Parameters to be measured SHOULD include the measured throughput per tunnel.

The nature of the traffic stream contributing to the result MUST be reported. All required reporting parameters of re-encapsulation throughput MUST be reflected in the results report, such as the transmitted packet size(s), offered load of the packet stream and transmit duration of offered frames.

## 5. Forwarding Latency

This section presents methodologies relating to the characterization of the forwarding latency of a DUT/SUT in a multicast environment. It extends the concept of latency characterization presented in RFC 2544.

In order to lessen the effect of packet buffering in the DUT/SUT, the latency tests MUST be run at the measured multicast throughput level of the DUT; multicast latency at other offered loads is optional.

Lastly, RFC 1242 and RFC 2544 draw distinction between two classes of devices: "store and forward" and "bit-forwarding." Each class impacts how latency is collected and subsequently presented. See the related RFCs for more information. In practice, much of the test equipment will collect the latency measurement for one class or the other, and, if needed, mathematically derive the reported value by the addition or subtraction of values accounting for medium propagation delay of the packet, bit times to the timestamp trigger within the packet, etc. Test equipment vendors SHOULD provide documentation regarding the composition and calculation latency values being reported. The user of this data SHOULD understand the nature of the latency values being reported, especially when comparing results collected from multiple test vendors. (E.g., If test vendor A presents a "store and forward" latency result and test vendor B presents a "bit-forwarding" latency result, the user may erroneously conclude the DUT has two differing sets of latency values.)

### 5.1. Multicast Latency

Objective

To produce a set of multicast latency measurements from a single, multicast ingress port of a DUT/SUT through multiple, egress multicast ports of that same DUT/SUT as provided for by the metric "Multicast Latency" in RFC 2432.

The procedures highlighted below attempt to draw from the collection methodology for latency in RFC 2544 to the degree possible. The methodology addresses two topological scenarios: one for a single device (DUT) characterization; a second scenario is

presented or multiple device (SUT) characterization.

Procedure

If the test trial is to characterize latency across a single Device Under Test (DUT), an example test topology might take the form of Figure 1 in section 3. That is, a single DUT with one ingress interface receiving the multicast test traffic from packet-transmitting component of the test apparatus and n egress interfaces on the same DUT forwarding the multicast test traffic back to the packet-receiving component of the test apparatus. Note that n reflects the number of TESTED egress interfaces on the DUT actually expected to forward the test traffic (as opposed to configured but untested, non-forwarding interfaces, for example).

If the multicast latencies are to be taken across multiple devices forming a System Under Test (SUT), an example test topology might take the form of Figure 2 in section 3.

The trial duration SHOULD be 120 seconds. Departures to the suggested traffic class guidelines MUST be disclosed with the respective trial results. The nature of the latency measurement, "store and forward" or "bit forwarding," MUST be associated with the related test trial(s) and disclosed in the results report.

End-to-end reach ability of the test traffic path MUST be verified prior to the engagement of a test trial. This implies that subsequent measurements are intended to characterize the latency across the tested device's or devices' normal traffic forwarding path (e.g., faster hardware-based engines) of the device(s) as opposed a non-standard traffic processing path (e.g. slower, software-based exception handlers). If the test trial is to be executed with the intent of characterizing a non-optimal, forwarding condition, then a description of the exception processing conditions being characterized MUST be included with the trial's results.

A test traffic stream is presented to the DUT. At the mid-point of the trial's duration, the test apparatus MUST inject a uniquely identifiable ("tagged") packet into the test traffic packets being presented. This tagged packet will be the basis for the latency measurements. By "uniquely identifiable," it is meant that the test apparatus MUST be able to discern the "tagged" packet from the other packets comprising the test traffic set. A packet generation timestamp, Timestamp A, reflecting the completion of the transmission of the tagged packet by the test apparatus, MUST be determined.

The test apparatus then monitors packets from the DUT's tested

egress port(s) for the expected tagged packet(s) until the cessation of traffic generation at the end of the configured trial duration.A value of the Offered Load presented the DUT/SUT MUST be noted.

The test apparatus MUST record the time of the successful detection of a tagged packet from a tested egress interface with a timestamp, Timestamp B. A set of Timestamp B values MUST be collected for all tested egress interfaces of the DUT/SUT.

A trial MUST be considered INVALID should any of the following conditions occur in the collection of the trial data:

- Forwarded test packets directed to improper destinations.
- Unexpected differences between Intended Load and Offered Load or unexpected differences between Offered Load and the resulting Forwarding Rate(s) on the DUT/SUT egress ports.
- Forwarded test packets improperly formed or packet header fields improperly manipulated.
- Failure to forward required tagged packet(s) on all expected egress interfaces.
- Reception of a tagged packet by the test apparatus outside the configured test duration interval or 5 seconds, whichever is greater.

Data from invalid trials SHOULD be considered inconclusive. Data from invalid trials MUST not form the basis of comparison.

The set of latency measurements, M, composed from each latency measurement taken from every ingress/tested egress interface pairing MUST be determined from a valid test trial:

```
M = { (Timestamp B(E0) - Timestamp A),
      (Timestamp B(E1) - Timestamp A), ...
      (Timestamp B(En) - Timestamp A) }
```

where (E0 ... En) represents the range of all tested egress interfaces and Timestamp B represents a tagged packet detection event for a given DUT/SUT tested egress interface.

Results

Two types of information MUST be reported: 1) the set of latency measurements and 2) the significant environmental, methodological, or device particulars giving insight into the test or its results.

Specifically, when reporting the results of a VALID test trial, the set of ALL latencies related to the tested ingress interface and each tested egress DUT/SUT interface of MUST be presented. The time units of the presented latency MUST be uniform and with sufficient precision for the medium or media being tested. Results MAY be offered in tabular format and SHOULD preserve the relationship of latency to ingress/egress interface to assist in trending across multiple trials.

The Offered Load of the test traffic presented the DUT/SUT, size of the "tagged" packet, transmit duration of offered frames and nature (i.e., store-and-forward or bit-forwarding) of the trial's

measurement MUST be associated with any reported test trial's result.

## 5.2. Min/Max Multicast Latency

Objective

To determine the difference between the maximum latency measurement and the minimum latency measurement from a collected set of latencies produced by the Multicast Latency benchmark.

Procedure

Collect a set of multicast latency measurements, as prescribed in section 5.1. This will produce a set of multicast latencies, M, where M is composed of individual forwarding latencies between DUT packet ingress and DUT packet egress port pairs. E.g.:

M = {L(I,E1),L(I,E2), à, L(I,En)}

where L is the latency between a tested ingress port, I, of the DUT, and Ex a specific, tested multicast egress port of the DUT. E1 through En are unique egress ports on the DUT.

From the collected multicast latency measurements in set M, identify MAX(M), where MAX is a function that yields the largest latency value from set M.

Identify MIN(M), when MIN is a function that yields the smallest latency value from set M.

The Max/Min value is determined from the following formula:

Result = MAX(M) û MIN(M)

Results

The result MUST be represented as a single numerical value in time units consistent with the corresponding latency measurements. In addition, the number of tested egress ports on the DUT MUST be reported.

The nature of the traffic stream contributing to the result MUST be reported. All required reporting parameters of multicast latency MUST be reflected in the min/max results report, such as the transmitted packet size(s), offered load of the packet stream in which the tagged packet was presented to the DUT and transmit duration of offered frames.

## 6. Overhead

This section presents methodology relating to the characterization of the overhead delays associated with explicit operations found in multicast environments.

### 6.1. Group Join Delay

Objective

To determine the time duration it takes a DUT/SUT to start forwarding multicast packets from the time a successful IGMP group membership report has been issued to the DUT/SUT.

Procedure

Traffic is sent on the source port at the same time as the IGMP JOIN Group message is transmitted from the destination ports. The join delay is the difference in time from when the IGMP Join is sent (timestamp A) and the first frame is forwarded to a receiving member port (timestamp B).

Group Join delay = timestamp B - timestamp A

One of the keys is to transmit at the fastest rate the DUT/SUT can handle multicast frames. This is to get the best resolution and the least margin of error in the Join Delay.

However, you do not want to transmit the frames so fast that frames are dropped by the DUT/SUT. Traffic should be sent at the throughput rate determined by the forwarding tests of section 4.

Results

The parameter to be measured is the join delay time for each multicast group address per destination port. In addition, the number of frames transmitted and received and percent loss may be reported.

### 6.2. Group Leave Delay

Objective

To determine the time duration it takes a DUT/SUT to cease forwarding multicast packets after a corresponding IGMP "Leave

Group" message has been successfully offered to the DUT/SUT.

Procedure

Traffic is sent on the source port at the same time as the IGMP Leave Group messages are transmitted from the destination ports. The leave delay is the difference in time from when the IGMP leave is sent (timestamp A) and the last frame is forwarded to a receiving member port (timestamp B).

Group Leave delay = timestamp B - timestamp A

One of the keys is to transmit at the fastest rate the DUT/SUT can handle multicast frames. This is to get the best resolution and least margin of error in the Leave Delay. However, you do not want to transmit the frames too fast that frames are dropped by the DUT/SUT. Traffic should be sent at the throughput rate determined by the forwarding tests of section 4.

Results

The parameter to be measured is the leave delay time for each multicast group address per destination port. In addition, the number of frames transmitted and received and percent loss may be reported.

## 7. Capacity

This section offers terms relating to the identification of multicast group limits of a DUT/SUT.

### 7.1. Multicast Group Capacity

Objective

To determine the maximum number of multicast groups a DUT/SUT can support while maintaining the ability to forward multicast frames to all multicast groups registered to that DUT/SUT.

Procedure

One or more destination ports of DUT/SUT will join an initial number of groups.

Then after a delay (enough time for all ports to join) the source port will transmit to each group at a transmission rate that the DUT/SUT can handle without dropping IP Multicast frames.

If all frames sent are forwarded by the DUT/SUT and received the test iteration is said to pass at the current capacity.

If the iteration passes at the capacity the test will add an user defined incremental value of groups to each receive port.

The iteration is to run again at the new group level and capacity tested as stated above.

Once the test fails at a capacity the capacity is stated to be the last Iteration that pass at a giving capacity.

Results

The parameter to be measured is the total number of group addresses that were successfully forwarded with no loss.

In addition, the nature of the traffic stream contributing to the result MUST be reported. All required reporting parameters MUST be reflected in the results report, such as the transmitted packet size(s) and offered load of the packet stream.

## 8. Interaction

Network forwarding devices are generally required to provide more functionality than just the forwarding of traffic. Moreover, network-forwarding devices may be asked to provide those functions in a variety of environments. This section offers terms to assist in the characterization of DUT/SUT behavior in consideration of potentially interacting factors.

### 8.1. Forwarding Burdened Multicast Latency

Objective

To produce a set of multicast latency measurements from a single, multicast ingress port of a DUT/SUT through multiple, egress multicast ports of that same DUT/SUT as provided for by the metric "Multicast Latency" in RFC 2432, while burdening the DUT/SUT by injecting addresses into the DUT/SUT address table.

Procedure

The Multicast Latency metrics can be influenced by forcing the DUT/SUT to perform extra processing of packets while multicast class traffic is being forwarded for latency measurements. As described in Section 5.1, a set of ports on the tester will be designated to be the source and destination in this test. In addition to this setup, another set of ports will be selected to transmit some multicast class traffic that is destined to multicast group addresses that have not been joined by these additional set of ports.

For example, ports 1,2, 3, and 4 form the burdened response setup (setup A) which is used to obtain the latency metrics and ports 5, 6, 7, and 8 form the non-burdened response setup (setup B) which

will afflict the burdened response setup. Setup B traffic will then join multicast group addresses not joined by the ports in this setup. By sending such multicast class traffic, the DUT/SUT will perform a lookup on the packets that will affect the processing of setup A traffic.

Results

Result reports MUST include the following parameters for each iteration: transmitted packet size, the number of frames offered, number of frames received per each group, number of multicast groups and forwarding rate in frames per second, number of addresses injected into address table for that iteration, and transmit duration of offered frames. The result report must also specify the number of source and destination ports within the multicast group, as well as the ports designated to inject addresses throughout the test.

The following metrics MUST be reported:

1) The set of latency measurements
2) The nature of latency measured (i.e., store-and-forward or bit-forwarding)
3) The significant environmental, methodological, or device particulars giving insight into the test or its results.

Constructing a table that contains the latency vs. number of injected addresses is desirable.

## 8.2. Forwarding Burdened Group Join Delay

Objective

To determine the time duration it takes a DUT/SUT to start forwarding multicast packets from the time a successful IGMP group membership report has been issued to the DUT/SUT while burdening the DUT/SUT by injecting addresses into the DUT/SUT address table on a unrelated set of ports.

Procedure

The port configuration in this test is similar to the one described in Sections 6.1 and 8.1, however, the additional set of transmit ports, which comprise setup B, do not send multicast class traffic. Setup A traffic must be influenced in such a way that will affect the DUT's/SUT's ability to process Group Join messages. Therefore, in this test, the ports in setup B will send a set of IGMP Group Join messages while the ports in setup A are also simultaneously joining its own set of group addresses. Since the

two sets of group addresses are independent of each other, the group join delay for setup A may be different than in the case when there were no other group addresses being joined.

Results

Similar to Section 6.1, the parameter to be measured is the leave delay time for each multicast group address per destination port. Result reports MUST specify the number of multicast groups joined in the join delay port group, the number of groups joined by the unrelated ports, the number of source and destination ports within the join delay port group, and the number of unrelated ports designated to inject addresses throughout the test.

Constructing a table that contains the join delay time vs. number of injected addresses is desirable.

## 9. Security Considerations

As this document is solely for the purpose of providing metric methodology and describes neither a protocol nor a protocol's implementation, there are no security considerations associated with this document.

## 10. Acknowledgements

The authors would like to acknowledge the following individuals for their help and participation of the compilation and editing of this document û Ralph Daniels, Netcom Systems, who made significant contributions to earlier versions of this draft, Michele Bustos, IXIA, and Kevin Dubray, Juniper Networks.

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