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Benchmarking Virtual Switches in the Open Platform for NFV (OPNFV)

Abstract

This memo describes the contributions of the Open Platform for NFV (OPNFV) project on Virtual Switch Performance (VSPERF), particularly in the areas of test setups and configuration parameters for the system under test. This project has extended the current and completed work of the Benchmarking Methodology Working Group in the IETF and references existing literature. The Benchmarking Methodology Working Group has traditionally conducted laboratory characterization of dedicated physical implementations of internetworking functions. Therefore, this memo describes the additional considerations when virtual switches are implemented on general-purpose hardware. The expanded tests and benchmarks are also influenced by the OPNFV mission to support virtualization of the "telco" infrastructure.

Status of This Memo

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1. Introduction

The Benchmarking Methodology Working Group (BMWG) has traditionally conducted laboratory characterization of dedicated physical implementations of internetworking functions. The black-box benchmarks of throughput, latency, forwarding rates, and others have served our industry for many years. Now, Network Function Virtualization (NFV) has the goal of transforming how internetwork functions are implemented and therefore has garnered much attention.

A virtual switch (vSwitch) is an important aspect of the NFV infrastructure; it provides connectivity between and among physical network functions and virtual network functions. As a result, there are many vSwitch benchmarking efforts but few specifications to guide the many new test design choices. This is a complex problem and an industry-wide work in progress. In the future, several of BMWG’s fundamental specifications will likely be updated as more testing experience helps to form consensus around new methodologies, and BMWG should continue to collaborate with all organizations that share the same goal.

This memo describes the contributions of the Open Platform for NFV (OPNFV) project on Virtual Switch Performance (VSPERF) characterization through the Danube 3.0 (fourth) release [DanubeRel] to the chartered work of the BMWG (with stable references to their test descriptions). This project has extended the current and completed work of the BMWG IETF and references existing literature. For example, the most often referenced RFC is [RFC2544] (which depends on [RFC1242]), so the foundation of the benchmarking work in OPNFV is common and strong. The recommended extensions are specifically in the areas of test setups and configuration parameters for the system under test.

See [VSPERFhome] for more background and the OPNFV website for general information [OPNFV].

The authors note that OPNFV distinguishes itself from other open source compute and networking projects through its emphasis on existing "telco" services as opposed to cloud computing. There are many ways in which telco requirements have different emphasis on performance dimensions when compared to cloud computing: support for and transfer of isochronous media streams is one example.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

1.2. Abbreviations

For the purposes of this document, the following abbreviations apply:

ACK	Acknowledge
ACPI	Advanced Configuration and Power Interface
BIOS	Basic Input Output System
BMWG	Benchmarking Methodology Working Group
CPDP	Control Plane Data Plane
CPU	Central Processing Unit
DIMM	Dual In-line Memory Module
DPDK	Data Plane Development Kit
DUT	Device Under Test
GRUB	Grand Unified Bootloader
ID	Identification
IMIX	Internet Mix
IP	Internet Protocol
IPPM	IP Performance Metrics
LAN	Local Area Network
LTD	Level Test Design
NFV	Network Functions Virtualization
NIC	Network Interface Card
NUMA	Non-uniform Memory Access
OPNFV	Open Platform for NFV
OS	Operating System
PCI	Peripheral Component Interconnect
PDV	Packet Delay Variation
SR/IOV	Single Root / Input Output Virtualization
SUT	System Under Test
TCP	Transmission Control Protocol
TSO	TCP Segment Offload
UDP	User Datagram Protocol
VM	Virtual Machine
VNF	Virtualised Network Function
VSPERF	OPNFV vSwitch Performance Project

2. Scope

The primary purpose and scope of the memo is to describe key aspects of vSwitch benchmarking, particularly in the areas of test setups and configuration parameters for the system under test, and extend the body of extensive BMWG literature and experience. Initial feedback indicates that many of these extensions may be applicable beyond this memo’s current scope (to hardware switches in the NFV infrastructure and to virtual routers, for example). Additionally, this memo serves as a vehicle to include more detail and relevant commentary from BMWG and other open source communities under BMWG’s chartered work to characterize the NFV infrastructure.

The benchmarking covered in this memo should be applicable to many types of vSwitches and remain vSwitch agnostic to a great degree. There has been no attempt to track and test all features of any specific vSwitch implementation.

3. Benchmarking Considerations

This section highlights some specific considerations (from [RFC8172]) related to benchmarks for virtual switches. The OPNFV project is sharing its present view on these areas as they develop their specifications in the Level Test Design (LTD) document as defined by [IEEE829].

3.1. Comparison with Physical Network Functions

To compare the performance of virtual designs and implementations with their physical counterparts, identical benchmarks are needed. BMWG has developed specifications for many physical network functions. The BMWG has recommended reusing existing benchmarks and methods in [RFC8172], and the OPNFV LTD expands on them as described here. A key configuration aspect for vSwitches is the number of parallel CPU cores required to achieve comparable performance with a given physical device or whether some limit of scale will be reached before the vSwitch can achieve the comparable performance level.

It’s unlikely that the virtual switch will be the only application running on the SUT, so CPU utilization, cache utilization, and memory footprint should also be recorded for the virtual implementations of internetworking functions. However, internally measured metrics such as these are not benchmarks; they may be useful for the audience (e.g., operations) to know and may also be useful if there is a problem encountered during testing.

Benchmark comparability between virtual and physical/hardware implementations of equivalent functions will likely place more detailed and exact requirements on the "testing systems" (in terms of stream generation, algorithms to search for maximum values, and their configurations). This is another area for standards development to appreciate; however, this is a topic for a future document.

3.2. Continued Emphasis on Black-Box Benchmarks

External observations remain essential as the basis for benchmarks. Internal observations with a fixed specification and interpretation will be provided in parallel to assist the development of operations procedures when the technology is deployed.

3.3. New Configuration Parameters

A key consideration when conducting any sort of benchmark is trying to ensure the consistency and repeatability of test results. When benchmarking the performance of a vSwitch, there are many factors that can affect the consistency of results; one key factor is matching the various hardware and software details of the SUT. This section lists some of the many new parameters that this project believes are critical to report in order to achieve repeatability.

It has been the goal of the project to produce repeatable results, and a large set of the parameters believed to be critical is provided so that the benchmarking community can better appreciate the increase in configuration complexity inherent in this work. The parameter set below is assumed sufficient for the infrastructure in use by the VSPERF project to obtain repeatable results from test to test.

Hardware details (platform, processor, memory, and network) including:

- BIOS version, release date, and any configurations that were modified
- Power management at all levels (ACPI sleep states, processor package, OS, etc.)
- CPU microcode level
- Number of enabled cores
- Number of cores used for the test
- Memory information (type and size)

- Memory DIMM configurations (quad rank performance may not be the same as dual rank) in size, frequency, and slot locations

- Number of physical NICs and their details (manufacturer, versions, type, and the PCI slot they are plugged into)

- NIC interrupt configuration (and any special features in use)

- PCI configuration parameters (payload size, early ACK option, etc.)

Software details including:

- OS RunLevel

- OS version (for host and VNF)

- Kernel version (for host and VNF)

- GRUB boot parameters (for host and VNF)

- Hypervisor details (type and version)

- Selected vSwitch, version number, or commit ID used

- vSwitch launch command line if it has been parameterized

- Memory allocation to the vSwitch

- Which NUMA node it is using and how many memory channels

- DPDK or any other software dependency version number or commit ID used

- Memory allocation to a VM - if it’s from Hugepages/elsewhere

- VM storage type - snapshot, independent persistent, independent non-persistent

- Number of VMs

- Number of virtual NICs (vNICs) - versions, type, and driver

- Number of virtual CPUs and their core affinity on the host

- Number of vNICs and their interrupt configurations

- Thread affinitization for the applications (including the vSwitch itself) on the host

- Details of resource isolation, such as CPUs designated for Host/ Kernel (isolcpu) and CPUs designated for specific processes (taskset).

Test traffic information:

- Test duration

- Number of flows

- Traffic type - UDP, TCP, and others

- Frame Sizes - fixed or IMIX [RFC6985] (note that with [IEEE802.1ac], frames may be longer than 1500 bytes and up to 2000 bytes)

- Deployment Scenario - defines the communications path in the SUT

3.4. Flow Classification

Virtual switches group packets into flows by processing and matching particular packet or frame header information, or by matching packets based on the input ports. Thus, a flow can be thought of as a sequence of packets that have the same set of header field values or have arrived on the same physical or logical port. Performance results can vary based on the parameters the vSwitch uses to match for a flow. The recommended flow classification parameters for any vSwitch performance tests are: the input port (physical or logical), the source MAC address, the destination MAC address, the source IP address, the destination IP address, and the Ethernet protocol type field (although classification may take place on other fields, such as source and destination transport port numbers). It is essential to increase the flow timeout time on a vSwitch before conducting any performance tests that do not intend to measure the flow setup time (see Section 3 of [RFC2889]). Normally, the first packet of a particular stream will install the flow in the virtual switch, which introduces additional latency; subsequent packets of the same flow are not subject to this latency if the flow is already installed on the vSwitch.

3.5. Benchmarks Using Baselines with Resource Isolation

This outline describes the measurement of baselines with isolated resources at a high level, which is the intended approach at this time.

1. Baselines:

   * Optional: Benchmark platform forwarding capability without a vSwitch or VNF for at least 72 hours (serves as a means of platform validation and a means to obtain the base performance for the platform in terms of its maximum forwarding rate and latency).

```
                                                    __
+--------------------------------------------------+   |
|   +------------------------------------------+   |   |
|   |                                          |   |   |
|   |          Simple Forwarding App           |   |  Host
|   |                                          |   |   |
|   +------------------------------------------+   |   |
|   |                 NIC                      |   |   |
+---+------------------------------------------+---+ __|
           ^                           :
           |                           |
           :                           v
+--------------------------------------------------+
|                                                  |
|                Traffic Generator                 |
|                                                  |
+--------------------------------------------------+
```

Figure 1: Benchmark Platform Forwarding Capability

- Benchmark VNF forwarding capability with direct connectivity (vSwitch bypass, e.g., SR/IOV) for at least 72 hours (serves as a means of VNF validation and a means to obtain the base performance for the VNF in terms of its maximum forwarding rate and latency). The metrics gathered from this test will serve as a key comparison point for vSwitch bypass technologies performance and vSwitch performance.

```
                                                                   __
         +--------------------------------------------------+ __     |
         |   +------------------------------------------+   |   |    |
         |   |                                          |   | Host/  |
         |   |                 VNF                      |   | Guest  |
         |   |                                          |   |   |    |
         |   +------------------------------------------+   | __|    |
         |   |          Passthrough/SR-IOV              |   |       Host
         |   +------------------------------------------+   |        |
         |   |                 NIC                      |   |        |
         +---+------------------------------------------+---+      __|
                    ^                           :
                    |                           |
                    :                           v
         +--------------------------------------------------+
         |                                                  |
         |                Traffic Generator                 |
         |                                                  |
         +--------------------------------------------------+
```

Figure 2: Benchmark VNF Forwarding Capability

- Benchmarking with isolated resources alone and with other resources (both hardware and software) disabled; for example, vSwitch and VM are SUT.

- Benchmarking with isolated resources alone, thus leaving some resources unused.

- Benchmarking with isolated resources and all resources occupied.

2. Next Steps:

   - Limited sharing

   - Production scenarios

   - Stressful scenarios

4. VSPERF Specification Summary

The overall specification in preparation is referred to as a Level Test Design (LTD) document, which will contain a suite of performance tests. The base performance tests in the LTD are based on the pre-existing specifications developed by the BMWG to test the performance of physical switches. These specifications include:

- Benchmarking Methodology for Network Interconnect Devices [RFC2544]

- Benchmarking Methodology for LAN Switching [RFC2889]

- Device Reset Characterization [RFC6201]

- Packet Delay Variation Applicability Statement [RFC5481]

The two most recent RFCs above ([RFC6201] and [RFC5481]) are being applied in benchmarking for the first time and represent a development challenge for test equipment developers. Fortunately, many members of the testing system community have engaged on the VSPERF project, including an open source test system.

In addition to this, the LTD also reuses the terminology defined by:

- Benchmarking Terminology for LAN Switching Devices [RFC2285]

It is recommended that these references be included in future benchmarking specifications:

- Methodology for IP Multicast Benchmarking [RFC3918]

- Packet Reordering Metrics [RFC4737]

As one might expect, the most fundamental internetworking characteristics of throughput and latency remain important when the switch is virtualized, and these benchmarks figure prominently in the specification.

When considering characteristics important to "telco" network functions, additional performance metrics are needed. In this case, the project specifications have referenced metrics from the IETF IP Performance Metrics (IPPM) literature. This means that the latency test described in [RFC2544] is replaced by measurement of a metric derived from IPPM’s [RFC7679], where a set of statistical summaries will be provided (mean, max, min, and percentiles). Further metrics planned to be benchmarked include packet delay variation as defined by [RFC5481], reordering, burst behaviour, DUT availability, DUT capacity, and packet loss in long-term testing at the throughput level, where some low level of background loss may be present and characterized.

Tests have been designed to collect the metrics below:

- Throughput tests are designed to measure the maximum forwarding rate (in frames per second, fps) and bit rate (in Mbps) for a constant load (as defined by [RFC1242]) without traffic loss.

- Packet and frame-delay distribution tests are designed to measure the average minimum and maximum packet (and/or frame) delay for constant loads.

- Packet delay tests are designed to understand latency distribution for different packet sizes and to uncover outliers over an extended test run.

- Scalability tests are designed to understand how the virtual switch performs with an increasing number of flows, number of active ports, configuration complexity of the forwarding logic, etc.

- Stream performance tests (with TCP or UDP) are designed to measure bulk data transfer performance, i.e., how fast systems can send and receive data through the switch.

- Control-path and data-path coupling tests are designed to understand how closely the data path and the control path are coupled, as well as the effect of this coupling on the performance of the DUT (for example, delay of the initial packet of a flow).

- CPU and memory consumption tests are designed to understand the virtual switch’s footprint on the system and are conducted as auxiliary measurements with the benchmarks above. They include CPU utilization, cache utilization, and memory footprint.

- The so-called "soak" tests, where the selected test is conducted over a long period of time (with an ideal duration of 24 hours but only long enough to determine that stability issues exist when found; there is no requirement to continue a test when a DUT exhibits instability over time). The key performance characteristics and benchmarks for a DUT are determined (using short duration tests) prior to conducting soak tests. The purpose of soak tests is to capture transient changes in performance, which may occur due to infrequent processes, memory leaks, or the low-probability coincidence of two or more processes. The stability of the DUT is the paramount consideration, so performance must be evaluated periodically during continuous testing, and this results in use of frame rate metrics [RFC2889] instead of throughput [RFC2544] (which requires stopping traffic to allow time for all traffic to exit internal queues), for example.

Additional test specification development should include:

- Request/response performance tests (with TCP or UDP), which measure the transaction rate through the switch.

- Noisy neighbor tests, in order to understand the effects of resource sharing on the performance of a virtual switch.

- Tests derived from examination of ETSI NFV Draft GS IFA003 requirements [IFA003] on characterization of acceleration technologies applied to vSwitches.

The flexibility of deployment of a virtual switch within a network means that it is necessary to characterize the performance of a vSwitch in various deployment scenarios. The deployment scenarios under consideration are shown in the following figures:

```
                                                         __
     +--------------------------------------------------+   |
     |              +--------------------+              |   |
     |              |                    |              |   |
     |              |                    v              |   |  Host
     |   +--------------+            +--------------+   |   |
     |   |   PHY Port   |  vSwitch   |   PHY Port   |   |   |
     +---+--------------+------------+--------------+---+ __|
                ^                           :
                |                           |
                :                           v
     +--------------------------------------------------+
     |                                                  |
     |                Traffic Generator                 |
     |                                                  |
     +--------------------------------------------------+
```

Figure 3: Physical Port to Virtual Switch to Physical Port

```
                                                         __
     +---------------------------------------------------+   |
     |                                                   |   |
     |   +-------------------------------------------+   |   |
     |   |                 Application               |   |   |
     |   +-------------------------------------------+   |   |
     |       ^                                  :        |   |
     |       |                                  |        |   |  Guest
     |       :                                  v        |   |
     |   +---------------+           +---------------+   |   |
     |   | Logical Port 0|           | Logical Port 1|   |   |
     +---+---------------+-----------+---------------+---+ __|
             ^                                  :
             |                                  |
             :                                  v         __
     +---+---------------+----------+---------------+---+   |
     |   | Logical Port 0|          | Logical Port 1|   |   |
     |   +---------------+          +---------------+   |   |
     |       ^                                  :       |   |
     |       |                                  |       |   |  Host
     |       :                                  v       |   |
     |   +--------------+            +--------------+   |   |
     |   |   PHY Port   |  vSwitch   |   PHY Port   |   |   |
     +---+--------------+------------+--------------+---+ __|
                ^                           :
                |                           |
                :                           v
     +--------------------------------------------------+
     |                                                  |
     |                Traffic Generator                 |
     |                                                  |
     +--------------------------------------------------+
```

Figure 4: Physical Port to Virtual Switch to VNF to Virtual Switch to Physical Port

```
                                                      __
     +----------------------+  +----------------------+  |
     |   Guest 1            |  |   Guest 2            |  |
     |   +---------------+  |  |   +---------------+  |  |
     |   |  Application  |  |  |   |  Application  |  |  |
     |   +---------------+  |  |   +---------------+  |  |
     |       ^       |      |  |       ^       |      |  |
     |       |       v      |  |       |       v      |  |  Guests
     |   +---------------+  |  |   +---------------+  |  |
     |   | Logical Ports |  |  |   | Logical Ports |  |  |
     |   |   0       1   |  |  |   |   0       1   |  |  |
     +---+---------------+--+  +---+---------------+--+__|
             ^       :                 ^       :
             |       |                 |       |
             :       v                 :       v       _
     +---+---------------+---------+---------------+--+ |
     |   |   0       1   |         |   3       4   |  | |
     |   | Logical Ports |         | Logical Ports |  | |
     |   +---------------+         +---------------+  | |
     |       ^       |                 ^       |      | |  Host
     |       |       \-----------------/       v      | |
     |   +--------------+          +--------------+   | |
     |   |   PHY Ports  | vSwitch  |   PHY Ports  |   | |
     +---+--------------+----------+--------------+---+_|
             ^                                 :
             |                                 |
             :                                 v
     +--------------------------------------------------+
     |                                                  |
     |                Traffic Generator                 |
     |                                                  |
     +--------------------------------------------------+
```

Figure 5: Physical Port to Virtual Switch to VNF to Virtual Switch to VNF to Virtual Switch to Physical Port

```
                                                          __
     +---------------------------------------------------+   |
     |                                                   |   |
     |   +-------------------------------------------+   |   |
     |   |                 Application               |   |   |
     |   +-------------------------------------------+   |   |
     |       ^                                           |   |
     |       |                                           |   |  Guest
     |       :                                           |   |
     |   +---------------+                               |   |
     |   | Logical Port 0|                               |   |
     +---+---------------+-------------------------------+ __|
             ^
             |
             :                                            __
     +---+---------------+------------------------------+   |
     |   | Logical Port 0|                              |   |
     |   +---------------+                              |   |
     |       ^                                          |   |
     |       |                                          |   |  Host
     |       :                                          |   |
     |   +--------------+                               |   |
     |   |   PHY Port   |  vSwitch                      |   |
     +---+--------------+------------ -------------- ---+ __|
                ^
                |
                :
     +--------------------------------------------------+
     |                                                  |
     |                Traffic Generator                 |
     |                                                  |
     +--------------------------------------------------+
```

Figure 6: Physical Port to Virtual Switch to VNF

```
                                                          __
     +---------------------------------------------------+   |
     |                                                   |   |
     |   +-------------------------------------------+   |   |
     |   |                 Application               |   |   |
     |   +-------------------------------------------+   |   |
     |                                          :        |   |
     |                                          |        |   |  Guest
     |                                          v        |   |
     |                               +---------------+   |   |
     |                               | Logical Port  |   |   |
     +-------------------------------+---------------+---+ __|
                                          :
                                          |
                                          v         __
     +-----------------------------+---------------+---+   |
     |                             | Logical Port  |   |   |
     |                             +---------------+   |   |
     |                                          :      |   |
     |                                          |      |   |  Host
     |                                          v      |   |
     |                               +--------------+  |   |
     |                     vSwitch   |   PHY Port   |  |   |
     +-------------------------------+--------------+--+ __|
                                      :
                                      |
                                      v
     +--------------------------------------------------+
     |                                                  |
     |                Traffic Generator                 |
     |                                                  |
     +--------------------------------------------------+
```

Figure 7: VNF to Virtual Switch to Physical Port

```
                                                      __
     +----------------------+  +----------------------+  |
     |   Guest 1            |  |   Guest 2            |  |
     |   +---------------+  |  |   +---------------+  |  |
     |   |  Application  |  |  |   |  Application  |  |  |
     |   +---------------+  |  |   +---------------+  |  |
     |              |       |  |       ^              |  |
     |              v       |  |       |              |  |  Guests
     |   +---------------+  |  |   +---------------+  |  |
     |   | Logical Ports |  |  |   | Logical Ports |  |  |
     |   |           0   |  |  |   |   0           |  |  |
     +---+---------------+--+  +---+---------------+--+__|
                     :                 ^
                     |                 |
                     v                 :               _
     +---+---------------+---------+---------------+--+ |
     |   |           1   |         |   1           |  | |
     |   | Logical Ports |         | Logical Ports |  | |
     |   +---------------+         +---------------+  | |
     |               |                 ^              | |  Host
     |               \-----------------/              | |
     |                                                | |
     |                    vSwitch                     | |
     +------------------------------------------------+_|
```

Figure 8: VNF to Virtual Switch to VNF

A set of deployment scenario figures is available on the VSPERF "Test Methodology" wiki page [TestTopo].

5. 3x3 Matrix Coverage

This section organizes the many existing test specifications into the "3x3" matrix (introduced in [RFC8172]). Because the LTD specification ID names are quite long, this section is organized into lists for each occupied cell of the matrix (not all are occupied; also, the matrix has grown to 3x4 to accommodate scale metrics when displaying the coverage of many metrics/benchmarks). The current version of the LTD specification is available; see [LTD].

The tests listed below assess the activation of paths in the data plane rather than the control plane.

A complete list of tests with short summaries is available on the VSPERF "LTD Test Spec Overview" wiki page [LTDoverV].

5.1. Speed of Activation

- Activation.RFC2889.AddressLearningRate
- PacketLatency.InitialPacketProcessingLatency

5.2. Accuracy of Activation

- CPDP.Coupling.Flow.Addition

5.3. Reliability of Activation

- Throughput.RFC2544.SystemRecoveryTime
- Throughput.RFC2544.ResetTime

5.4. Scale of Activation

- Activation.RFC2889.AddressCachingCapacity

5.5. Speed of Operation

- Throughput.RFC2544.PacketLossRate
- Stress.RFC2544.0PacketLoss
- Throughput.RFC2544.PacketLossRateFrameModification
- Throughput.RFC2544.BackToBackFrames
- Throughput.RFC2889.MaxForwardingRate
- Throughput.RFC2889.ForwardPressure
- Throughput.RFC2889.BroadcastFrameForwarding
- Throughput.RFC2544.WorstN-BestN
- Throughput.Overlay.Network.<tech>.RFC2544.PacketLossRatio

5.6. Accuracy of Operation

- Throughput.RFC2889.ErrorFramesFiltering
- Throughput.RFC2544.Profile

5.7. Reliability of Operation

- Throughput.RFC2889.Soak
- Throughput.RFC2889.SoakFrameModification
- PacketDelayVariation.RFC3393.Soak

5.8. Scalability of Operation

- Scalability.RFC2544.0PacketLoss
- MemoryBandwidth.RFC2544.0PacketLoss.Scalability
- Scalability.VNF.RFC2544.PacketLossProfile
- Scalability.VNF.RFC2544.PacketLossRatio

5.9. Summary

	SPEED	ACCURACY	RELIABILITY	SCALE
Activation	X	X	X	X
Operation	X	X	X	X
De-activation				

6. Security Considerations

Benchmarking activities as described in this memo are limited to technology characterization of a Device Under Test/System Under Test (DUT/SUT) using controlled stimuli in a laboratory environment with dedicated address space and the constraints specified in the sections above.

The benchmarking network topology will be an independent test setup and MUST NOT be connected to devices that may forward the test traffic into a production network or misroute traffic to the test management network.

Further, benchmarking is performed on a "black-box" basis and relies solely on measurements observable external to the DUT/SUT.

Special capabilities SHOULD NOT exist in the DUT/SUT specifically for benchmarking purposes. Any implications for network security arising from the DUT/SUT SHOULD be identical in the lab and in production networks.

7. References

7.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC2285] Mandeville, R., "Benchmarking Terminology for LAN Switching Devices", RFC 2285, DOI 10.17487/RFC2285, February 1998, <https://www.rfc-editor.org/info/rfc2285>.

[RFC2544] Bradner, S. and J. McQuaid, "Benchmarking Methodology for Network Interconnect Devices", RFC 2544, DOI 10.17487/RFC2544, March 1999, <https://www.rfc-editor.org/info/rfc2544>.

[RFC2889] Mandeville, R. and J. Perser, "Benchmarking Methodology for LAN Switching Devices", RFC 2889, DOI 10.17487/RFC2889, August 2000, <https://www.rfc-editor.org/info/rfc2889>.

[RFC3918] Stopp, D. and B. Hickman, "Methodology for IP Multicast Benchmarking", RFC 3918, DOI 10.17487/RFC3918, October 2004, <https://www.rfc-editor.org/info/rfc3918>.

[RFC4737] Morton, A., Ciavattone, L., Ramachandran, G., Shalunov, S., and J. Perser, "Packet Reordering Metrics", RFC 4737, DOI 10.17487/RFC4737, November 2006, <https://www.rfc-editor.org/info/rfc4737>.

[RFC6201] Asati, R., Pignataro, C., Calabria, F., and C. Olvera, "Device Reset Characterization", RFC 6201, DOI 10.17487/RFC6201, March 2011, <https://www.rfc-editor.org/info/rfc6201>.

[RFC6985] Morton, A., "IMIX Genome: Specification of Variable Packet Sizes for Additional Testing", RFC 6985, DOI 10.17487/RFC6985, July 2013, <https://www.rfc-editor.org/info/rfc6985>.

[RFC7679] Almes, G., Kalidindi, S., Zekauskas, M., and A. Morton, Ed., "A One-Way Delay Metric for IP Performance Metrics (IPPM)", STD 81, RFC 7679, DOI 10.17487/RFC7679, January 2016, <https://www.rfc-editor.org/info/rfc7679>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

7.2. Informative References

[BENCHMARK-METHOD]
Huang, L., Ed., Rong, G., Ed., Mandeville, B., and B. Hickman, "Benchmarking Methodology for Virtualization Network Performance", Work in Progress, draft-huang-bmwg-virtual-network-performance-03, July 2017.

[DanubeRel]
OPNFV, "Danube", <https://wiki.opnfv.org/display/SWREL/Danube>.

[IEEE802.1ac]
IEEE, "IEEE Standard for Local and metropolitan area networks -- Media Access Control (MAC) Service Definition", IEEE 802.1AC-2016, DOI 10.1109/IEEESTD.2017.7875381, 2016, <https://standards.ieee.org/findstds/standard/802.1AC-2016.html>.

[IEEE829] IEEE, "IEEE Standard for Software and System Test Documentation", IEEE 829-2008, DOI 10.1109/IEEESTD.2008.4578383, <http://ieeexplore.ieee.org/document/4578383/>.

[IFA003] ETSI, "Network Functions Virtualisation (NFV); Acceleration Technologies; vSwitch Benchmarking and Acceleration Specification", ETSI GS NFV-IFA 003 V2.1.1, April 2016, <http://www.etsi.org/deliver/etsi_gs/NFV-IFA/001_099/003/02.01.01_60/gs_NFV-IFA003v020101p.pdf>.

[LTD] Tahhan, M., "VSPERF Level Test Design (LTD)", <http://docs.opnfv.org/en/stable-danube/submodules/vswitchperf/docs/testing/developer/requirements/vswitchperf_ltd.html#>.

[LTDoverV] Morton, A., "LTD Test Spec Overview", <https://wiki.opnfv.org/display/vsperf/LTD+Test+Spec+Overview>.

[OPNFV] OPNFV, "OPNFV", <https://www.opnfv.org/>.

[RFC1242] Bradner, S., "Benchmarking Terminology for Network Interconnection Devices", RFC 1242, DOI 10.17487/RFC1242, July 1991, <https://www.rfc-editor.org/info/rfc1242>.

[RFC5481] Morton, A. and B. Claise, "Packet Delay Variation Applicability Statement", RFC 5481, DOI 10.17487/RFC5481, March 2009, <https://www.rfc-editor.org/info/rfc5481>.

[RFC8172] Morton, A., "Considerations for Benchmarking Virtual Network Functions and Their Infrastructure", RFC 8172, DOI 10.17487/RFC8172, July 2017, <https://www.rfc-editor.org/info/rfc8172>.

[TestTopo] Snyder, E., "Test Methodology", <https://wiki.opnfv.org/display/vsperf/Test+Methodology>.

[VSPERFhome] Tahhan, M., "VSPERF Home", <https://wiki.opnfv.org/display/vsperf/VSperf+Home>.

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