

**Considerations for Benchmarking Virtual Network Functions and Their
Infrastructure
draft-morton-bmwg-virtual-net-03**

Abstract

Benchmarking Methodology Working Group has traditionally conducted laboratory characterization of dedicated physical implementations of internetworking functions. This memo investigates additional considerations when network functions are virtualized and performed in commodity off-the-shelf hardware.

NOTES:

3.4 Added inter-actions/dependencies within resource domains

4.3 Added new metrics for characterization: PDV, reordering, mean delay, etc.

4.4 Resolved the question of capacity and the 3x3 Matrix

Requirements Language

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](#) [[RFC2119](#)].

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <http://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on August 6, 2015.

Copyright Notice

Copyright (c) 2015 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to [BCP 78](#) and the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

- [1.](#) Introduction [2](#)
- [2.](#) Scope [3](#)
- [3.](#) Considerations for Hardware and Testing [4](#)
 - [3.1.](#) Hardware Components [4](#)
 - [3.2.](#) Configuration Parameters [4](#)
 - [3.3.](#) Testing Strategies [5](#)
 - [3.4.](#) Attention to Shared Resources [5](#)
- [4.](#) Benchmarking Considerations [6](#)
 - [4.1.](#) Comparison with Physical Network Functions [6](#)
 - [4.2.](#) Continued Emphasis on Black-Box Benchmarks [6](#)
 - [4.3.](#) New Benchmarks and Related Metrics [7](#)
 - [4.4.](#) Assessment of Benchmark Coverage [7](#)
- [5.](#) Security Considerations [9](#)
- [6.](#) IANA Considerations [9](#)
- [7.](#) Acknowledgements [9](#)
- [8.](#) References [10](#)
 - [8.1.](#) Normative References [10](#)
 - [8.2.](#) Informative References [11](#)
- Author's Address [11](#)

[1.](#) Introduction

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. [[RFC1242](#)] and [[RFC2544](#)] are the cornerstones of the work.

An emerging set of service provider and vendor development goals is to reduce costs while increasing flexibility of network devices, and drastically accelerate their deployment. Network Function Virtualization (NFV) has the promise to achieve these goals, and therefore has garnered much attention. It now seems certain that some network functions will be virtualized following the success of cloud computing and virtual desktops supported by sufficient network path capacity, performance, and widespread deployment; many of the same techniques will help achieve NFV.

See <http://www.etsi.org/technologies-clusters/technologies/nfv> for more background, for example, the white papers there may be a useful starting place. The Performance and Portability Best Practices [NFV.PER001] are particularly relevant to BMWG. There are currently work-in-progress documents available in the Open Area http://docbox.etsi.org/ISG/NFV/Open/Latest_Drafts/ including drafts describing Infrastructure aspects and service quality.

2. Scope

BMWG will consider the new topic of Virtual Network Functions and related Infrastructure to ensure that common issues are recognized from the start, using background materials from industry and SDOs (e.g., IETF, ETSI NFV).

This memo investigates additional methodological considerations necessary when benchmarking VNF instantiated and hosted in commodity off-the-shelf (COTS) hardware. An essential consideration is benchmarking both physical and virtual network functions, thereby allowing direct comparison.

A clearly related goal: the benchmarks for the capacity of COTS to host a plurality of VNF instances should be investigated. Existing networking technology benchmarks will also be considered for adaptation to NFV and closely associated technologies.

A non-goal is any overlap with traditional computer benchmark development and their specific metrics (SPECmark suites such as SPECCPU).

A colossal non-goal is any form of architecture development related to NFV and associated technologies in BMWG, as has been the case since BMWG began work in 1989.

3. Considerations for Hardware and Testing

This section lists the new considerations which must be addressed to benchmark VNF(s) and their supporting infrastructure.

3.1. Hardware Components

New Hardware devices will become part of the test set-up.

1. High volume server platforms (COTS, possibly with virtual technology enhancements).
2. Storage systems with large capacity, high speed, and high reliability.
3. Network Interface ports specially designed for efficient service of many virtual NICs.
4. High capacity Ethernet Switches.

Labs conducting comparisons of different VNFs may be able to use the same hardware platform over many studies, until the steady march of innovations overtakes their capabilities (as happens with the lab's traffic generation and testing devices today).

3.2. Configuration Parameters

It will be necessary to configure and document the settings for the entire COTS platform, including:

- o number of server blades (shelf occupation)
- o CPUs
- o caches
- o storage system
- o I/O

as well as configurations that support the devices which host the VNF itself:

- o Hypervisor
- o Virtual Machine
- o Infrastructure Virtual Network

and finally, the VNF itself, with items such as:

- o specific function being implemented in VNF
- o number of VNF components in the service function chain
- o number of physical interfaces and links transited in the service function chain

3.3. Testing Strategies

The concept of characterizing performance at capacity limits may change. For example:

1. It may be more representative of system capacity to characterize the case where Virtual Machines (VM, hosting the VNF) are operating at 50% Utilization, and therefore sharing the "real" processing power across many VMs.
2. Another important case stems from the need for partitioning functions. A noisy neighbor (VM hosting a VNF in an infinite loop) would ideally be isolated and the performance of other VMs would continue according to their specifications.
3. System errors will likely occur as transients, implying a distribution of performance characteristics with a long tail (like latency), leading to the need for longer-term tests of each set of configuration and test parameters.
4. The desire for Elasticity and flexibility among network functions will include tests where there is constant flux in the VM instances. Requests for new VMs and Releases for VMs hosting VNFs no longer needed would be a normal operational condition.
5. All physical things can fail, and benchmarking efforts can also examine recovery aided by the virtual architecture with different approaches to resiliency.

3.4. Attention to Shared Resources

Since many components of the new NFV Infrastructure are virtual, test set-up design must have prior knowledge of inter-actions/dependencies within the various resource domains in the System Under Test (SUT). For example, a virtual machine performing the role of a traditional tester function such as generating and/or receiving traffic should avoid sharing any SUT resources with the Device Under Test DUT. Otherwise, the results will have unexpected dependencies not encountered in physical device benchmarking. The shared-resource

aspect of test design remains one of the critical challenges to overcome in a reasonable way to produce useful results.

4. Benchmarking Considerations

This section discusses considerations related to Benchmarks applicable to VNFs and their associated technologies.

4.1. Comparison with Physical Network Functions

In order to compare the performance of virtual designs and implementations with their physical counterparts, identical benchmarks must be used. Since BMWG has developed specifications for many network functions already, there will be re-use of existing benchmarks through references, while allowing for the possibility of benchmark curation during development of new methodologies. Consideration should be given to quantifying the number of parallel VNFs required to achieve comparable performance with a given physical device, or whether some limit of scale was reached before the VNFs could achieve the comparable level.

4.2. Continued Emphasis on Black-Box Benchmarks

When the network functions under test are based on Open Source code, there may be a tendency to rely on internal measurements to some extent, especially when the externally-observable phenomena only support an inference of internal events (such as routing protocol convergence). However, external observations remain essential as the basis for Benchmarks. Internal observations with fixed specification and interpretation may be provided in parallel, to assist the development of operations procedures when the technology is deployed, for example. Internal metrics and measurements from Open Source implementations may be the only direct source of performance results in a desired dimension, but corroborating external observations are still required to assure the integrity of measurement discipline was maintained for all reported results.

A related aspect of benchmark development is where the scope includes multiple approaches to a common function under the same benchmark. For example, there are many ways to arrange for activation of a network path between interface points and the activation times can be compared if the start-to-stop activation interval has a generic and unambiguous definition. Thus, generic benchmark definitions are preferred over technology/protocol specific definitions where possible.

4.3. New Benchmarks and Related Metrics

There will be new classes of benchmarks needed for network design and assistance when developing operational practices (possibly automated management and orchestration of deployment scale). Examples follow in the paragraphs below, many of which are prompted by the goals of increased elasticity and flexibility of the network functions, along with accelerated deployment times.

Time to deploy VNFs: In cases where the COTS hardware is already deployed and ready for service, it is valuable to know the response time when a management system is tasked with "standing-up" 100's of virtual machines and the VNFs they will host.

Time to migrate VNFs: In cases where a rack or shelf of hardware must be removed from active service, it is valuable to know the response time when a management system is tasked with "migrating" some number of virtual machines and the VNFs they currently host to alternate hardware that will remain in-service.

Time to create a virtual network in the COTS infrastructure: This is a somewhat simplified version of existing benchmarks for convergence time, in that the process is initiated by a request from (centralized or distributed) control, rather than inferred from network events (link failure). The successful response time would remain dependent on dataplane observations to confirm that the network is ready to perform.

Also, it appears to be valuable to measure traditional packet transfer performance metrics during the assessment of traditional and new benchmarks, including metrics that may be used to support service engineering such as the Spatial Composition metrics found in [\[RFC6049\]](#). Examples include Mean one-way delay in [section 4.1 of \[RFC6049\]](#), Packet Delay Variation (PDV) in [\[RFC5481\]](#), and Packet Reordering [\[RFC4737\]](#) [\[RFC4689\]](#).

4.4. Assessment of Benchmark Coverage

It can be useful to organize benchmarks according to their applicable lifecycle stage and the performance criteria they intend to assess. The table below provides a way to organize benchmarks such that there is a clear indication of coverage for the intersection of lifecycle stages and performance criteria.

	SPEED	ACCURACY	RELIABILITY
Activation			
Operation			
De-activation			

For example, the "Time to deploy VNFs" benchmark described above would be placed in the intersection of Activation and Speed, making it clear that there are other potential performance criteria to benchmark, such as the "percentage of unsuccessful VM/VNF stand-ups" in a set of 100 attempts. This example emphasizes that the Activation and De-activation lifecycle stages are key areas for NFV and related infrastructure, and encourage expansion beyond traditional benchmarks for normal operation. Thus, reviewing the benchmark coverage using this table (sometimes called the 3x3 matrix) can be a worthwhile exercise in BMWG.

In one of the first applications of the 3x3 matrix on BMWG, we discovered that metrics on measured size, capacity, or scale do not easily match one of the three columns above. There are three possibilities to resolve this:

- o Add a column, Scaleability, but then it would be expected to have metrics in most of the Activation, Operation, and De-activation functions (which may not be the case).
- o Include Scalability under Reliability: This fits the user perspective of the 3x3 matrix because the size or capacity of a device contributes to the likelihood that a request will be blocked, or that operation will be un-reliable when operating in an overload state.
- o Keep size, capacity, and scale metrics separate from the 3x3 matrix.

After some discussion, including some of the original developers of the 3x3 matrix, it is suggested to keep capacity metrics separate from the 3x3 matrix and list them separately. This approach encourages use of the 3x3 matrix to organize reports of results, where the capacity at which the various metrics were measured would be included in the title of the matrix (and results for multiple capacities would result in separate 3x3 matrices, if there were sufficient measurements/results to organize in that way).

5. 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, relying 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.

6. IANA Considerations

No IANA Action is requested at this time.

7. Acknowledgements

The author acknowledges an encouraging conversation on this topic with Mukhtiar Shaikh and Ramki Krishnan in November 2013. Bhavani Parise and Ilya Varlashkin have provided useful suggestions to expand these considerations. Bhuvaneshwaran Vengainathan has already tried the 3x3 matrix with SDN controller draft, and contributed to many discussions. Scott Bradner quickly pointed out shared resource dependencies in an early vSwitch measurement proposal, and the topic was included here as a key consideration.

8. References

8.1. Normative References

- [NFV.PER001] "Network Function Virtualization: Performance and Portability Best Practices", Group Specification ETSI GS NFV-PER 001 V1.1.1 (2014-06), June 2014.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), March 1997.
- [RFC2330] Paxson, V., Almes, G., Mahdavi, J., and M. Mathis, "Framework for IP Performance Metrics", [RFC 2330](#), May 1998.
- [RFC2544] Bradner, S. and J. McQuaid, "Benchmarking Methodology for Network Interconnect Devices", [RFC 2544](#), March 1999.
- [RFC2679] Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Delay Metric for IPPM", [RFC 2679](#), September 1999.
- [RFC2680] Almes, G., Kalidindi, S., and M. Zekauskas, "A One-way Packet Loss Metric for IPPM", [RFC 2680](#), September 1999.
- [RFC2681] Almes, G., Kalidindi, S., and M. Zekauskas, "A Round-trip Delay Metric for IPPM", [RFC 2681](#), September 1999.
- [RFC3393] Demichelis, C. and P. Chimento, "IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)", [RFC 3393](#), November 2002.
- [RFC3432] Raisanen, V., Grotefeld, G., and A. Morton, "Network performance measurement with periodic streams", [RFC 3432](#), November 2002.
- [RFC4689] Poretsky, S., Perser, J., Erramilli, S., and S. Khurana, "Terminology for Benchmarking Network-layer Traffic Control Mechanisms", [RFC 4689](#), October 2006.
- [RFC4737] Morton, A., Ciavattone, L., Ramachandran, G., Shalunov, S., and J. Perser, "Packet Reordering Metrics", [RFC 4737](#), November 2006.
- [RFC5357] Hedayat, K., Krzanowski, R., Morton, A., Yum, K., and J. Babiarez, "A Two-Way Active Measurement Protocol (TWAMP)", [RFC 5357](#), October 2008.

- [RFC5905] Mills, D., Martin, J., Burbank, J., and W. Kasch, "Network Time Protocol Version 4: Protocol and Algorithms Specification", [RFC 5905](#), June 2010.

8.2. Informative References

- [RFC1242] Bradner, S., "Benchmarking terminology for network interconnection devices", [RFC 1242](#), July 1991.
- [RFC5481] Morton, A. and B. Claise, "Packet Delay Variation Applicability Statement", [RFC 5481](#), March 2009.
- [RFC6049] Morton, A. and E. Stephan, "Spatial Composition of Metrics", [RFC 6049](#), January 2011.
- [RFC6248] Morton, A., "[RFC 4148](#) and the IP Performance Metrics (IPPM) Registry of Metrics Are Obsolete", [RFC 6248](#), April 2011.
- [RFC6390] Clark, A. and B. Claise, "Guidelines for Considering New Performance Metric Development", [BCP 170](#), [RFC 6390](#), October 2011.

Author's Address

Al Morton
AT&T Labs
200 Laurel Avenue South
Middletown,, NJ 07748
USA

Phone: +1 732 420 1571
Fax: +1 732 368 1192
Email: acmorton@att.com
URI: <http://home.comcast.net/~acmacm/>