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Benchmarking Methodology for LAN Switching Devices

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Status of this Memo

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1. Introduction

This document is intended to provide methodology for the benchmarking of local area network (LAN) switching devices. It extends the methodology already defined for benchmarking network interconnecting devices in RFC 2544 to switching devices.

This RFC primarily deals with devices which switch frames at the Medium Access Control (MAC) layer. It provides a methodology for benchmarking switching devices, forwarding performance, congestion control, latency, address handling and filtering. In addition to defining the tests, this document also describes specific formats for reporting the results of the tests.

A previous document, "Benchmarking Terminology for LAN Switching Devices" (RFC 2285), 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.

2. Requirements

The following RFCs SHOULD be consulted before attempting to make use of this document:

* RFC 1242 "Benchmarking Terminology for Network Interconnect Devices"

* RFC 2285 "Benchmarking Terminology for LAN Switching Devices"

* RFC 2544 "Benchmarking Methodology for Network Interconnect Devices"

For the sake of clarity and continuity, this RFC adopts the template for benchmarking tests set out in Section 26 of RFC 2544.

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.

3. Test setup

This document extends the general test setup described in section 6 of RFC 2544 to the benchmarking of LAN switching devices. RFC 2544 primarily describes non-meshed traffic where input and output interfaces are grouped in mutually exclusive sending and receiving pairs. In fully meshed traffic, each interface of a DUT/SUT is set up to both receive and transmit frames to all the other interfaces under test.

Prior to each test run, the DUT/SUT MUST learn the MAC addresses used in the test and the address learning SHOULD be verified. Addresses not learned will be forwarded as flooded frames and reduce the amount of correctly forwarded frames. The rate at which address learning frames are offered may have to be adjusted to be as low as 50 frames per second or even less, to guarantee successful learning. The DUT/SUT address aging time SHOULD be configured to be greater than the period of the learning phase of the test plus the test duration plus any configuration time required by the testing device. Addresses SHOULD NOT age out until the test duration is completed. More than one learning trial may be needed for the association of the address to the port to occur.

If a DUT/SUT uses a hashing algorithm with address learning, the DUT/SUT may not learn the necessary addresses to perform the tests. The format of the MAC addresses MUST be adjustable so that the address mapping may be re-arranged to make a DUT/SUT learn addresses without confusion.

It is recommended that SNMP and Spanning Tree be disabled when bench-marking switching devices unless investigating overhead behavior. If such protocols cannot be turned off, it is recommended that the levels of offered load be reduced (less than 100%) to allow for the additional management frames.

4. Frame formats and sizes

The frame format is defined in RFC 2544 section 8 and MUST contain a unique signature field located in the UDP DATA area of the Test Frame (see Appendix C of RFC 2544). The purpose of the signature field is filter out frames that are not part of the offered load.

The signature field MUST be unique enough to identify the frames not originating from the DUT/SUT. The signature field SHOULD be located after byte 56 (ISO/IEC 8802-3 collision window) or at the end of the frame. The length, contents and method of detection is not defined in this memo.

The signature field MAY have a unique identifier per port. This would filter out misforwarded frames. It is possible for a DUT/SUT to strip off the MAC layer, send it through its switching matrix, and transmit it out with the correct destination MAC address but the wrong payload.

For frame sizes, refer to RFC 2544, section 9.

There are three possible frame formats for layer 2 Ethernet switches: standard MAC Ethernet frames, standard MAC Ethernet frames with vendor-specific tags added to them, and IEEE 802.3ac frames tagged to accommodate 802.3p&q. The two types of tagged frames may exceed the standard maximum length frame of 1518 bytes, and may not be accepted by the interface controllers of some DUT/SUTs. It is recommended to check the compatibility of the DUT/SUT with tagged frames before testing.

Devices switching tagged frames of over 1518 bytes will have a lower maximum forwarding rate than standard untagged frames.

5. Benchmarking Tests

The following tests offer objectives, procedures, and reporting formats for benchmarking LAN switching devices.

5.1 Fully meshed throughput, frame loss and forwarding rates

5.1.1 Objective

To determine the throughput, frame loss and forwarding rates of DUT/SUTs offered fully meshed traffic as defined in RFC 2285.

5.1.2 Setup Parameters

When offering bursty full meshed traffic, the following parameters MUST be defined. Each parameter is configured with the following considerations.

Frame Size - Recommended frame sizes are 64, 128, 256, 512, 1024, 1280 and 1518 bytes, per RFC 2544 section 9. The four CRC bytes are included in the frame size specified.

Interframe Gap (IFG) - The IFG between frames inside a burst MUST be at the minimum specified by the standard (9.6 us for 10Mbps Ethernet, 960 ns for 100Mbps Ethernet, and 96 ns for 1 Gbps Ethernet).

Interburst Gap (IBG) - This is the interval between bursts of traffic. Refer to Appendix A Formulas, for the formula used to compute IBG.

Duplex mode - Half duplex or full duplex.

Load / Port - Load per port is expressed in a percentage of the medium's maximum intended load possible. The actual transmitted frame per second is dependent upon half duplex or full duplex operation. The test SHOULD be run multiple times with a different load per port in each case.

In half duplex mode, exactly half of the intended load SHOULD be transmitted to each of the ports under test. For example, with a 100% load of 64-byte frames, the intended load for each port under test is 7440 frames received per second and 7440 frames transmitted per second (for 10Mbps Ethernet).

In full duplex mode, the entire intended load SHOULD be transmitted to each of the ports under test. For example, with a 100% load of 64-byte frames, the intended load for each port under test is 14880 frames received per second and 14880 frames transmitted per second (for 10Mbps Ethernet).

Burst Size - The burst size defines the number of frames sent back-to-back at the minimum legal IFG (96 bit times) before pausing transmission to receive frames. Burst sizes SHOULD vary between 1 and 930 frames. A burst size of 1 will simulate non-bursty traffic.

Addresses per port - Represents the number of addresses which are being tested for each port. Number of addresses SHOULD be a binary exponential (i.e. 1, 2, 4, 8, 16, 32, 64, 128, 256, ...). Recommended values are 1, 16 and 256.

Test Duration - Test duration SHOULD be between 1 and 300 seconds. RFC 2285 recommends a duration of at least 10 seconds for each test.

5.1.3 Procedure

All ports MUST transmit the exact number of frames. All ports SHOULD start transmitting their frames within 1% of the test duration. For a test duration of 10 seconds, all ports SHOULD have started transmitting frames with 100 milliseconds of each other.

Each port in the test MUST send frames to all other ports in a round robin type fashion. The following table shows how each port in a test MUST transmit frames to all other ports in the test. In this example, there are six ports with 1 address per port:

Source Port	Destination Ports (in order of transmission)					
Port #1	2	3	4	5	6	2...
Port #2	3	4	5	6	1	3...
Port #3	4	5	6	1	2	4...
Port #4	5	6	1	2	3	5...
Port #5	6	1	2	3	4	6...
Port #6	1	2	3	4	5	1...

As shown in the table, there is an equal distribution of destination addresses for each transmit opportunity. This keeps the test balanced so that one destination port is not overloaded by the test algorithm and all ports are equally and fully loaded throughout the test. Not following this algorithm exactly will produce inconsistent results.

For tests using multiple addresses per port, the actual port destinations are the same as described above and the actual source/destination address pairs SHOULD be chosen randomly to exercise the DUT/SUT's ability to perform address lookups.

For every address, the testing device MUST send learning frames to allow the DUT/SUT to update its address tables properly.

5.1.4 Measurements

Each port should receive the same number of frames that it transmitted. Each receiving port MUST categorize, then count the frames into one of two groups:

1.) Received Frames: received frames MUST have the correct destination MAC address and SHOULD match a signature field.

2.) Flood count: defined in RFC 2285 3.8.3.

Any frame received which does not have the correct destination address MUST not be counted as a received frame and SHOULD be counted as part of a flood count.

Any frame originating from the DUT/SUT MUST not be counted as a received frame. Frames originating from the DUT/SUT MAY be counted as flooded frames or not counted at all.

Frame loss rate of the DUT/SUT SHOULD be reported as defined in RFC 2544 section 26.3 with the following notes: Frame loss rate SHOULD be measured at the end of the test duration. The term "rate", for this measurement only, does not imply the units in the fashion of "per seconds."

Throughput measurement is defined in RFC 2544.

Forwarding rate (FR) of the DUT/SUT SHOULD be reported as the number of frames per second that the device is observed to successfully transmit to the correct destination interface in response to a specified offered load. The offered load MUST also be cited.

Forwarding rate at maximum offered load (FRMOL) MUST be reported as the number of frames per second that a device can successfully transmit to the correct destination interface in response to the maximum offered load as defined in RFC 2285, section 3.6. The maximum offered load MUST also be cited.

Maximum forwarding rate (MFR) MUST be reported as the highest forwarding rate of a DUT/SUT taken from an iterative set of forwarding rate measurements. The load applied to the device MUST also be cited.

5.1.5 Reporting format

The results for these tests SHOULD be reported in the form of a graph. The x coordinate SHOULD be the frame size, the y coordinate SHOULD be the test results. There SHOULD be at least two lines on the graph, one plotting the theoretical and one plotting the test results.

To measure the DUT/SUT's ability to switch traffic while performing many different address lookups, the number of addresses per port MAY be increased in a series of tests.

5.2 Partially meshed overloading

5.2.1 Objective

To determine the throughput when transmitting from/to multiple ports and to/from one port. As with the fully meshed throughput test, this test is a measure of the capability of the DUT to switch frames without frame loss. Results of this test can be used to determine the ability of the DUT to utilize an Ethernet port when switching traffic from multiple Ethernet ports.

5.2.2 Setup Parameters

When offering bursty meshed traffic, the following parameters MUST be defined. Each parameter is configured with the following considerations.

Frame Size - Recommended frame sizes are 64, 128, 256, 512, 1024, 1280 and 1518 bytes, per RFC 2544 section 9. The four CRC bytes are included in the frame size specified.

Traffic Direction - Traffic can be generated in one direction, the reverse direction, or both directions.

Interframe Gap (IFG) - The IFG between frames inside a burst MUST be at the minimum specified by the standard (9.6 us for 10Mbps Ethernet, 960 ns for 100Mbps Ethernet, and 96 ns for 1 Gbps Ethernet).

Interburst Gap (IBG) - This is the interval between bursts of traffic. Refer to Appendix A, Calculating Interburst Gap, for the formula used to compute IBG.

Duplex mode - Half duplex or full duplex.

Load / Port - Load per port is expressed in a percentage of the medium's maximum intended load possible. The actual transmitted frame per second is dependent upon half duplex or full duplex operation. The test SHOULD be run multiple times with a different load per port in each case.

In half duplex mode, exactly half of the intended load SHOULD be transmitted to each of the ports under test. For example, with a 100% load of 64-byte frames, the intended load for each port under test is 7440 frames received per second and 7440 frames transmitted per second (for 10Mbps Ethernet).

In full duplex mode, the entire intended load SHOULD be transmitted to each of the ports under test. For example, with a 100% load of 64-byte frames, the intended load for each port under test is 14880 frames received per second and 14880 frames transmitted per second (for 10Mbps Ethernet).

Burst Size - The burst size defines the number of frames sent back-to-back at the minimum legal IFG (96 bit times) before pausing transmission to receive frames. Burst sizes SHOULD vary between 1 and 930 frames. A burst size of 1 will simulate non-bursty traffic.

Addresses per port - Represents the number of addresses which are being tested for each port. Number of addresses SHOULD be a binary exponential (i.e. 1, 2, 4, 8, 16, 32, 64, 128, 256, ...). Recommended values are 1, 16 and 256.

Test Duration - Test duration SHOULD be between 1 and 300 seconds. RFC 2285 recommends a duration of at least 10 seconds for each test.

5.2.3 Procedure

In this test, each transmitting port MUST transmit the exact number of frames. Depending upon traffic direction, some or all of the ports will be transmitting.

Frames transmitted from the Many Ports MUST be destined to the One port. Frames transmitted from the One Port MUST be destined to the Many ports in a round robin type fashion. See section 5.1.3 for a description of the round robin fashion.

For tests using multiple addresses per port, the actual port destinations are the same as described above and the actual source/destination address pairs SHOULD be chosen randomly to exercise the DUT/SUT's ability to perform address lookups.

```
        +----------+
        |          |
        |   Many   | <--------
        |          |         \
        +----------+          \
                               \
        +----------+            \               +-------------+
        |          |             ------------>  |             |
        |   Many   |  <---------------------->  |     One     |
        |          |             ------------>  |             |
        +----------+            /               +-------------+
                               /
        +----------+          /
        |          |         /
        |   Many   |  <-------
        |          |
        +----------+
```

For every address, the testing device MUST send learning frames to allow the DUT/SUT to update its address tables properly.

5.2.4 Measurements

Each receiving port MUST categorize, then count the frames into one of two groups:

1.) Received Frames: received frames MUST have the correct destination MAC address and SHOULD match a signature field.

2.) Flood count: defined in RFC 2285 3.8.3.

Any frame received which does not have the correct destination address MUST not be counted as a received frame and SHOULD be counted as part of a flood count.

Any frame originating from the DUT/SUT MUST not be counted as a received frame. Frames originating from the DUT/SUT MAY be counted as flooded frames or not counted at all.

Forwarding rate (FR) of the DUT/SUT SHOULD be reported as the number of frames per second that the device is observed to successfully transmit to the correct destination interface in response to a specified offered load. The offered load MUST also be cited.

Forwarding rate at maximum offered load (FRMOL) MUST be reported as the number of frames per second that a device can successfully transmit to the correct destination interface in response to the maximum offered load as defined in RFC 2285, section 3.6. The maximum offered load MUST also be cited.

Maximum forwarding rate (MFR) MUST be reported as the highest forwarding rate of a DUT/SUT taken from an iterative set of forwarding rate measurements. The load applied to the device MUST also be cited.

5.2.5 Reporting Format

The results for these tests SHOULD be reported in the form of a graph. The x coordinate SHOULD be the frame size, the y coordinate SHOULD be the test results. There SHOULD be at least two lines on the graph, one plotting the theoretical and one plotting the test results.

To measure the DUT/SUT's ability to switch traffic while performing many different address lookups, the number of addresses per port MAY be increased in a series of tests.

5.3 Head-of-line blocking

5.3.1 Objective

To determine how a DUT handles congestion. Namely, does the device implement congestion control and does congestion on one port affect an uncongested port?

5.3.2 Setup Parameters

The following parameters MUST be defined. Each variable is configured with the following considerations.

Frame Size - Recommended frame sizes are 64, 128, 256, 512, 1024, 1280 and 1518 bytes, per RFC 2544 section 9. The four CRC bytes are included in the frame size specified.

Duplex mode - Half duplex or full duplex.

Interframe Gap (IFG) - The IFG between frames MUST be at the minimum specified by the standard (9.6 us for 10Mbps Ethernet, 960 ns for 100Mbps Ethernet, and 96 ns for 1 Gbps Ethernet).

Addresses per port - Represents the number of addresses which are being tested for each port. Number of addresses SHOULD be a binary exponential (i.e. 1, 2, 4, 8, 16, 32, 64, 128, 256, ...). Recommended values are 1, 16 and 256.

Test Duration - Test duration SHOULD be between 1 and 300 seconds. RFC 2285 recommends a duration of at least 10 seconds for each test.

5.3.3 Procedure

This test MUST consist of a multiple of four ports. Four ports are REQUIRED and MAY be expanded to fully utilize the DUT/SUT in increments of four. Each group of four will contain a test block with two of the ports as source transmitters and two of the ports as receivers. The diagram below depicts the flow of traffic between the switch ports:

```
+----------+   50 % MOL                  +-------------+
|          |  ------------------------>  |             |
|          |   50 % MOL                  | uncongested |
|          |  ---------                  |             |
+----------+           \                 +-------------+
                        \
                         \
                          \
+----------+               \             +-------------+
|          |                --------->   |             |
|          |   100 % MOL                 | congested   |
|          |  ------------------------>  |             |
+----------+                             +-------------+
```

Both source transmitters MUST transmit the exact number of frames. The first source MUST transmit frames at the MOL with the destination address of the two receive ports in an alternating order. The first frame to the uncongested receive port, second frame to the congested receive port, then repeat. The second source transmitter MUST transmit frames at the MOL only to the congested receive port.

Both receive ports SHOULD distinguish between frames originating from the source ports and frames originating from the DUT/SUT. Only frames from the source ports SHOULD be counted.

The uncongested receive port should be receiving at a rate of half the MOL. The number of frames received on the uncongested port SHOULD be 50% of the frames transmitted by the first source transmitter. The congested receive port should be receiving at the MOL. The number of frames received on the congested port should be between 100% and 150% of the frames transmitted by one source transmitter.

Frames destined to uncongested ports in a switch device should not be dropped due to other ports being congested, even if the source is sending to both the congested and uncongested ports.

5.3.4 Measurements

Any frame received which does not have the correct destination address MUST not be counted as a received frame and SHOULD be counted as part of a flood count.

Any frame originating from the DUT/SUT MUST not be counted as a received frame. Frames originating from the DUT/SUT MAY be counted as flooded frames or not counted at all.

Frame loss rate of the DUT/SUT's congested and uncongested ports MUST be reported as defined in RFC 2544 section 26.3 with the following notes: Frame loss rate SHOULD be measured at the end of the test duration. The term "rate", for this measurement only, does not imply the units in the fashion of "per seconds."

Forwarding rate (FR) of the DUT/SUT's congested and uncongested ports MUST be reported as the number of frames per second that the device is observed to successfully transmit to the correct destination interface in response to a specified offered load. The offered load MUST also be cited.

5.3.5 Reporting format

This test MUST report the frame lost rate at the uncongested port, the maximum forwarding rate (at 50% offered load) at the uncongested port, and the frame lost rate at the congested port. This test MAY report the frame counts transmitted and frame counts received by the ports.

If the DUT implements a flow control mechanism, an indication of this is presented by observing no frame loss on the congested port. It should be noted that this test expects the overall load to the congested port to be greater than 100%. Therefore if the load is greater than 100% and no frame loss is detected, then the DUT must be implementing a flow control mechanism. The type of flow control mechanism used is beyond the scope of this memo.

If there is frame loss at the uncongested port, "Head of Line" blocking exists. The DUT cannot forward the amount of traffic to the congested port and as a result it is also losing frames destined to the uncongested port.

It should be noted that some DUTs may not be able to handle the 100% load presented at the input port. In this case, there may be frame loss reported at the uncongested port which is due to the load at the input port rather than the congested port's load.

If the uncongested frame loss is reported as zero, but the maximum forwarding rate is less than 7440 (for 10Mbps Ethernet), then this may be an indication of congestion control being enforced by the DUT. In this case, the congestion control is affecting the throughput of the uncongested port.

If no congestion control is detected, the expected percentage frame loss for the congested port is 33% at 150% overload. It is receiving

100% load from 1 port, and 50% from another, and can only get 100% possible throughput, therefore having a frame loss rate of 33% (150%-50%/150%).

5.4 Partially Meshed Multiple Devices

5.4.1 Objective

To determine the throughput, frame loss and forwarding rates of two switching devices equipped with multiple Ethernet ports and one high speed backbone uplink (Gigabit Ethernet, ATM, SONET).

5.4.2 Setup Parameters

When offering bursty partially meshed traffic, the following parameters MUST be defined. Each variable is configured with the following considerations.

Frame Size - Recommended frame sizes are 64, 128, 256, 512, 1024, 1280 and 1518 bytes, per RFC 2544 section 9. The four CRC bytes are included in the frame size specified.

Interframe Gap (IFG) - The IFG between frames inside a burst MUST be at the minimum specified by the standard (9.6 us for 10Mbps Ethernet, 960 ns for 100Mbps Ethernet, and 96 ns for 1 Gbps Ethernet).

Interburst Gap (IBG) - This is the interval between bursts of traffic. Refer to Appendix A, Calculating Interburst Gap, for the formula used to compute IBG.

Duplex mode - Half duplex or full duplex.

Load / Port - Load per port is expressed in a percentage of the medium's maximum intended load possible. The actual transmitted frame per second is dependent upon half duplex or full duplex operation. The test SHOULD be run multiple times with a different load per port in each case.

In half duplex mode, exactly half of the intended load SHOULD be transmitted to each of the ports under test. For example, with a 100% load of 64-byte frames, the intended load for each port under test is 7440 frames received per second and 7440 frames transmitted per second (for 10Mbps Ethernet).

In full duplex mode, the entire intended load SHOULD be transmitted to each of the ports under test. For example, with a 100% load of 64-byte frames, the intended load for each port under test is 14880 frames received per second and 14880 frames transmitted per second (for 10Mbps Ethernet).

Burst Size - The burst size defines the number of frames sent back-to-back at the minimum legal IFG (96 bit times) before pausing transmission to receive frames. Burst sizes

SHOULD vary between 1 and 930 frames.

Addresses per port - Represents the number of addresses which are being tested for each port. Number of addresses SHOULD be a binary exponential (i.e. 1, 2, 4, 8, 16, 32, 64, 128, 256, ...). Recommended values are 1, 16 and 256.

Test Duration - Test duration SHOULD be between 1 and 300 seconds. RFC 2285 recommends a duration of at least 10 seconds for each test.

Local Traffic - A Boolean value of ON or OFF. The frame sequence algorithm MAY be altered to remove local traffic. With local traffic ON, the algorithm is exactly the same as a fully meshed throughput. With local traffic OFF, the port sends frames to all other ports on the other side of the backbone uplink in a round robin type fashion.

5.4.3 Procedure

All ports MUST transmit the exact number of frames. All ports SHOULD start transmitting their frames within 1% of the test duration. For a test duration of 10 seconds, all ports SHOULD have started transmitting frames with 100 milliseconds of each other.

Each port in the test MUST send frames to all other ports in a round robin type fashion as defined in section 5.1. Local traffic MAY be removed from the round robin list in order to send the entire load across the backbone uplink.

For tests using multiple addresses per port, the actual port destinations are the same as described above and the actual source/destination address pairs SHOULD be chosen randomly to exercise the DUT/SUT's ability to perform address lookups.

For every address, the testing device MUST send learning frames to allow the DUT/SUT to update its address tables properly.

To measure the DUT/SUT's ability to switch traffic while performing many different address lookups, the number of addresses per port MAY be increased in a series of tests.

5.4.4 Measurements

Each port should receive the same amount of frames that is transmitted. Each receiving port MUST categorize, then count the frames into one of two groups:

1.) Received frames MUST have the correct destination MAC address and SHOULD match a signature field.

2.) Flood count (defined in RFC 2285 3.8.3).

Any frame received which does not have the correct destination address MUST not be counted as a received frame and SHOULD be counted as part of a flood count.

Any frame originating from the DUT/SUT MUST not be counted as a received frame. Frames originating from the DUT/SUT MAY be counted as flooded frames or not counted at all.

Frame loss rate of the DUT/SUT SHOULD be reported as defined in RFC 2544 section 26.3 with the following notes: Frame loss rate SHOULD be measured at the end of the test duration. The term "rate", for this measurement only, does not imply the units in the fashion of "per seconds."

Forwarding rate (FR) of the DUT/SUT SHOULD be reported as the number of frames per second that the device is observed to successfully transmit to the correct destination interface in response to a specified offered load. The offered load MUST also be cited.

Forwarding rate at maximum offered load (FRMOL) MUST be reported as the number of frames per second that a device can successfully transmit to the correct destination interface in response to the maximum offered load as defined in RFC 2285, section 3.6. The maximum offered load MUST also be cited.

Maximum forwarding rate (MFR) MUST be reported as the highest forwarding rate of a DUT/SUT taken from an iterative set of forwarding rate measurements. The load applied to the device MUST also be cited.

5.4.5 Reporting format

The results for these tests SHOULD be reported in the form of a graph. The x coordinate SHOULD be the frame size, the y coordinate SHOULD be the test results. There SHOULD be at least two lines on the graph, one plotting the theoretical and one plotting the test results.

To measure the DUT/SUT's ability to switch traffic while performing many different address lookups, the number of addresses per port MAY be increased in a series of tests.

5.5 Multiple streams of unidirectional traffic

5.5.1 Objective

To determine the throughput of the DUT/SUT when presented multiple streams of unidirectional traffic with half of the ports on the DUT/SUT are receiving frames destined to the other half of the ports.

5.1.2 Setup Parameters

The following parameters MUST be defined. Each variable is configured with the following considerations.

Frame Size - Recommended frame sizes are 64, 128, 256, 512, 1024, 1280 and 1518 bytes, per RFC 2544 section 9. The four CRC bytes are included in the frame size specified.

Duplex mode - Half duplex or full duplex.

Load / Port - Load per port is expressed in a percentage of the medium's maximum intended load possible. The actual transmitted frame per second is dependent upon half duplex or full duplex operation. The test SHOULD be run multiple times with a different load per port in each case.

In half duplex mode, exactly half of the intended load SHOULD be transmitted to each of the ports under test. For example, with a 100% load of 64-byte frames, the intended load for each port under test is 7440 frames received per second and 7440 frames transmitted per second (for 10Mbps Ethernet).

In full duplex mode, the entire intended load SHOULD be transmitted to each of the ports under test. For example, with a 100% load of 64-byte frames, the intended load for each port under test is 14880 frames received per second and 14880 frames transmitted per second (for 10Mbps Ethernet).

Addresses per port - Represents the number of addresses which are being tested for each port. Number of addresses SHOULD be a binary exponential (i.e. 1, 2, 4, 8, 16, 32, 64, 128, 256, ...). Recommended values are 1, 16 and 256.

Test Duration - Test duration SHOULD be between 1 and 300 seconds. RFC 2285 recommends a duration of at least 10 seconds for each test.

5.5.3 Procedure

Ports do not send and receive frames simultaneously. As a consequence, there should be no collisions unless the DUT is misforwarding frames, generating flooded or Spanning-Tree frames or is enabling some flow control mechanism. Ports used for this test are either transmitting or receiving, but not both. Those ports which are transmitting send frames destined to addresses corresponding to each of the ports receiving. This creates a unidirectional mesh of traffic.

All ports MUST transmit the exact number of frames. All ports SHOULD start transmitting their frames within 1% of the test duration. For a test duration of 10 seconds, all ports SHOULD have started transmitting frames with 100 milliseconds of each other.

Each transmitting port in the test MUST send frames to all receiving ports in a round robin type fashion. The following table shows how each port in a test MUST transmit frames to all other ports in the test. In this 8 port example, port 1 through 4 are transmitting and ports 5 through 8 are receiving; each with 1 address per port:

Source Port, then Destination Ports (in order of transmission)

Port #1	5	6	7	8	5	6...
Port #2	6	7	8	5	6	7...
Port #3	7	8	5	6	7	8...
Port #4	8	5	6	7	8	5...

As shown in the table, there is an equal distribution of destination addresses for each transmit opportunity. This keeps the test balanced so that one destination port is not overloaded by the test algorithm and all receiving ports are equally and fully loaded throughout the test. Not following this algorithm exactly will product inconsistent results.

For tests using multiple addresses per port, the actual port destinations are the same as described above and the actual source/destination address pairs SHOULD be chosen randomly to exercise the DUT/SUT's ability to perform address lookups.

For every address, the testing device MUST send learning frames to allow the DUT/SUT to load its address tables properly. The address table's aging time SHOULD be set sufficiently longer than the learning time and test duration time combined. If the address table ages out during the test, the results will show a lower performing DUT/SUT.

To measure the DUT/SUT's ability to switch traffic while performing many different address lookups, the number of addresses per port MAY be increased in a series of tests.

5.5.4 Measurements

Each port should receive the same number of frames that it transmitted. Each receiving port MUST categorize, then count the frames into one of two groups:

1.) Received Frames: received frames MUST have the correct destination MAC address and SHOULD match a signature field.

2.) Flood count: defined in RFC 2285 3.8.3.

Any frame received which does not have the correct destination address MUST not be counted as a received frame and SHOULD be counted as part of a flood count.

Any frame originating from the DUT/SUT MUST not be counted as a received frame. Frames originating from the DUT/SUT MAY be counted as flooded frames or not counted at all.

Frame loss rate of the DUT/SUT SHOULD be reported as defined in RFC 2544 section 26.3 with the following notes: Frame loss rate SHOULD be measured at the end of the test duration. The term "rate", for this measurement only, does not imply the units in the fashion of "per seconds."

Forwarding rate (FR) of the DUT/SUT SHOULD be reported as the number of frames per second that the device is observed to successfully transmit to the correct destination interface in response to a specified offered load. The offered load MUST also be cited.

Forwarding rate at maximum offered load (FRMOL) MUST be reported as the number of frames per second that a device can successfully transmit to the correct destination interface in response to the maximum offered load as defined in RFC 2285, section 3.6. The maximum offered load MUST also be cited.

Maximum forwarding rate (MFR) MUST be reported as the highest forwarding rate of a DUT/SUT taken from an iterative set of forwarding rate measurements. The load applied to the device MUST also be cited.

5.1.5 Reporting format

The results for these tests SHOULD be reported in the form of a graph. The x coordinate SHOULD be the frame size, the y coordinate SHOULD be the test results. There SHOULD be at least two lines on the graph, one plotting the theoretical and one plotting the test results.

To measure the DUT/SUT's ability to switch traffic while performing many different address lookups, the number of addresses per port MAY be increased in a series of tests.

5.6 Filter illegal frames

5.6.1 Objective

The objective of the filter illegal frame test is to determine the behavior of the DUT under errors or abnormal frame conditions. The results of the test indicate if the DUT/SUT filters the errors, or simply propagates the errored frames along to the destination.

5.1.2 Setup Parameters

The following parameters MUST be defined. Each variable is configured with the following considerations.

Load / Port - Load per port is expressed in a percentage of the medium's maximum intended load possible. The actual transmitted frame per second is dependent upon half duplex or full duplex operation. The test SHOULD be run multiple times with a different load per port in each case.

Test Duration - Test duration SHOULD be between 1 and 300 seconds. RFC 2285 recommends a duration of at least 10 seconds for each test.

5.6.3 Procedure

Each of the illegal frames for Ethernet MUST be checked:

Oversize - The DUT/SUT MAY filter frames larger than 1518 bytes from being propagated through the DUT/SUT (ISO 8802-3 4.2.4.2.1). Oversized frames transmitted to the DUT/SUT should not appear as receive frames or as error frames on any port. DUT/SUT supporting tagged Frames MAY forward frames up to and including 1522 bytes long (IEEE 802.3ac 4.2.4.2.1).

Undersize - The DUT/SUT MUST filter frames less than 64 bytes from being propagated through the DUT/SUT (per ISO 8802-3 4.2.4.2.2). Undersized frames (or collision fragments) transmitted to the DUT/SUT MUST not appear as receive frames or as error frames on another port.

CRC Errors - The DUT/SUT MUST filter frames that fail the Frame Check Sequence Validation (ISO 8802-3 4.2.4.1.2) from being propagated through the DUT/SUT. Frames with an invalid CRC transmitted to the DUT/SUT should not appear as receive frames or as error frames on another port.

Dribble Bit Errors - The DUT/SUT MUST correct and forward frames containing dribbling bits. Frames transmitted to the DUT/SUT that do not end in an octet boundary but contain a valid frame check sequence MUST be accepted by the DUT/SUT (ISO 8802-3 4.2.4.2.1) and forwarded to the correct receive port with the frame ending in an octet boundary (ISO 8802-3 3.4).

Alignment Errors - The DUT/SUT MUST filter frames than fail the Frame Check Sequence Validation AND do not end in an octet boundary. This is a combination of a CRC error and a Dribble Bit error. When both errors are occurring in the same frame, the DUT/SUT MUST determine the CRC error takes precedence and filters the frame (ISO 8802-3 4.2.4.1.2) from being propagated.

5.7 Broadcast frame handling and latency test

5.7.1 Objective

The objective of the Broadcast Frame Handling and Latency Test is to determine the throughput and latency of the DUT when handling broadcast traffic. The ability to forward broadcast frames will depend on special features built into the device for that purpose. It is therefore necessary to determine the ability of switches to handle broadcast frames, since there may be many different ways of implementing such a feature.

5.7.2 Setup Parameters

The following parameters MUST be defined. Each variable is configured with the following considerations.

Frame Size - Recommended frame sizes are 64, 128, 256, 512, 1024, 1280 and 1518 bytes, per RFC 2544 section 9. The four CRC bytes are included in the frame size specified.

Duplex mode - Half duplex or full duplex.

Load / Port - Load per port is expressed in a percentage of the medium's maximum intended load possible. The actual transmitted frame per second is dependent upon half duplex or full duplex operation. The test SHOULD be run multiple times with a different load per port in each case.

In half duplex mode, exactly half of the intended load SHOULD be transmitted to each of the ports under test. For example, with a 100% load of 64-byte frames, the intended load for each port under test is 7440 frames received per second and 7440 frames transmitted per second (for 10Mbps Ethernet).

In full duplex mode, the entire intended load SHOULD be transmitted to each of the ports under test. For example, with a 100% load of 64-byte frames, the intended load for each port under test is 14880 frames received per second and 14880 frames transmitted per second (for 10Mbps Ethernet).

Test Duration - Test duration SHOULD be between 1 and 300 seconds. RFC 2285 recommends a duration of at least 10 seconds for each test.

5.7.3 Procedure

For this test, there are two parts to be run.

Broadcast Frame Throughput - This portion of the test uses a single source test port to transmit frames with a broadcast address using the frame specified in RFC 2544. Selected receive ports then measure the forwarding rate and Frame loss rate.

Broadcast Frame Latency - This test uses the same setup as the Broadcast Frame throughput, but instead of a large stream of frames being sent, only one frame is sent and the latency to each of the receive ports are measured in seconds.

5.7.4 Measurements

Frame loss rate of the DUT/SUT SHOULD be reported as defined in RFC 2544 section 26.3 with the following notes: Frame loss rate SHOULD be measured at the end of the test duration. The term "rate", for this measurement only, does not imply the units in the fashion of "per seconds."

Forwarding rate (FR) of the DUT/SUT SHOULD be reported as the number of frames per second that the device is observed to successfully transmit to the correct destination interface in response to a specified offered load. The offered load MUST also be cited.

5.8 Maximum forwarding rate and minimum interframe gap

5.8.1 Objective

The objective of the Maximum forwarding rate test is to find the peak value of the Forwarding Rate when the Offered Load is varied between the throughput (RFC 1242) and the Maximum Offered Load (RFC 2285).

The Minimum Interframe gap Test overloads a DUT/SUT port and measure the output for forward pressure. If the DUT/SUT transmits frames with an interframe gap less than 96 bits (ISO 8802-3 4.2.3.2.2), then forward pressure is detected.

5.8.2 Setup Parameters

The following parameters MUST be defined. Each variable is configured with the following considerations.

Frame Size - Recommended frame sizes are 64, 128, 256, 512, 1024, 1280 and 1518 bytes, per RFC 2544 section 9. The four CRC bytes are included in the frame size specified.

Duplex mode - Half duplex or full duplex.

Test Duration - Test duration SHOULD be between 1 and 300 seconds. RFC 2285 recommends a duration of at least 10 seconds for each test.

Step Size - The minimum incremental resolution that the Offered Load (OL) will be incremented in frames per second. The smaller the step size, the more accurate the measurement and the more iterations required. As the Offered Load approaches the Maximum Offered Load, the minimum step size will increase because of gap resolution on the testing device.

5.8.3 Procedure

If the throughput and the Maximum Offered Load are the same, then Maximum Forwarding rate is equal to the Maximum Offered Load.

This test SHOULD at a minimum be performed in a two-port configuration as described below. Learning frames MUST be sent to allow the DUT/SUT to update its address tables properly.

The first port (port 1) device transmits frames at the Offered Load to the DUT/SUT. A second port (port 2) receives frames from the DUT/SUT and measures the Forwarding Rate.

The Offered Load is incremented for each Step Size to find the Maximum Forwarding Rate. The algorithm for the test is as follows:

```
 CONSTANT
   MOL = ... frames/sec; {Maximum Offered Load}
 VARIABLE
   MFR   := 0 frames/sec; {Maximum Forwarding Rate}
   OLOAD := starting throughput in frames/sec; {offered load}
   STEP  := ... frames/sec; {Step Size}
 BEGIN
   OLOAD := OLOAD - STEP;
 DO
 BEGIN
   OLOAD := OLOAD + STEP
   IF (OLOAD > MOL) THEN
   BEGIN
     OLOAD := MOL
   END
     AddressLearning; {Port 2 broadcast frame with its source
address}
      Transmit(OLOAD); {Port 1 sends frames to Port 2 at Offered load}
      IF (Port 2 Forwarding Rate > MFR) THEN
      BEGIN
         MFR := Port 2 Forwarding Rate; {A higher value than before}
      END
```

```
END
WHILE (OLOAD >= MOL); {MFR equals Maximum Forwarding Rate}
DONE
```

The Minimum Interframe gap test SHOULD, at a minimum, be performed in a two-port configuration as described below. Learning frames MUST be sent to allow the DUT/SUT to update its address tables properly.

The first port (port 1) device transmits frames with an interframe gap of 88 bits to the DUT/SUT. This will apply forward pressure to the DUT/SUT and overload it at a rate of one byte per frame. The frames MUST be constructed with a source address of port 1 and a destination address of port 2.

A second port (port 2) receives frames from the DUT/SUT and measures the Forwarding Rate. The measured Forwarding Rate SHOULD not exceed the medium's maximum theoretical utilization.

5.8.4 Measurements

Port 2 MUST categorize, then count the frames into one of two groups:

1.) Received Frames: received frames MUST have the correct destination MAC address and SHOULD match a signature field.

2.) Flood count: defined in RFC 2285 3.8.3.

Any frame received which does not have the correct destination address MUST not be counted as a received frame and SHOULD be counted as part of a flood count.

Any frame originating from the DUT/SUT MUST not be counted as a received frame. Frames originating from the DUT/SUT MAY be counted as flooded frames or not counted at all.

5.8.5 Reporting format

Maximum forwarding rate (MFR) MUST be reported as the highest forwarding rate of a DUT/SUT taken from an iterative set of forwarding rate measurements. The load applied to the device MUST also be cited.

Forwarding rate (FR) of the DUT/SUT SHOULD be reported as the number of frames per second that the device is observed to successfully transmit to the correct destination interface in response to a specified offered load. The offered load MUST also be cited.

5.9 Address Caching Capacity

5.9.1 Objective

To determine the address caching capacity of a LAN switching device as defined in RFC 2285, section 3.8.1.

5.9.2 Setup Parameters

The following parameters MUST be defined. Each variable is configured with the following considerations.

Age Time - The maximum time that a DUT/SUT will keep a learned address in its forwarding table.

Addresses Learning Rate - The rate at which new addresses are offered to the DUT/SUT to be learned. The rate at which address learning frames are offered may have to be adjusted to be as low as 50 frames per second or even less, to guarantee successful learning.

Initial Addresses - The initial number of addresses to start the test with. The number MUST be between 1 and the maximum number supported by the implementation.

5.9.3 Procedure

The aging time of the DUT/SUT MUST be known. The aging time MUST be longer than the time necessary to produce frames at the specified rate. If a low frame rate is used for the test, then it may be possible that sending a large amount of frames may actually take longer than the aging time.

This test SHOULD at a minimum be performed in a three-port configuration as described below.

This test MUST consist of a multiple of three ports. Three ports are REQUIRED and MAY be expanded to fully utilized the DUT/SUT in increments of three. Each group of three will contain a test block as follows:

The first port (port 1) send frames with varying source addresses and a fixed destination address corresponding to the MAC address of the receiving port (port 2) of the DUT/SUT. By receiving frames with varying source addresses, the DUT/SUT will learn these new addresses from the sending port of the test device. The source addresses MAY be in sequential order.

A second port (port 2) acts as the receiving port for the address learning frames. This port also sends test frames back to the addresses learned on the first port. The algorithm for this is explained below.

A third port (port 3) on the DUT/SUT act as a monitoring port to listen for flooded frames.

It is highly recommended that SNMP, Spanning Tree, and any other frames originating from the DUT/SUT be disabled when running this test. If such protocols cannot be turned off, the flood count MUST be modified only to count frame originating from port 1 and MUST NOT count frames originating from the DUT/SUT.
The algorithm for the test is as follows:

```
 CONSTANT
   AGE = ...;  {value greater that DUT aging time}
   MAX = ...;  {maximum address support by implementation}
 VARIABLE
   LOW  := 0;    {Highest passed valve}
   HIGH := MAX;  {Lowest failed value}
   N    := ...;  {user specified initial starting point}
 BEGIN
   DO
     BEGIN
     PAUSE(AGE);   {Age out any learned addresses}
       AddressLearning(Port 2); {broadcast a frame with its source
                                Address and broadcast destination}
       AddressLearning(Port 1); {N frames with varying source
addresses
                                to Port 2}
     Transmit(Port 2); {N frames with varying destination addresses
                       corresponding to Port 1}
     IF (Port 3 receive frame != 0) OR
        (Port 1 receive frames < Port 2 transmit) THEN
       BEGIN  {Address Table of DUT/SUT was full}
         HIGH := N;
       END
     ELSE
       BEGIN  {Address Table of DUT/SUT was NOT full}
         LOW := N;
       END
     N := LOW + (HIGH - LOW)/2;
   END WHILE (HIGH - LOW < 2);
 END {Value of N equals number of addresses supported by DUT/SUT}
```

Using a binary search approach, the test targets the exact number of addresses supported per port with consistent test iterations. Due to the aging time of DUT/SUT address tables, each iteration may take some time during the waiting period for the addresses to clear. If possible, configure the DUT/SUT for a low value for the aging time.

Once the high and low values of N meet, then the threshold of address handling has been found.

5.9.4 Measurements

Whether the offered addresses per port was successful forwarded without flooding.

5.9.5 Reporting format

After the test is run, results for each iteration SHOULD be displayed in a table to include:

The number of addresses used for each test iteration (varied).

The intended load used for each test iteration (fixed).

Number of test frames that were transmitted by test port number 2. This SHOULD match the number of addresses used for the test iteration. Test frames are the frames sent with varying destination addresses to confirm that the DUT/SUT has learned all of the addresses for each test iteration.

The flood count on port 2 during the test portion of each test. If the number is non-zero, this is an indication of the DUT/SUT flooding a frame in which the destination address is not in the address table.

The number of frames correctly forwarded to test port 1 during the test portion of the test. Received frames MUST have the correct destination MAC address and SHOULD match a signature field. For a passing test iteration, this number should be equal to the number of frames transmitted by port 2.

The flood count on port 1 during the test portion of each test. If the number is non-zero, this is an indication of the DUT/SUT flooding a frame in which the destination address is not in the address table.

The flood count on port 3. If the value is not zero, then this indicates that for that test iteration, the DUT/SUT could not determine the proper destination port for that many frames. In other words, the DUT/SUT flooded the frame to all ports since its address table was full.

5.10 Address Learning Rate

5.10.1 Objective

To determine the rate of address learning of a LAN switching device as defined in RFC 2285, section 3.8.2.

5.10.2 Setup Parameters

The following parameters MUST be defined. Each variable is configured with the following considerations.

Age Time - The maximum time that a DUT/SUT will keep a learned address in its forwarding table.

Initial Addresses Learning Rate - The starting rate at which new addresses are offered to the DUT/SUT to be learned.

Number of Addresses - The number of addresses that the DUT/SUT must learn. The number MUST be between 1 and the maximum number supported by the implementation. It is recommended no to exceed the address caching capacity found in section 5.9

5.10.3 Procedure

The aging time of the DUT/SUT MUST be known. The aging time MUST be longer than the time necessary to produce frames at the specified rate. If a low frame rate is used for the test, then it may be possible that sending a large amount of frames may actually take longer than the aging time.

This test SHOULD at a minimum be performed in a three-port configuration as described below.

This test MUST consist of a multiple of three ports. Three ports are REQUIRED and MAY be expanded to fully utilized the DUT/SUT in increments of three. Each group of three will contain a test block as described in section 5.9.

An algorithm similar to the one used to determine address caching capacity can be used to determine the address learning rate. This test iterates the rate at which address learning frames are offered by the test device connected to the DUT/SUT. It is recommended to set the number of addresses offered to the DUT/SUT in this test to the maximum caching capacity.

The address learning rate might be determined for different numbers of addresses but in each test run, the number MUST remain constant and SHOULD be equal to or less than the maximum address caching capacity.

5.10.4 Measurements

Whether the offered addresses per port was successful forwarded without flooding at the offered learning rate.

5.10.5 Reporting format

After the test is run, results for each iteration SHOULD be displayed in a table:

The number of addresses used for each test iteration (fixed).

The intended load used for each test iteration (varied).

Number of test frames that were transmitted by test port number 2. This SHOULD match the number of addresses used for the test iteration. Test frames are the frames sent with varying destination addresses to confirm that the DUT/SUT has learned all of the addresses for each test iteration.

The flood count on port 2 during the test portion of each test. If the number is non-zero, this is an indication of the DUT/SUT flooding a frame in which the destination address is not in the address table.

The number of frames correctly forwarded to test port 1 during the test portion of the test. Received frames MUST have the correct destination MAC address and SHOULD match a signature field. For a passing test iteration, this number should be equal to the number of frames transmitted by port 2.

The flood count on port 1 during the test portion of each test. If the number is non-zero, this is an indication of the DUT/SUT flooding a frame in which the destination address is not in the address table.

The flood count on port 3. If the value is not zero, then this indicates that for that test iteration, the DUT/SUT could not determine the proper destination port for that many frames. In other words, the DUT/SUT flooded the frame to all ports since its address table was full.

6. Security Considerations

This document does not yet address Security Considerations.

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Appendix A: Formulas

A.1 Calculating the InterBurst Gap

IBG is defined in RFC 2285 as the interval between two bursts. To achieve a desired load, the follow Input Parameter need to be defined:

LENGTH - Frame size in bytes including the CRC.

LOAD   - The intended load in percent. Range is 0 to 100.

BURST - The number of frames in the burst (integer value).

SPEED - media's speed in bits/sec
   Ethernet is 10,000,000 bits/sec
   Fast Ethernet is 100,000,000 bits/sec
   Gigabit Ethernet is 1,000,000,000 bits/sec

DUPLEX - A constant to adjust the transmit rate for full or half duplex mode. In full duplex the value is 100, in half duplex the value is 200.

IFG   - A constant 96 bits for the minimum interframe gap.

The IBG (in seconds) can be calculated:

```
       (DUPLEX/LOAD - 1) * BURST * (IFG + 64 + 8*LENGTH)] + IFG
IBG = ----------------------------------------------------------
                                SPEED
```

A.2 Calculating the Number of Bursts for the Test Duration

The number of burst for the test duration is rounded up to the nearest integer number. The follow Input Parameter need to be defined:

LENGTH - Frame size in bytes including the CRC.

BURST - The number of frames in the burst (integer value).

SPEED - media's speed in bits/sec
   Ethernet is 10,000,000 bits/sec
   Fast Ethernet is 100,000,000 bits/sec
   Gigabit Ethernet is 1,000,000,000 bits/sec

IFG   - A constant 96 bits for the minimum interframe gap.

IBG   - Found in the above formula

DURATION - Test duration in seconds.

An intermediate number of the Burst duration needs to be calculated first:

```
              IFG*(BURST-1) + BURST*(64 + 8*LENGTH)
 TXTIME  =  -----------------------------------------
                               SPEED
```

Number of Burst for the Test Duration (rounded up):

```
                    DURATION
 #OFBURSTS =   --------------
               (TXTIME + IBG)
```

Example:

```
  LENGTH   = 64  bytes per frame
  LOAD     = 100 % offered load
  BURST    = 24  frames per burst
  SPEED    = 10  Mbits/sec (Ethernet)
  DUPLEX   = 200 (half duplex)
  DURATION = 10  seconds test

    IBG       = 1612.8 uS
      TXTIME    = 1603.2 uS
    #OFBURSTS = 3110
```