



**VSPERF**

*Release draft (d35eb91)*

**OPNFV**

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## CONTENTS

<b>1</b>	<b>VSPERF Installation Guide</b>	<b>3</b>
1.1	Installing vswitchperf . . . . .	3
1.2	'vsperf' Traffic Gen Guide . . . . .	4
<b>2</b>	<b>VSPERF User Guide</b>	<b>9</b>
<b>3</b>	<b>VSPERF Design</b>	<b>11</b>
3.1	VSPERF Design Document . . . . .	11
3.2	Traffic Generator Integration Guide . . . . .	17
<b>4</b>	<b>VSPERF LEVEL TEST DESIGN (LTD)</b>	<b>21</b>
4.1	Introduction . . . . .	21
4.2	Details of the Level Test Design . . . . .	22
<b>5</b>	<b>VSPERF News</b>	<b>55</b>
5.1	OPNFV Brahmaputra Release . . . . .	55
5.2	November 2015 . . . . .	56
5.3	October 2015 . . . . .	56
5.4	September 2015 . . . . .	56
5.5	August 2015 . . . . .	56
5.6	July 2015 . . . . .	56
5.7	May 2015 . . . . .	56
<b>6</b>	<b>VSPERF Results</b>	<b>59</b>
6.1	OPNFV Brahmaputra Scenarios . . . . .	59
6.2	OPNFV Brahmaputra Results . . . . .	60
<b>7</b>	<b>Indices</b>	<b>61</b>



VSPERF is an OPNFV testing project.

VSPERF will develop a generic and architecture agnostic vSwitch testing framework and associated tests, that will serve as a basis for validating the suitability of different vSwitch implementations in a Telco NFV deployment environment. The output of this project will be utilized by the OPNFV Performance and Test group and its associated projects, as part of OPNFV Platform and VNF level testing and validation.

- Project Wiki: [https://wiki.opnfv.org/characterize\\_vswitch\\_performance\\_for\\_telco\\_nfv\\_use\\_cases](https://wiki.opnfv.org/characterize_vswitch_performance_for_telco_nfv_use_cases)
- Project Repository: <https://gerrit.opnfv.org/gerrit/#/q/vswitchperf>
- Continuous Integration <https://build.opnfv.org/ci/view/vswitchperf/>



## VSPERF INSTALLATION GUIDE

### 1.1 Installing vswitchperf

#### 1.1.1 Supported Operating Systems

- CentOS 7
- Fedora 20
- Fedora 21
- Fedora 22
- Ubuntu 14.04

#### 1.1.2 Supported vSwitches

The vSwitch must support Open Flow 1.3 or greater.

- OVS (built from source).
- OVS with DPDK (built from source).

#### 1.1.3 Supported Hypervisors

- Qemu version 2.3.

#### 1.1.4 Available VNFs

A simple VNF that forwards traffic through a VM, using:

- DPDK testpmd
- Linux Brigde
- custom l2fwd module

The VM image can be downloaded from: [http://artifacts.opnfv.org/vswitchperf/vloop-vnf-ubuntu-14.04\\_20151216.qcow2](http://artifacts.opnfv.org/vswitchperf/vloop-vnf-ubuntu-14.04_20151216.qcow2)

## 1.1.5 Other Requirements

The test suite requires Python 3.3 and relies on a number of other packages. These need to be installed for the test suite to function.

Installation of required packages, preparation of Python 3 virtual environment and compilation of OVS, DPDK and QEMU is performed by script `systems/build_base_machine.sh`. It should be executed under user account, which will be used for vsperf execution.

**Please Note:** Password-less sudo access must be configured for given user account before script is executed.

Execution of installation script:

```
$ cd systems
$ ./build_base_machine.sh
```

**Please Note:** you don't need to go into any of the systems subdirectories, simply run the top level `build_base_machine.sh`, your OS will be detected automatically.

Script `build_base_machine.sh` will install all the vsperf dependencies in terms of system packages, Python 3.x and required Python modules. In case of CentOS 7 it will install Python 3.3 from an additional repository provided by Software Collections ([a link](#)). Installation script will also use `virtualenv` to create a vsperf virtual environment, which is isolated from the default Python environment. This environment will reside in a directory called `vsperfenv` in `$HOME`.

You will need to activate the virtual environment every time you start a new shell session. Its activation is specific to your OS:

### CentOS 7

```
$ scl enable python33 bash
$ cd $HOME/vsperfenv
$ source bin/activate
```

### Fedora and Ubuntu

```
$ cd $HOME/vsperfenv
$ source bin/activate
```

### Working Behind a Proxy

If you're behind a proxy, you'll likely want to configure this before running any of the above. For example:

```
export http_proxy=proxy.mycompany.com:123
export https_proxy=proxy.mycompany.com:123
```

## 1.2 'vsperf' Traffic Gen Guide

### 1.2.1 Overview

VSPERF supports the following traffic generators:

- Dummy (DEFAULT): Allows you to use your own external traffic generator.



- IXIA (IxNet and IxOS)
- Spirent TestCenter

To see the list of traffic gens from the cli:

```
$ ./vsperf --list-trafficgens
```

This guide provides the details of how to install and configure the various traffic generators.

## 1.2.2 Background Information

The traffic default configuration can be found in `tools/pkt_gen/trafficgen/trafficgenhelper.py`, and is configured as follows:

```
TRAFFIC_DEFAULTS = {
    'l2': {
        'framesize': 64,
        'srcmac': '00:00:00:00:00:00',
        'dstmac': '00:00:00:00:00:00',
        'srcport': 3000,
        'dstport': 3001,
    },
    'l3': {
        'proto': 'tcp',
        'srcip': '1.1.1.1',
        'dstip': '90.90.90.90',
    },
    'vlan': {
        'enabled': False,
        'id': 0,
        'priority': 0,
        'cfi': 0,
    },
}
```

The framesize paramter can be overridden from the configuration files by adding the following to your custom configuration file `10_custom.conf`:

```
TRAFFICGEN_PKT_SIZES = (64, 128,)
```

OR from the commandline:

```
$ ./vsperf --test-param "pkt_sizes=x,y" $TESTNAME
```

You can also modify the traffic transmission duration and the number of trials run by the traffic generator by extending the example commandline above to:

```
$ ./vsperf --test-param "pkt_sizes=x,y;duration=10;rfc2455_trials=3" $TESTNAME
```

## 1.2.3 Dummy Setup

To select the Dummy generator please add the following to your custom configuration file `10_custom.conf`.

```
TRAFFICGEN = 'Dummy'
```

OR run `vsperf` with the `--trafficgen` argument

```
$ ./vsperf --trafficgen Dummy $TESTNAME
```

Where \$TESTNAME is the name of the vsperf test you would like to run. This will setup the vSwitch and the VNF (if one is part of your test) print the traffic configuration and prompt you to transmit traffic when the setup is complete.

```
Please send 'continuous' traffic with the following stream config:
```

```
30mS, 90mpps, multistream False
```

```
and the following flow config:
```

```
{
  "flow_type": "port",
  "l3": {
    "srcip": "1.1.1.1",
    "proto": "tcp",
    "dstip": "90.90.90.90"
  },
  "traffic_type": "continuous",
  "multistream": 0,
  "bidir": "True",
  "vlan": {
    "cfi": 0,
    "priority": 0,
    "id": 0,
    "enabled": false
  },
  "frame_rate": 90,
  "l2": {
    "dstport": 3001,
    "srcport": 3000,
    "dstmac": "00:00:00:00:00:00",
    "srcmac": "00:00:00:00:00:00",
    "framesize": 64
  }
}
```

```
What was the result for 'frames tx'?
```

When your traffic gen has completed traffic transmission and provided the results please input these at the vsperf prompt. vsperf will try to verify the input:

```
Is '$input_value' correct?
```

Please answer with y OR n.

**VPSERF will ask you for:**

- Result for 'frames tx'
- Result for 'frames rx'
- Result for 'min latency'
- Result for 'max latency'
- Result for 'avg latency'

Finally vsperf will print out the results for your test and generate the appropriate logs and csv files.

### 1.2.4 IXIA Setup

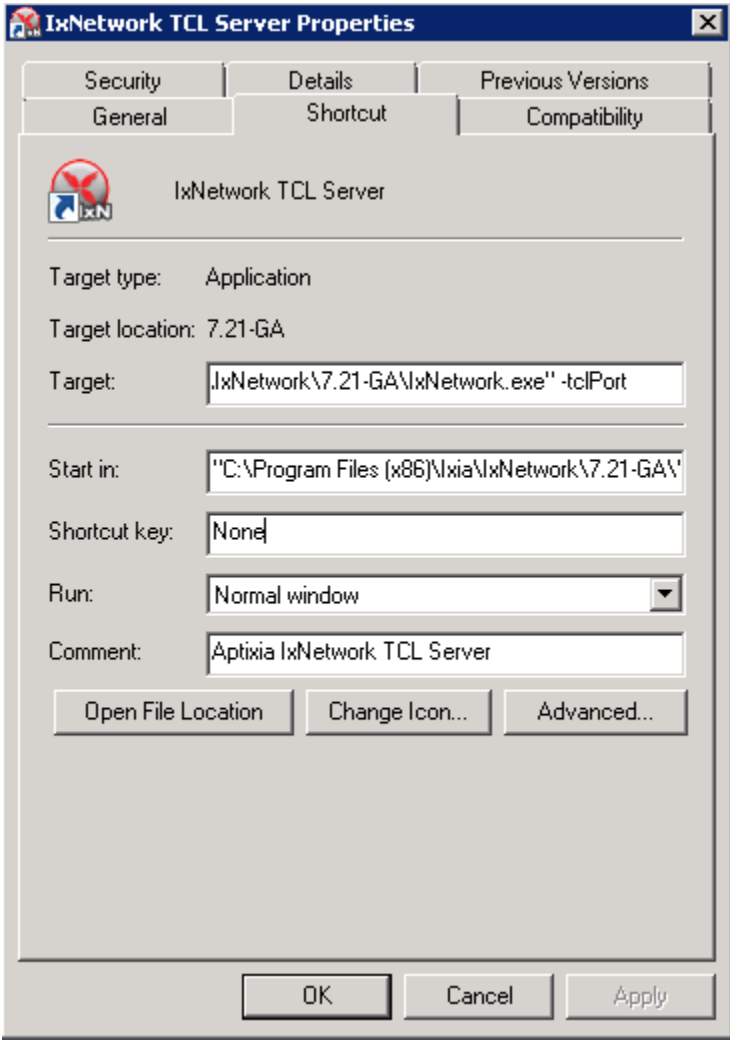
#### On the CentOS 7 system

You need to install IxNetworkTclClient\$(VER\_NUM)Linux.bin.tgz.

#### On the IXIA client software system

Find the IxNetwork TCL server app (start -> All Programs -> IXIA -> IxNetwork -> IxNetwork\_\$(VER\_NUM) -> IxNetwork TCL Server)

Right click on IxNetwork TCL Server, select properties - Under shortcut tab in the Target dialogue box make sure there is the argument “-tclport xxxx” where xxxx is your port number (take note of this port number you will need it for the 10\_custom.conf file).



Hit Ok and start the TCL server application

### 1.2.5 Spirent Setup

Spirent installation files and instructions are available on the Spirent support website at:

<http://support.spirent.com>

Select a version of Spirent TestCenter software to utilize. This example will use Spirent TestCenter v4.57 as an example. Substitute the appropriate version in place of 'v4.57' in the examples, below.

### **On the CentOS 7 System**

Download and install the following:

Spirent TestCenter Application, v4.57 for 64-bit Linux Client

### **Spirent Virtual Deployment Service (VDS)**

Spirent VDS is required for both TestCenter hardware and virtual chassis in the vsperf environment. For installation, select the version that matches the Spirent TestCenter Application version. For v4.57, the matching VDS version is 1.0.55. Download either the ova (VMware) or qcow2 (QEMU) image and create a VM with it. Initialize the VM according to Spirent installation instructions.

### **Using Spirent TestCenter Virtual (STCv)**

STCv is available in both ova (VMware) and qcow2 (QEMU) formats. For VMware, download:

Spirent TestCenter Virtual Machine for VMware, v4.57 for Hypervisor - VMware ESX.ESXi

Virtual test port performance is affected by the hypervisor configuration. For best practice results in deploying STCv, the following is suggested:

- Create a single VM with two test ports rather than two VMs with one port each
- Set STCv in DPDK mode
- Give STCv  $2*n + 1$  cores, where  $n$  = the number of ports. For vsperf, cores = 5.
- Turning off hyperthreading and pinning these cores will improve performance
- Give STCv 2 GB of RAM

To get the highest performance and accuracy, Spirent TestCenter hardware is recommended. vsperf can run with either stype test ports.

## VSPERF USER GUIDE

<<<<<< **HEAD** testusage.rst

>>>>>> **179c643...** Adding document on supporting new testcase integration.rst



## VSPERF DESIGN

### 3.1 VSPERF Design Document

#### 3.1.1 Intended Audience

This document is intended to aid those who want to modify the vsperf code. Or to extend it - for example to add support for new traffic generators, deployment scenarios and so on.

#### 3.1.2 Usage

##### Example Connectivity to DUT

Establish connectivity to the VSPERF DUT Linux host, such as the DUT in Pod 3, by following the steps in [Testbed POD3](#)

The steps cover booking the DUT and establishing the VSPERF environment.

##### Example Command Lines

List all the cli options:

```
$ ./vsperf -h
```

Run all tests that have tput in their name - p2p\_tput, pvp\_tput etc.:

```
$ ./vsperf --tests 'tput'
```

As above but override default configuration with settings in '10\_custom.conf'. This is useful as modifying configuration directly in the configuration files in `conf/NN_*.py` shows up as changes under git source control:

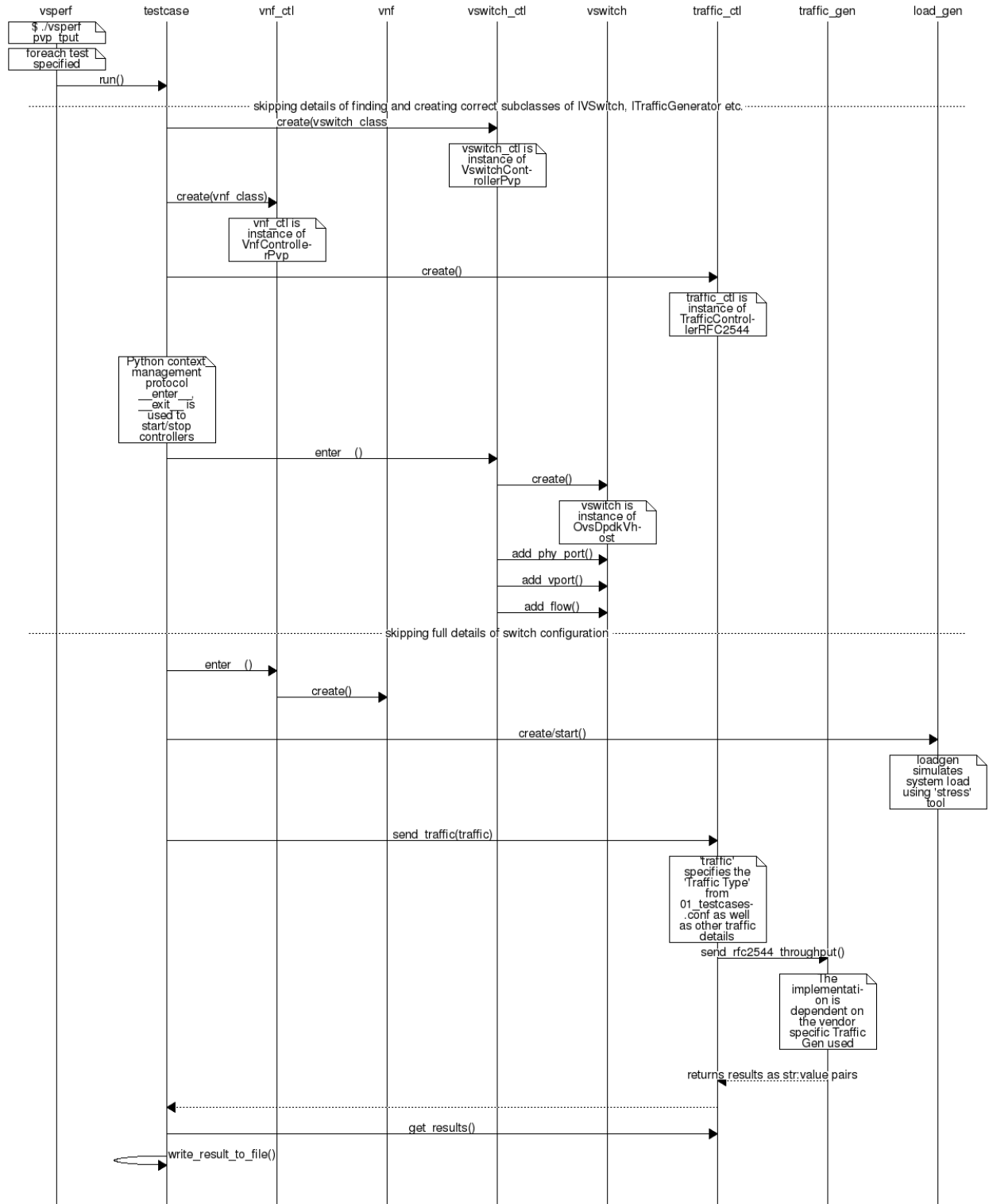
```
$ ./vsperf --conf-file=<path_to_custom_conf>/10_custom.conf --tests 'tput'
```

Override specific test parameters. Useful for shortening the duration of tests for development purposes:

```
$ ./vsperf --test-params 'duration=10;rfc2544_trials=1;pkt_sizes=64' --tests 'pvp_tput'
```

#### 3.1.3 Typical Test Sequence

This is a typical flow of control for a test.



### 3.1.4 Configuration

The conf package contains the configuration files (\*.conf) for all system components, it also provides a settings object that exposes all of these settings.



Settings are not passed from component to component. Rather they are available globally to all components once they import the conf package.

```
from conf import settings
...
log_file = settings.getValue('LOG_FILE_DEFAULT')
```

Settings files (\*.conf) are valid python code so can be set to complex types such as lists and dictionaries as well as scalar types:

```
first_packet_size = settings.getValue('PACKET_SIZE_LIST')[0]
```

## Configuration Procedure and Precedence

Configuration files follow a strict naming convention that allows them to be processed in a specific order. All the .conf files are named NN\_name.conf, where NN is a decimal number. The files are processed in order from 00\_name.conf to 99\_name.conf so that if the name setting is given in both a lower and higher numbered conf file then the higher numbered file is the effective setting as it is processed after the setting in the lower numbered file.

The values in the file specified by --conf-file takes precedence over all the other configuration files and does not have to follow the naming convention.

## Other Configuration

conf.settings also loads configuration from the command line and from the environment.

### 3.1.5 VM, vSwitch, Traffic Generator Independence

VSPERF supports different vSwitches, Traffic Generators, VNFs and Forwarding Applications by using standard object-oriented polymorphism:

- Support for vSwitches is implemented by a class inheriting from IVSwitch.
- Support for Traffic Generators is implemented by a class inheriting from ITrafficGenerator.
- Support for VNF is implemented by a class inheriting from IVNF.
- Support for Forwarding Applications is implemented by a class inheriting from IPktFwd.

By dealing only with the abstract interfaces the core framework can support many implementations of different vSwitches, Traffic Generators, VNFs and Forwarding Applications.

## IVSwitch

```
class IVSwitch:
    start(self)
    stop(self)
    add_switch(switch_name)
    del_switch(switch_name)
    add_phy_port(switch_name)
    add_vport(switch_name)
    get_ports(switch_name)
    del_port(switch_name, port_name)
    add_flow(switch_name, flow)
    del_flow(switch_name, flow=None)
```

## ITrafficGenerator

```
class ITrafficGenerator:
    connect()
    disconnect()

    send_burst_traffic(traffic, numpkts, time, framerate)

    send_cont_traffic(traffic, time, framerate)
    start_cont_traffic(traffic, time, framerate)
    stop_cont_traffic(self):

    send_rfc2544_throughput(traffic, trials, duration, lossrate)
    start_rfc2544_throughput(traffic, trials, duration, lossrate)
    wait_rfc2544_throughput(self)

    send_rfc2544_back2back(traffic, trials, duration, lossrate)
    start_rfc2544_back2back(traffic, , trials, duration, lossrate)
    wait_rfc2544_back2back()
```

Note `send_xxx()` blocks whereas `start_xxx()` does not and must be followed by a subsequent call to `wait_xxx()`.

## IVnf

```
class IVnf:
    start(memory, cpus,
          monitor_path, shared_path_host,
          shared_path_guest, guest_prompt)
    stop()
    execute(command)
    wait(guest_prompt)
    execute_and_wait (command)
```

## IPktFwd

```
class IPktFwd:
    start()
    stop()
```

## Controllers

Controllers are used in conjunction with abstract interfaces as way of decoupling the control of vSwitches, VNFs, TrafficGenerators and Forwarding Applications from other components.

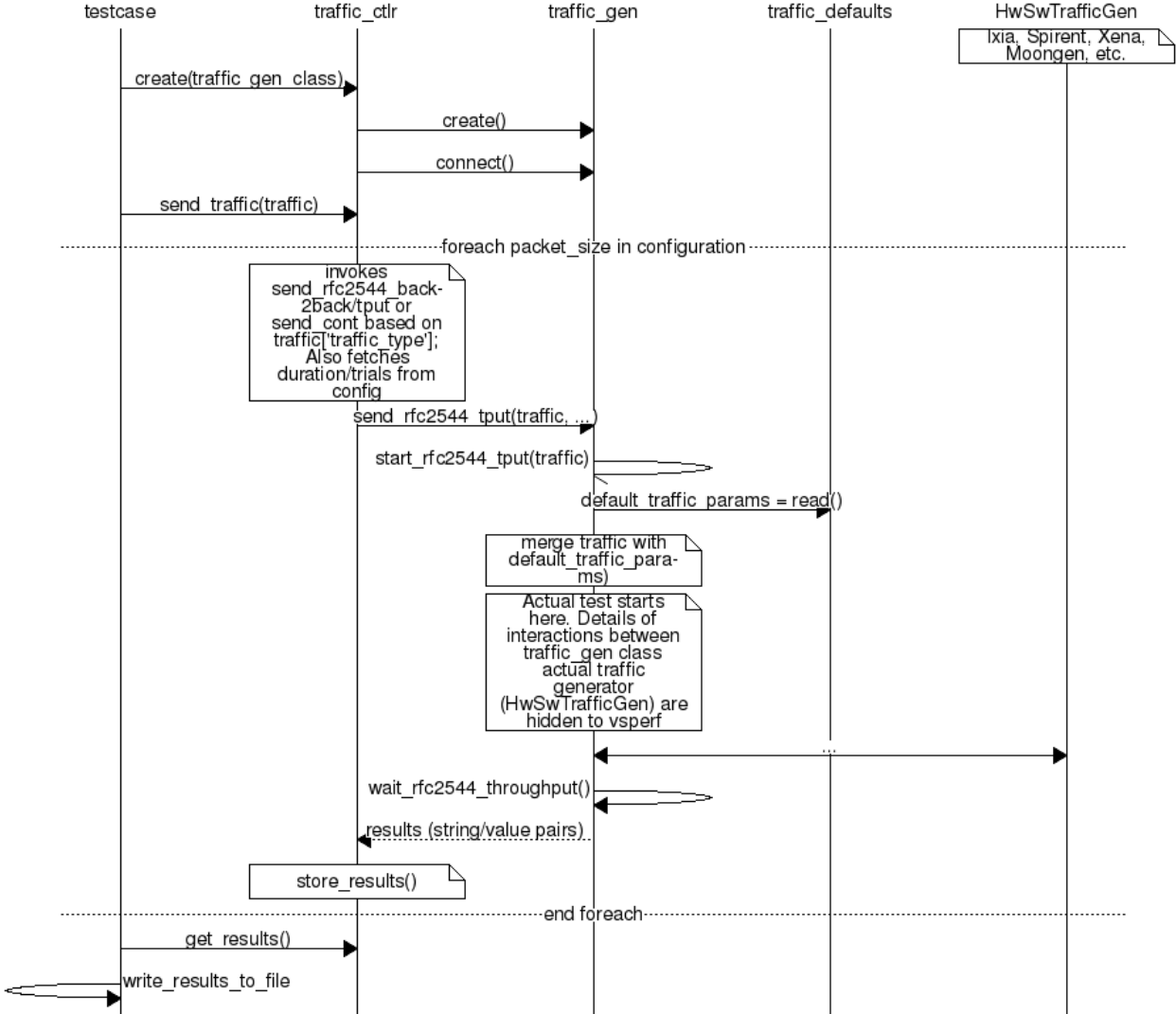
The controlled classes provide basic primitive operations. The Controllers sequence and co-ordinate these primitive operation in to useful actions. For instance the `vswitch_controller_PVP` can be used to bring any vSwitch (that implements the primitives defined in `IVSwitch`) into the configuration required by the Phy-to-Phy Deployment Scenario.

In order to support a new vSwitch only a new implementation of `IVSwitch` needs be created for the new vSwitch to be capable of fulfilling all the Deployment Scenarios provided for by existing or future vSwitch Controllers.

Similarly if a new Deployment Scenario is required it only needs to be written once as a new vSwitch Controller and it will immediately be capable of controlling all existing and future vSwitches in to that Deployment Scenario.

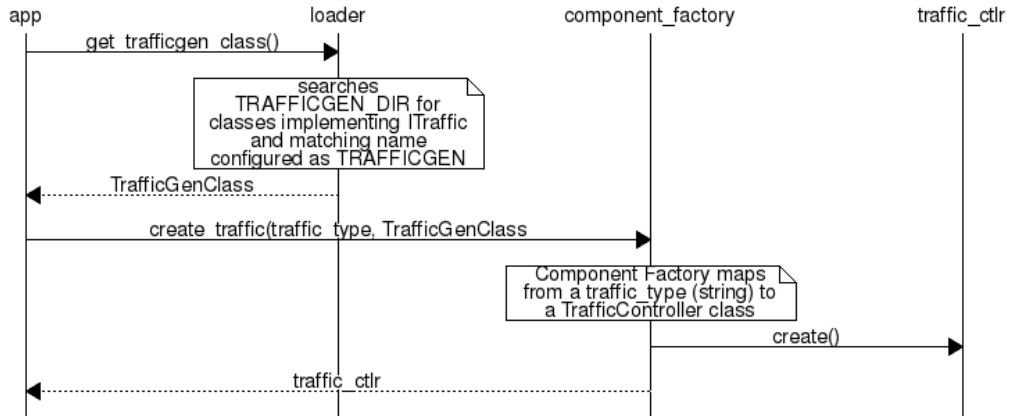
Similarly the Traffic Controllers can be used to co-ordinate basic operations provided by implementers of ITraffic-Generator to provide useful tests. Though traffic generators generally already implement full test cases i.e. they both generate suitable traffic and analyse returned traffic in order to implement a test which has typically been predefined in an RFC document. However the Traffic Controller class allows for the possibility of further enhancement - such as iterating over tests for various packet sizes or creating new tests.

### Traffic Controller's Role



### Loader & Component Factory

The working of the Loader package (which is responsible for *finding* arbitrary classes based on configuration data) and the Component Factory which is responsible for *choosing* the correct class for a particular situation - e.g. Deployment Scenario can be seen in this diagram.



### 3.1.6 Routing Tables

Vsperf uses a standard set of routing tables in order to allow tests to easily mix and match Deployment Scenarios (PVP, P2P topology), Tuple Matching and Frame Modification requirements.

Table 0	table#0 - Match table. Flows designed to force 5 & 10 tuple matches go here.
	v
Table 1	table#1 - Routing table. Flow entries to forward packets between ports goes here. The chosen port is communicated to subsequent tables by setting the metadata value to the egress port number. Generally this table is set-up by the vSwitchController.
	v
Table 2	table#2 - Frame modification table. Frame modification flow rules are isolated in this table so that they can be turned on or off without affecting the routing or tuple-matching flow rules. This allows the frame modification and tuple matching required by the tests in the VSWITCH PERFORMANCE FOR TELCO NFV test specification to be independent of the Deployment Scenario set up by the vSwitchController.
	v
Table 3	table#3 - Egress table. Egress packets on the ports setup in Table 1.

## 3.2 Traffic Generator Integration Guide

### 3.2.1 Intended Audience

This document is intended to aid those who want to integrate new traffic generator into the vsperf code. It is expected, that reader has already read generic part of [VSPERF Design Document](#).

Let us create a sample traffic generator called **sample\_tg**, step by step.

### 3.2.2 Step 1 - create a directory

Implementation of trafficgens is located at tools/pkt\_gen/ directory, where every implementation has its dedicated sub-directory. It is required to create a new directory for new traffic generator implementations.

E.g.

```
$ mkdir tools/pkt_gen/sample_tg
```

### 3.2.3 Step 2 - create a trafficgen module

Every trafficgen class must inherit from generic **ITrafficGenerator** interface class. VSPERF during its initialization scans content of pkt\_gen directory for all python modules, that inherit from **ITrafficGenerator**. These modules are automatically added into the list of supported traffic generators.

Example:

Let us create a draft of tools/pkt\_gen/sample\_tg/sample\_tg.py module.

```
from tools.pkt_gen import trafficgen

class SampleTG(trafficgen.ITrafficGenerator):
    """
    A sample traffic generator implementation
    """
    pass
```

VSPERF is immediately aware of the new class:

```
$ ./vsperf --list-trafficgen
```

Output should look like:

```
Classes derived from: ITrafficGenerator
=====
* Ixia:           A wrapper around the IXIA traffic generator.
* IxNet:          A wrapper around IXIA IxNetwork applications.
* Dummy:          A dummy traffic generator whose data is generated by the user.
* SampleTG:       A sample traffic generator implementation
* TestCenter:     Spirent TestCenter
```

### 3.2.4 Step 3 - configuration

All configuration values, required for correct traffic generator function, are passed from VSPERF to the traffic generator in a dictionary. Default values shared among all traffic generators are defined in `tools/pkt_gen/trafficgen/trafficgenhelper.py` as `TRAFFIC_DEFAULTS` dictionary. Default values are loaded by `ITrafficGenerator` interface class automatically, so it is not needed to load them explicitly. In case that there are any traffic generator specific default values, then they should be set within class specific `__init__` function.

VSPERF passes test specific configuration within `traffic` dictionary to every start and send function. So implementation of these functions must ensure, that default values are updated with the testcase specific values. Proper merge of values is assured by call of `merge_spec` function from `trafficgenhelper` module.

Example of `merge_spec` usage in `tools/pkt_gen/sample_tg/sample_tg.py` module:

```
from tools.pkt_gen.trafficgen.trafficgenhelper import merge_spec

def start_rfc2544_throughput(self, traffic=None, duration=30):
    self._params = {}
    self._params['traffic'] = self.traffic_defaults.copy()
    if traffic:
        self._params['traffic'] = trafficgen.merge_spec(
            self._params['traffic'], traffic)
```

### 3.2.5 Step 4 - generic functions

There are some generic functions, which every traffic generator should provide. Although these functions are mainly optional, at least empty implementation must be provided. This is required, so that developer is explicitly aware of these functions.

The `connect` function is called from the traffic generator controller from its `__enter__` method. This function should assure proper connection initialization between DUT and traffic generator. In case, that such implementation is not needed, empty implementation is required.

The `disconnect` function should perform clean up of any connection specific actions called from the `connect` function.

Example in `tools/pkt_gen/sample_tg/sample_tg.py` module:

```
def connect(self):
    pass

def disconnect(self):
    pass
```

### 3.2.6 Step 5 - supported traffic types

Currently VSPERF supports three different types of tests for traffic generators, these are identified in vsperf through the traffic type, which include:

- **RFC2544 throughput** - Send fixed size packets at different rates, using traffic configuration, until minimum rate at which no packet loss is detected is found. Methods with its implementation have suffix `_rfc2544_throughput`.
- **RFC2544 back2back** - Send fixed size packets at a fixed rate, using traffic configuration, for specified time interval. Methods with its implementation have suffix `_rfc2544_back2back`.
- **continuous flow** - Send fixed size packets at given framerate, using traffic configuration, for specified time interval. Methods with its implementation have suffix `_cont_traffic`.

In general, both synchronous and asynchronous interfaces must be implemented for each traffic type. Synchronous functions start with prefix **send\_**. Asynchronous with prefixes **start\_** and **wait\_** in case of throughput and back2back and **start\_** and **stop\_** in case of continuous traffic type.

Example of synchronous interfaces:

```
def send_rfc2544_throughput(self, traffic=None, trials=3, duration=20,
                           lossrate=0.0, multistream=False):
def send_rfc2544_back2back(self, traffic=None, trials=1, duration=20,
                           lossrate=0.0):
def send_cont_traffic(self, traffic=None, duration=20, multistream=False):
```

Example of asynchronous interfaces:

```
def start_rfc2544_throughput(self, traffic=None, trials=3, duration=20,
                             lossrate=0.0):
def wait_rfc2544_throughput(self):

def start_rfc2544_back2back(self, traffic=None, trials=1, duration=20,
                             lossrate=0.0):
def wait_rfc2544_back2back(self):

def start_cont_traffic(self, traffic=None, duration=20, multistream=False):
def stop_cont_traffic(self):
```

Description of parameters used by **send**, **start**, **wait** and **stop** functions:

- param **trials**: Number of trials to execute
- param **duration**: **Duration of continuous test or per iteration duration** in case of RFC2544 throughput or back2back traffic types.
- param **lossrate**: Acceptable lossrate percentage.
- param **multistream**: Enable or disable multistream feature.

### 3.2.7 Step 6 - passing back results

It is expected that methods **send**, **wait** and **stop** will return values measured by traffic generator within a dictionary. Dictionary keys are defined in **ResultsConstants** implemented in **core/results/results\_constants.py**. Please check sections for RFC2544 Throughput & Continuous and for Back2Back. The same key names should be used by all traffic generator implementations.





## VSPERF LEVEL TEST DESIGN (LTD)

### 4.1 Introduction

The objective of the OPNFV project titled “**Characterize vSwitch Performance for Telco NFV Use Cases**”, is to evaluate a virtual switch to identify its suitability for a Telco Network Function Virtualization (NFV) environment. The intention of this Level Test Design (LTD) document is to specify the set of tests to carry out in order to objectively measure the current characteristics of a virtual switch in the Network Function Virtualization Infrastructure (NFVI) as well as the test pass criteria. The detailed test cases will be defined in *details-of-LTD*, preceded by the *doc-id* and the *scope*.

This document is currently in draft form.

#### 4.1.1 Document identifier

The document id will be used to uniquely identify versions of the LTD. The format for the document id will be: OPNFV\_vswitchperf\_LTD\_REL\_STATUS, where by the status is one of: draft, reviewed, corrected or final. The document id for this version of the LTD is: OPNFV\_vswitchperf\_LTD\_Brahmaputra\_REVIEWED.

#### 4.1.2 Scope

The main purpose of this project is to specify a suite of performance tests in order to objectively measure the current packet transfer characteristics of a virtual switch in the NFVI. The intent of the project is to facilitate testing of any virtual switch. Thus, a generic suite of tests shall be developed, with no hard dependencies to a single implementation. In addition, the test case suite shall be architecture independent.

The test cases developed in this project shall not form part of a separate test framework, all of these tests may be inserted into the Continuous Integration Test Framework and/or the Platform Functionality Test Framework - if a vSwitch becomes a standard component of an OPNFV release.

#### 4.1.3 References

- RFC 1242 Benchmarking Terminology for Network Interconnection Devices
- RFC 2544 Benchmarking Methodology for Network Interconnect Devices
- RFC 2285 Benchmarking Terminology for LAN Switching Devices
- RFC 2889 Benchmarking Methodology for LAN Switching Devices
- RFC 3918 Methodology for IP Multicast Benchmarking
- RFC 4737 Packet Reordering Metrics

- RFC 5481 Packet Delay Variation Applicability Statement
- RFC 6201 Device Reset Characterization

## 4.2 Details of the Level Test Design

This section describes the features to be tested (*FeaturesToBeTested*), the test approach (*Approach*); it also identifies the sets of test cases or scenarios (*TestIdentification*) along with the pass/fail criteria and the test deliverables.

### 4.2.1 Features to be tested

Characterizing virtual switches (i.e. Device Under Test (DUT) in this document) includes measuring the following performance metrics:

- **Throughput** as defined by RFC1242: The maximum rate at which **none** of the offered frames are dropped by the DUT. The maximum frame rate and bit rate that can be transmitted by the DUT without any error should be recorded. Note there is an equivalent bit rate and a specific layer at which the payloads contribute to the bits. Errors and improperly formed frames or packets are dropped.
- **Packet delay** introduced by the DUT and its cumulative effect on E2E networks. Frame delay can be measured equivalently.
- **Packet delay variation**: measured from the perspective of the VNF/application. Packet delay variation is sometimes called “jitter”. However, we will avoid the term “jitter” as the term holds different meaning to different groups of people. In this document we will simply use the term packet delay variation. The preferred form for this metric is the PDV form of delay variation defined in RFC5481. The most relevant measurement of PDV considers the delay variation of a single user flow, as this will be relevant to the size of end-system buffers to compensate for delay variation. The measurement system’s ability to store the delays of individual packets in the flow of interest is a key factor that determines the specific measurement method. At the outset, it is ideal to view the complete PDV distribution. Systems that can capture and store packets and their delays have the freedom to calculate the reference minimum delay and to determine various quantiles of the PDV distribution accurately (in post-measurement processing routines). Systems without storage must apply algorithms to calculate delay and statistical measurements on the fly. For example, a system may store temporary estimates of the minimum delay and the set of (100) packets with the longest delays during measurement (to calculate a high quantile, and update these sets with new values periodically. In some cases, a limited number of delay histogram bins will be available, and the bin limits will need to be set using results from repeated experiments. See section 8 of RFC5481.
- **Packet loss** (within a configured waiting time at the receiver): All packets sent to the DUT should be accounted for.
- **Burst behaviour**: measures the ability of the DUT to buffer packets.
- **Packet re-ordering**: measures the ability of the device under test to maintain sending order throughout transfer to the destination.
- **Packet correctness**: packets or Frames must be well-formed, in that they include all required fields, conform to length requirements, pass integrity checks, etc.
- **Availability and capacity** of the DUT i.e. when the DUT is fully “up” and connected, following measurements should be captured for DUT without any network packet load:
  - Includes average power consumption of the CPUs (in various power states) and system over specified period of time. Time period should not be less than 60 seconds.
  - Includes average per core CPU utilization over specified period of time. Time period should not be less than 60 seconds.

- Includes the number of NIC interfaces supported.
- Includes headroom of VM workload processing cores (i.e. available for applications).

## 4.2.2 Approach

In order to determine the packet transfer characteristics of a virtual switch, the tests will be broken down into the following categories:

### Test Categories

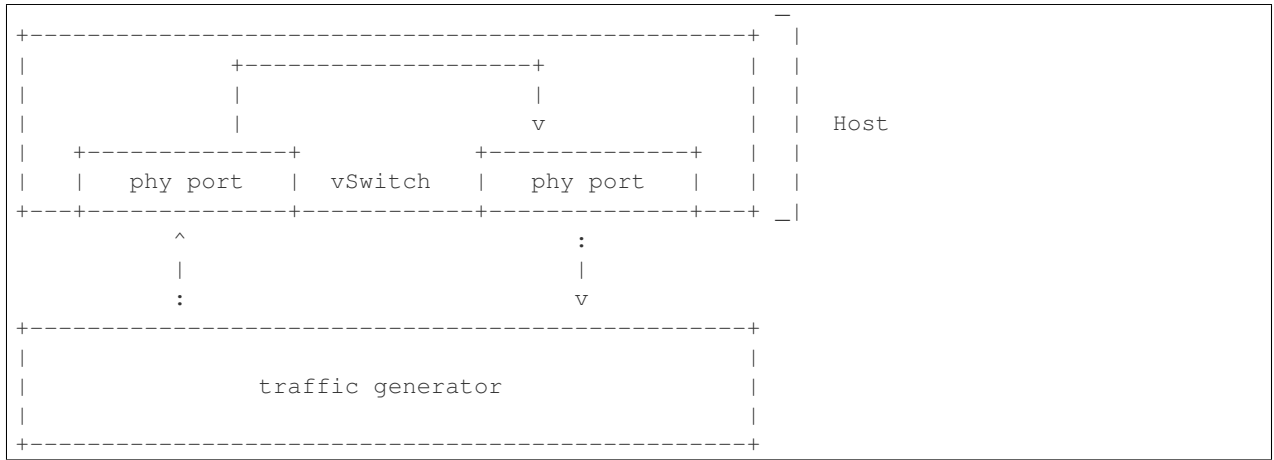
- **Throughput Tests** to measure the maximum forwarding rate (in frames per second or fps) and bit rate (in Mbps) for a constant load (as defined by [RFC1242](#)) without traffic loss.
- **Packet and Frame Delay Tests** to measure average, min and max packet and frame delay for constant loads.
- **Stream Performance Tests** (TCP, UDP) to measure bulk data transfer performance, i.e. how fast systems can send and receive data through the virtual switch.
- **Request/Response Performance Tests** (TCP, UDP) the measure the transaction rate through the virtual switch.
- **Packet Delay Tests** to understand latency distribution for different packet sizes and over an extended test run to uncover outliers.
- **Scalability Tests** to understand how the virtual switch performs as the number of flows, active ports, complexity of the forwarding logic's configuration... it has to deal with increases.
- **Control Path and Datapath Coupling Tests**, to understand how closely coupled the datapath and the control path are as well as the effect of this coupling on the performance of the DUT.
- **CPU and Memory Consumption Tests** to understand the virtual switch's footprint on the system, this includes:
  - CPU core utilization.
  - CPU cache utilization.
  - Memory footprint.
  - System bus (QPI, PCI, ..) utilization.
  - Memory lanes utilization.
  - CPU cycles consumed per packet.
  - Time To Establish Flows Tests.
- **Noisy Neighbour Tests**, to understand the effects of resource sharing on the performance of a virtual switch.

**Note:** some of the tests above can be conducted simultaneously where the combined results would be insightful, for example Packet/Frame Delay and Scalability.

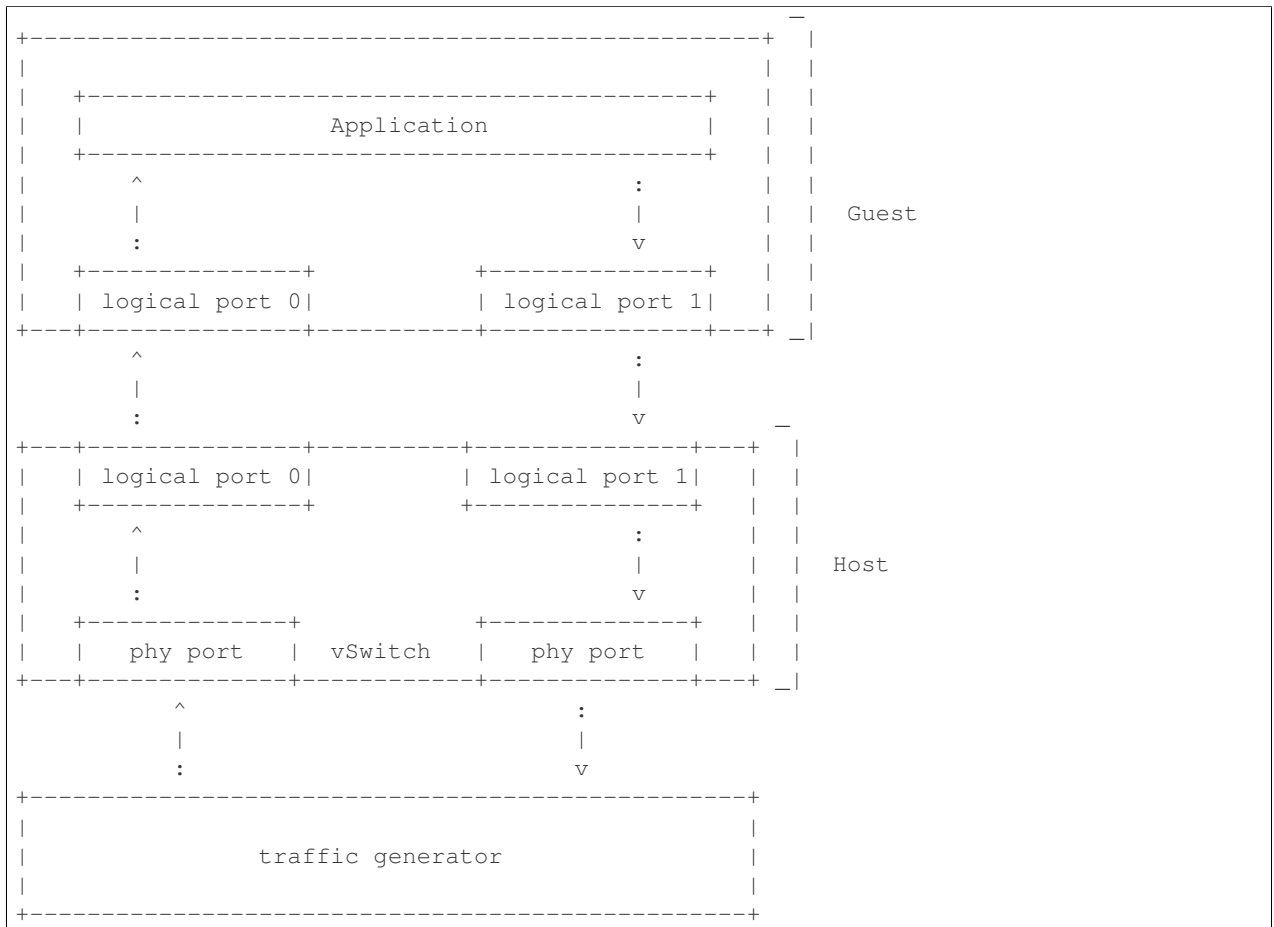
### Deployment Scenarios

The following represents possible deployment test scenarios which can help to determine the performance of both the virtual switch and the datapaths to physical ports (to NICs) and to logical ports (to VNFs):

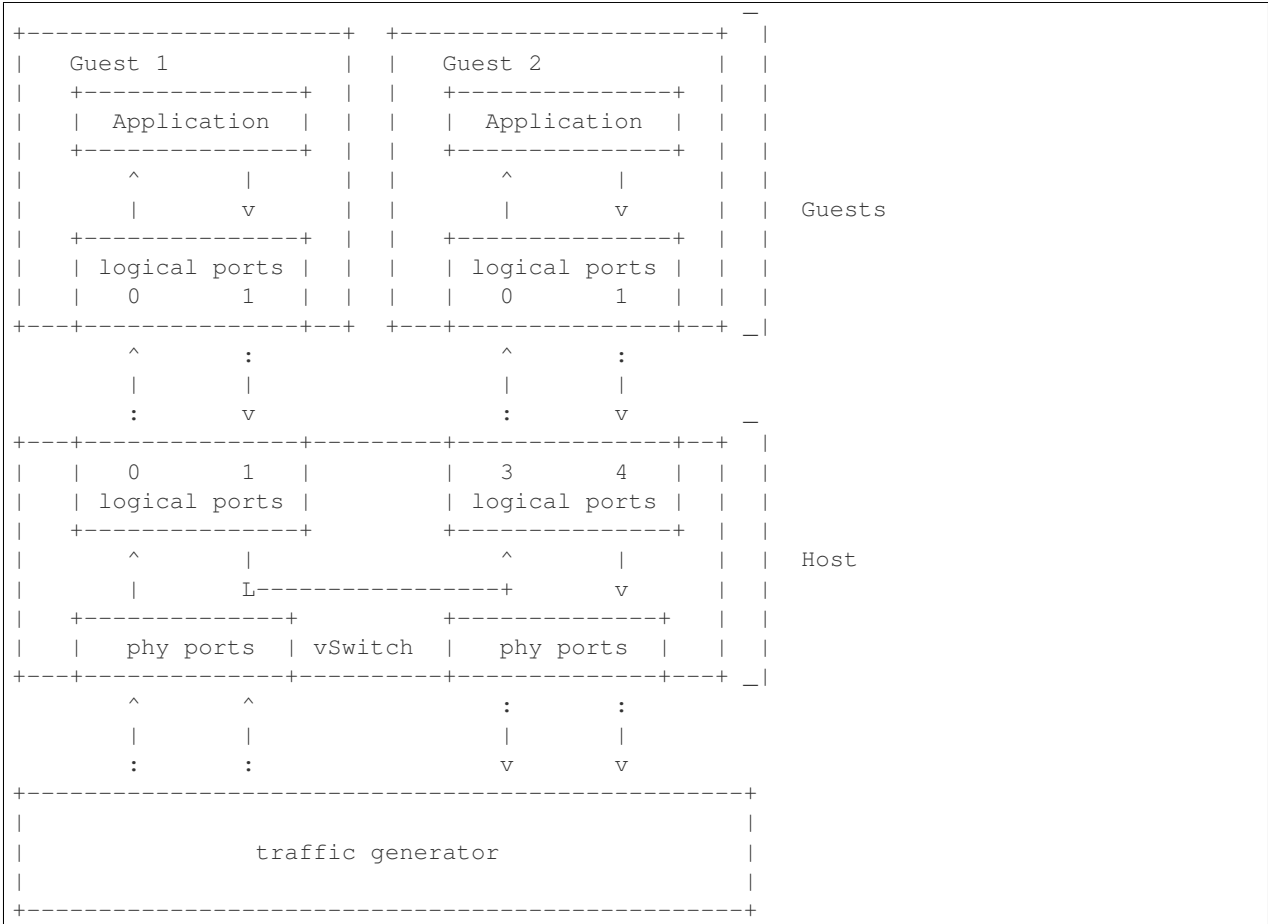
Physical port → vSwitch → physical port



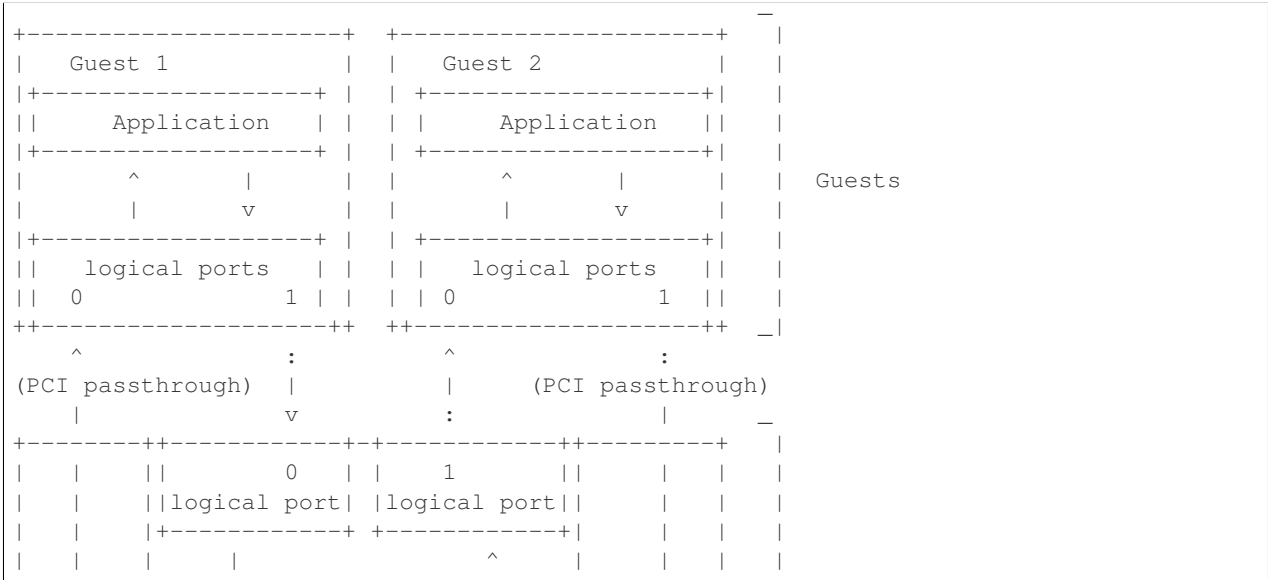
Physical port → vSwitch → VNF → vSwitch → physical port

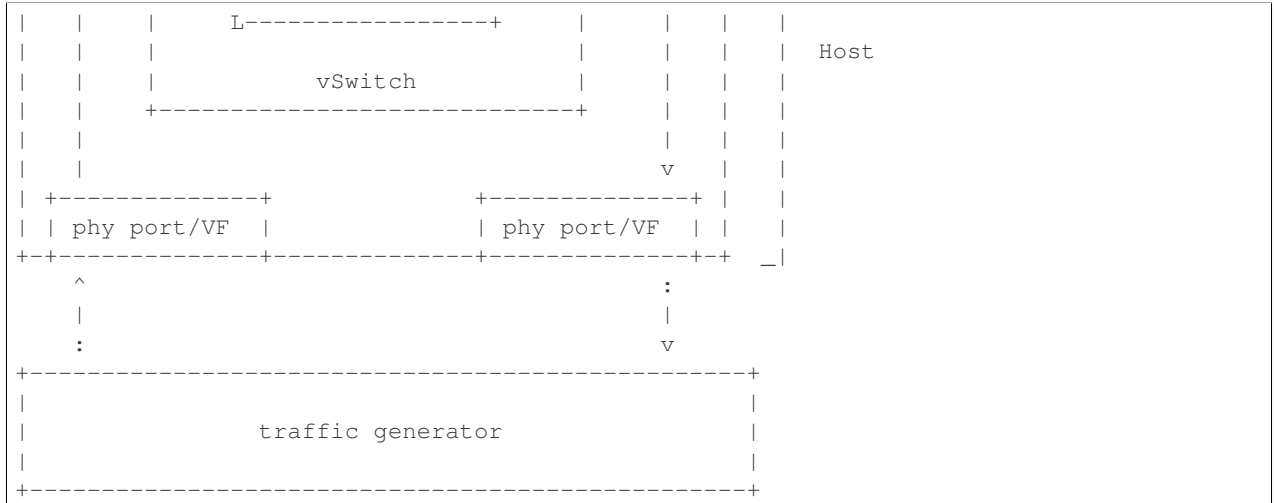


Physical port → vSwitch → VNF → vSwitch → VNF → vSwitch → physical port

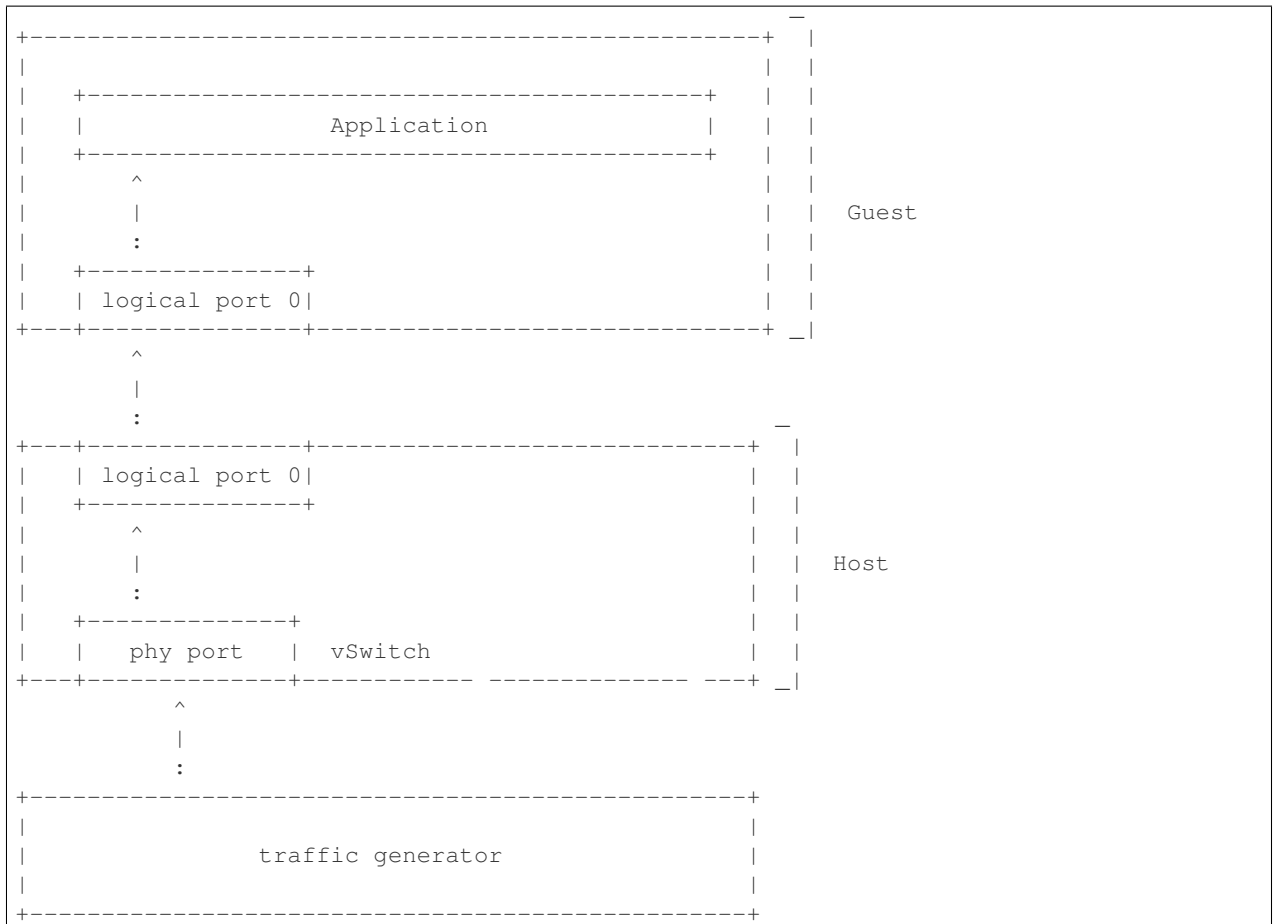


Physical port → VNF → vSwitch → VNF → physical port

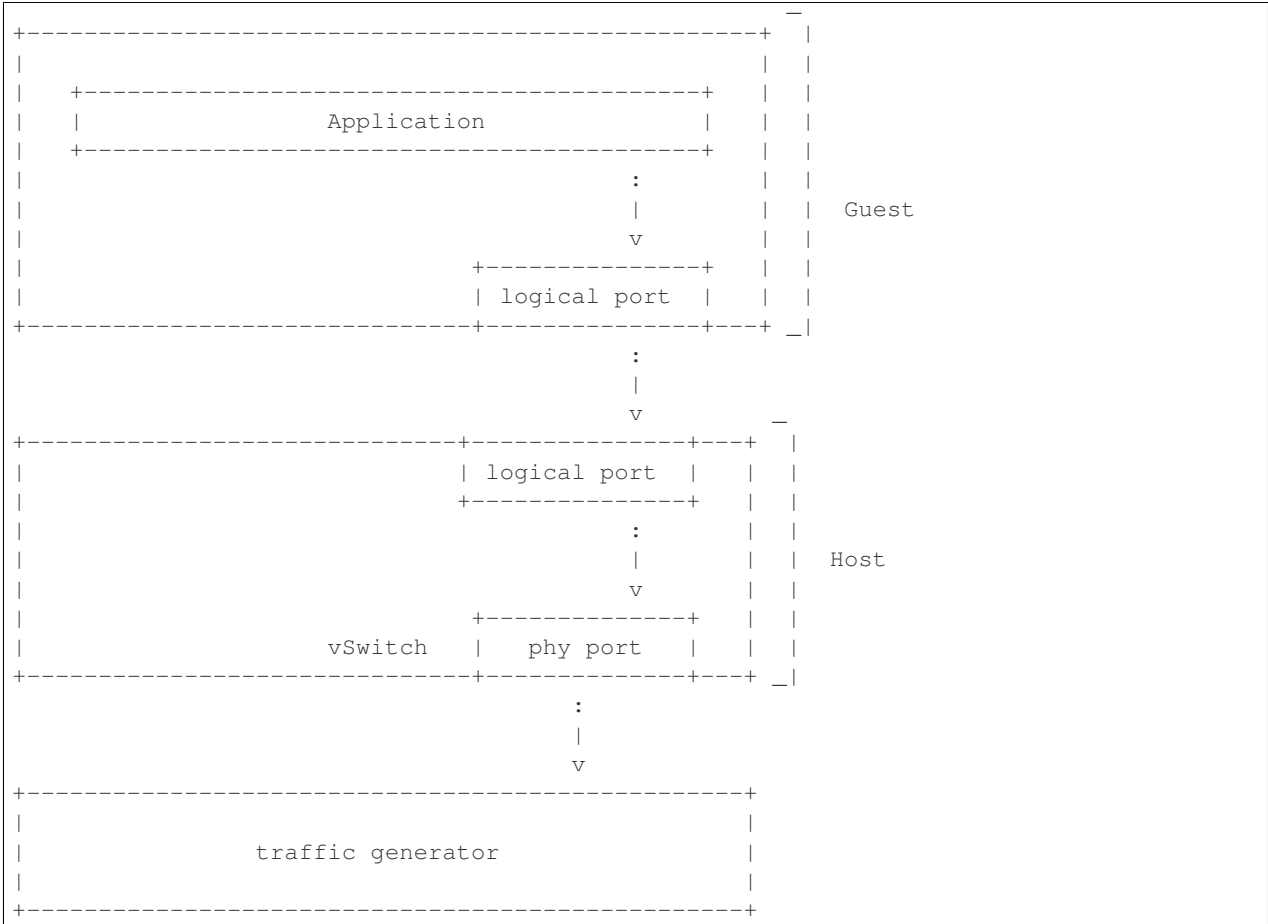




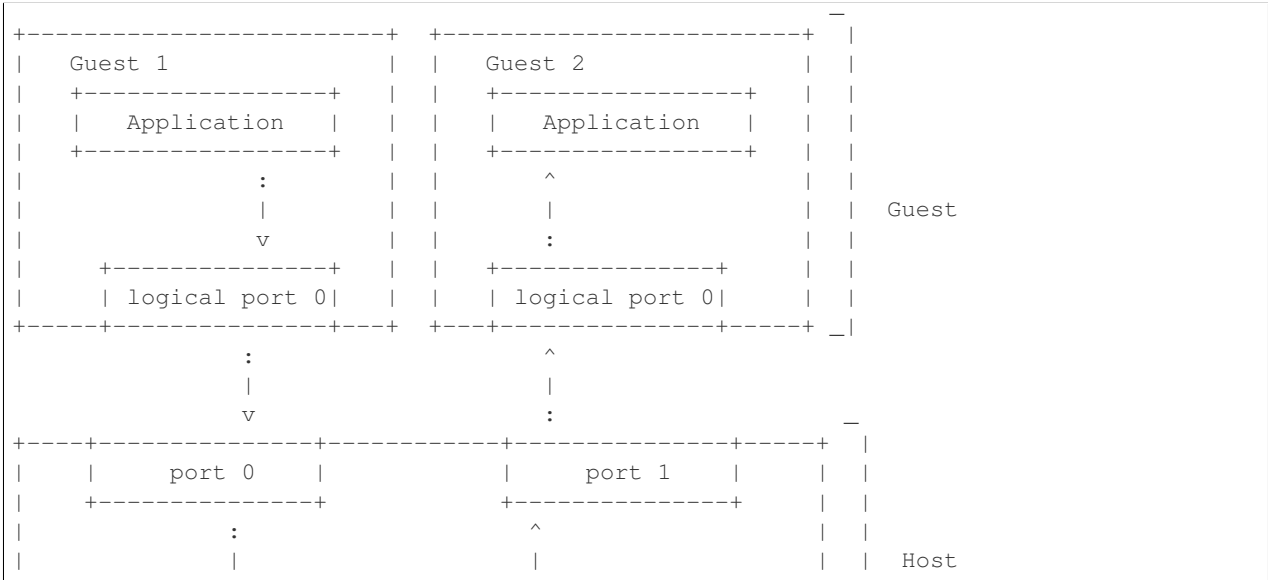
**Physical port → vSwitch → VNF**



VNF → vSwitch → physical port



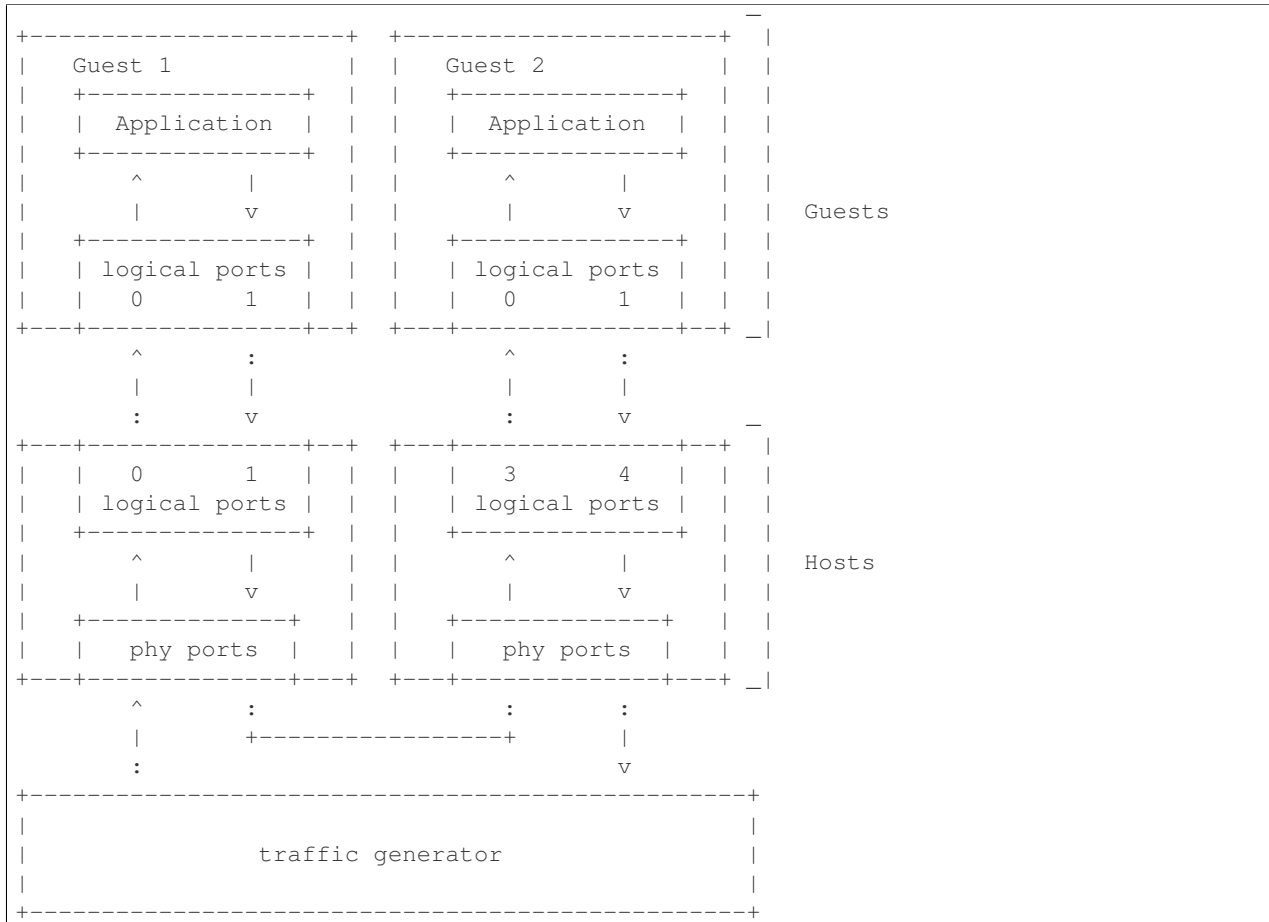
VNF → vSwitch → VNF → vSwitch





HOST 1(Physical port → virtual switch → VNF → virtual switch → Physical port) → HOST 2(Physical port → virtual switch → VNF → virtual switch → Physical port)

**HOST 1 (PVP) → HOST 2 (PVP)**



**Note:** For tests where the traffic generator and/or measurement receiver are implemented on VM and connected to the virtual switch through vNIC, the issues of shared resources and interactions between the measurement devices and the device under test must be considered.

**Note:** Some RFC 2889 tests require a full-mesh sending and receiving pattern involving more than two ports. This possibility is illustrated in the Physical port → vSwitch → VNF → vSwitch → VNF → vSwitch → physical port diagram above (with 2 sending and 2 receiving ports, though all ports could be used bi-directionally).

**Note:** When Deployment Scenarios are used in RFC 2889 address learning or cache capacity testing, an additional port from the vSwitch must be connected to the test device. This port is used to listen for flooded frames.



## General Methodology:

To establish the baseline performance of the virtual switch, tests would initially be run with a simple workload in the VNF (the recommended simple workload VNF would be DPDK's testpmd application forwarding packets in a VM or vloop\_vnf a simple kernel module that forwards traffic between two network interfaces inside the virtualized environment while bypassing the networking stack). Subsequently, the tests would also be executed with a real Telco workload running in the VNF, which would exercise the virtual switch in the context of higher level Telco NFV use cases, and prove that its underlying characteristics and behaviour can be measured and validated. Suitable real Telco workload VNFs are yet to be identified.

## Default Test Parameters

The following list identifies the default parameters for suite of tests:

- Reference application: Simple forwarding or Open Source VNF.
- Frame size (bytes): 64, 128, 256, 512, 1024, 1280, 1518, 2K, 4k OR Packet size based on use-case (e.g. RTP 64B, 256B) OR Mix of packet sizes as maintained by the Functest project <[https://wiki.opnfv.org/traffic\\_profile\\_management](https://wiki.opnfv.org/traffic_profile_management)>.
- Reordering check: Tests should confirm that packets within a flow are not reordered.
- Duplex: Unidirectional / Bidirectional. Default: Full duplex with traffic transmitting in both directions, as network traffic generally does not flow in a single direction. By default the data rate of transmitted traffic should be the same in both directions, please note that asymmetric traffic (e.g. downlink-heavy) tests will be mentioned explicitly for the relevant test cases.
- Number of Flows: Default for non scalability tests is a single flow. For scalability tests the goal is to test with maximum supported flows but where possible will test up to 10 Million flows. Start with a single flow and scale up. By default flows should be added sequentially, tests that add flows simultaneously will explicitly call out their flow addition behaviour. Packets are generated across the flows uniformly with no burstiness. For multi-core tests should consider the number of packet flows based on vSwitch/VNF multi-thread implementation and behavior.
- Traffic Types: UDP, SCTP, RTP, GTP and UDP traffic.
- Deployment scenarios are:
  - Physical → virtual switch → physical.
  - Physical → virtual switch → VNF → virtual switch → physical.
  - Physical → virtual switch → VNF → virtual switch → VNF → virtual switch → physical.
  - Physical → VNF → virtual switch → VNF → physical.
  - Physical → virtual switch → VNF.
  - VNF → virtual switch → Physical.
  - VNF → virtual switch → VNF.

Tests MUST have these parameters unless otherwise stated. **Test cases with non default parameters will be stated explicitly.**

**Note:** For throughput tests unless stated otherwise, test configurations should ensure that traffic traverses the installed flows through the virtual switch, i.e. flows are installed and have an appropriate time out that doesn't expire before packet transmission starts.

## Flow Classification

Virtual switches classify packets into flows by processing and matching particular header fields in the packet/frame and/or the input port where the packets/frames arrived. The vSwitch then carries out an action on the group of packets that match the classification parameters. Thus a flow is considered to be a sequence of packets that have a shared set of header field values or have arrived on the same port and have the same action applied to them. Performance results can vary based on the parameters the vSwitch uses to match for a flow. The recommended flow classification parameters for L3 vSwitch performance tests are: the input port, the source IP address, the destination IP address and the Ethernet protocol type field. It is essential to increase the flow time-out time on a vSwitch before conducting any performance tests that do not measure the flow set-up time. Normally the first packet of a particular flow will install the flow in the vSwitch which adds an additional latency, subsequent packets of the same flow are not subject to this latency if the flow is already installed on the vSwitch.

## Test Priority

Tests will be assigned a priority in order to determine which tests should be implemented immediately and which tests implementations can be deferred.

Priority can be of following types: - Urgent: Must be implemented immediately. - High: Must be implemented in the next release. - Medium: May be implemented after the release. - Low: May or may not be implemented at all.

## SUT Setup

The SUT should be configured to its “default” state. The SUT’s configuration or set-up must not change between tests in any way other than what is required to do the test. All supported protocols must be configured and enabled for each test set up.

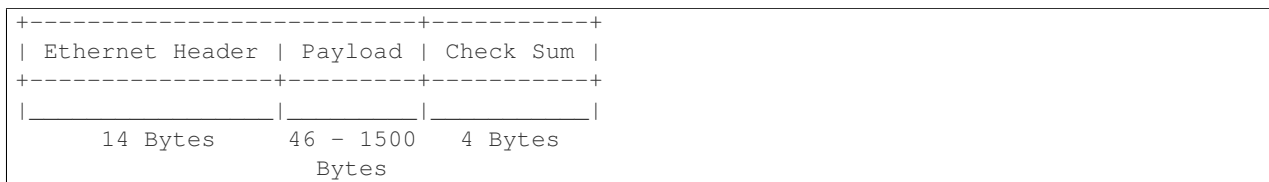
## Port Configuration

The DUT should be configured with n ports where n is a multiple of 2. Half of the ports on the DUT should be used as ingress ports and the other half of the ports on the DUT should be used as egress ports. Where a DUT has more than 2 ports, the ingress data streams should be set-up so that they transmit packets to the egress ports in sequence so that there is an even distribution of traffic across ports. For example, if a DUT has 4 ports 0(ingress), 1(ingress), 2(egress) and 3(egress), the traffic stream directed at port 0 should output a packet to port 2 followed by a packet to port 3. The traffic stream directed at port 1 should also output a packet to port 2 followed by a packet to port 3.

## Frame Formats

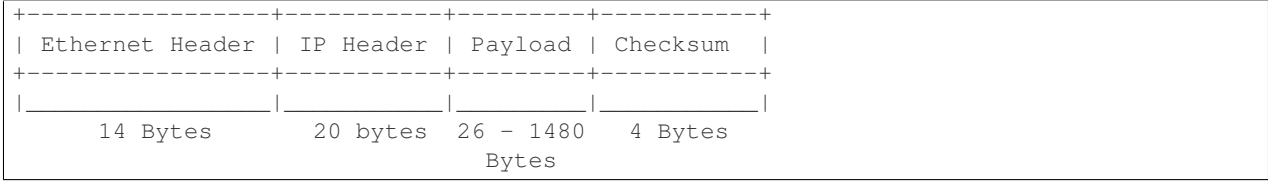
### Frame formats Layer 2 (data link layer) protocols

- Ethernet II

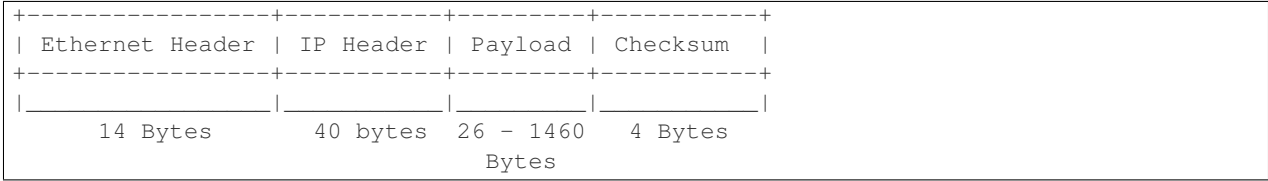


### Layer 3 (network layer) protocols

- IPv4

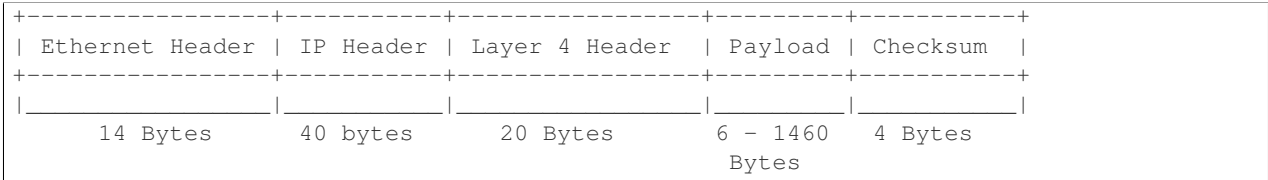


- IPv6



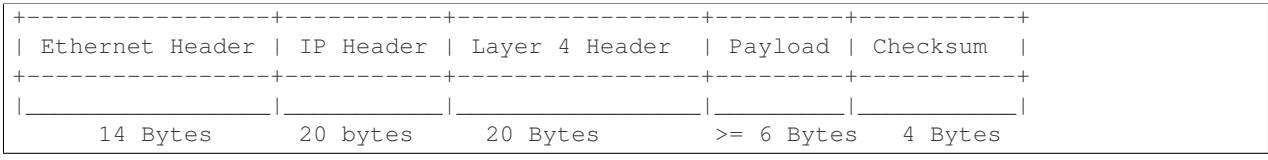
**Layer 4 (transport layer) protocols**

- TCP
- UDP
- SCTP



**Layer 5 (application layer) protocols**

- RTP
- GTP



**Packet Throughput**

There is a difference between an Ethernet frame, an IP packet, and a UDP datagram. In the seven-layer OSI model of computer networking, packet refers to a data unit at layer 3 (network layer). The correct term for a data unit at layer 2 (data link layer) is a frame, and at layer 4 (transport layer) is a segment or datagram.

Important concepts related to 10GbE performance are frame rate and throughput. The MAC bit rate of 10GbE, defined in the IEEE standard 802.3ae, is 10 billion bits per second. Frame rate is based on the bit rate and frame format definitions. Throughput, defined in IETF RFC 1242, is the highest rate at which the system under test can forward the offered load, without loss.

The frame rate for 10GbE is determined by a formula that divides the 10 billion bits per second by the preamble + frame length + inter-frame gap.

The maximum frame rate is calculated using the minimum values of the following parameters, as described in the IEEE 802.3ae standard:

- Preamble: 8 bytes \* 8 = 64 bits

- Frame Length: 64 bytes (minimum) \* 8 = 512 bits
- Inter-frame Gap: 12 bytes (minimum) \* 8 = 96 bits

Therefore, Maximum Frame Rate (64B Frames) = MAC Transmit Bit Rate / (Preamble + Frame Length + Inter-frame Gap) = 10,000,000,000 / (64 + 512 + 96) = 10,000,000,000 / 672 = 14,880,952.38 frame per second (fps)

### System isolation and validation

A key consideration when conducting any sort of benchmark is trying to ensure the consistency and repeatability of test results between runs. When benchmarking the performance of a virtual switch there are many factors that can affect the consistency of results. This section describes these factors and the measures that can be taken to limit their effects. In addition, this section will outline some system tests to validate the platform and the VNF before conducting any vSwitch benchmarking tests.

#### System Isolation:

When conducting a benchmarking test on any SUT, it is essential to limit (and if reasonable, eliminate) any noise that may interfere with the accuracy of the metrics collected by the test. This noise may be introduced by other hardware or software (OS, other applications), and can result in significantly varying performance metrics being collected between consecutive runs of the same test. In the case of characterizing the performance of a virtual switch, there are a number of configuration parameters that can help increase the repeatability and stability of test results, including:

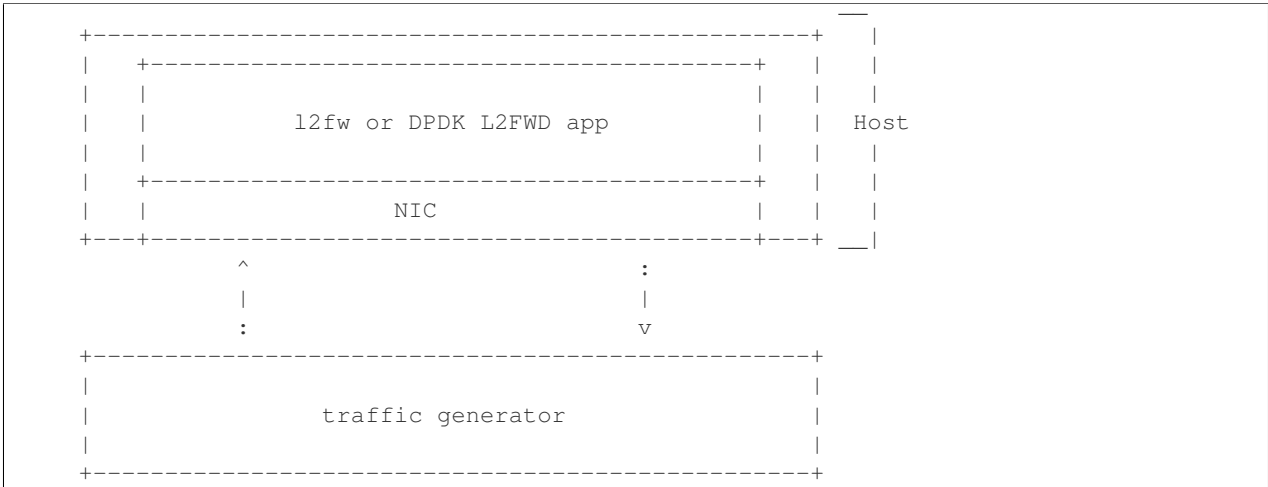
- OS/GRUB configuration:
  - maxcpus = n where n >= 0; limits the kernel to using 'n' processors. Only use exactly what you need.
  - isolcpus: Isolate CPUs from the general scheduler. Isolate all CPUs bar one which will be used by the OS.
  - use taskset to affinitize the forwarding application and the VNFs onto isolated cores. VNFs and the vSwitch should be allocated their own cores, i.e. must not share the same cores. vCPUs for the VNF should be affinitized to individual cores also.
  - Limit the amount of background applications that are running and set OS to boot to runlevel 3. Make sure to kill any unnecessary system processes/daemons.
  - Only enable hardware that you need to use for your test – to ensure there are no other interrupts on the system.
  - Configure NIC interrupts to only use the cores that are not allocated to any other process (VNF/vSwitch).
- NUMA configuration: Any unused sockets in a multi-socket system should be disabled.
- CPU pinning: The vSwitch and the VNF should each be affinitized to separate logical cores using a combination of maxcpus, isolcpus and taskset.
- BIOS configuration: BIOS should be configured for performance where an explicit option exists, sleep states should be disabled, any virtualization optimization technologies should be enabled, and hyperthreading should also be enabled, turbo boost and overlocking should be disabled.

#### System Validation:

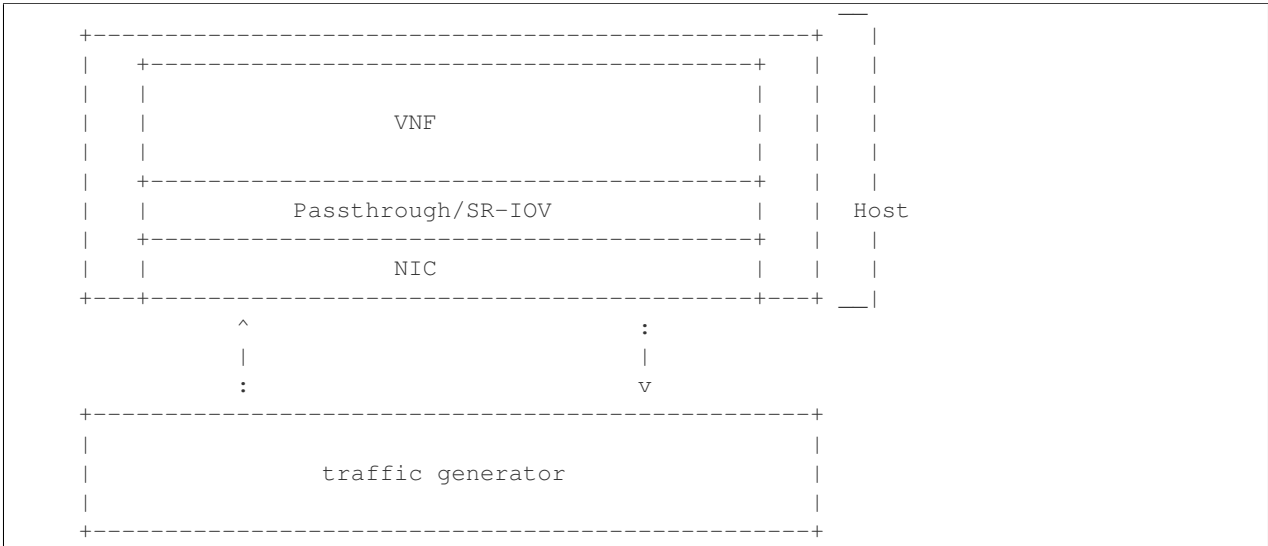
System validation is broken down into two sub-categories: Platform validation and VNF validation. The validation test itself involves verifying the forwarding capability and stability for the sub-system under test. The rationale behind system validation is two fold. Firstly to give a tester confidence in the stability of the platform or VNF that is being tested; and secondly to provide base performance comparison points to understand the overhead introduced by the virtual switch.

- Benchmark platform forwarding capability: This is an OPTIONAL test used to verify the platform and measure the base performance (maximum forwarding rate in fps and latency) that can be achieved by the platform

without a vSwitch or a VNF. The following diagram outlines the set-up for benchmarking Platform forwarding capability:



- **Benchmark VNF forwarding capability:** This test is used to verify the VNF and measure the base performance (maximum forwarding rate in fps and latency) that can be achieved by the VNF without a vSwitch. The performance metrics collected by this test will serve as a key comparison point for NIC passthrough technologies and vSwitches. VNF in this context refers to the hypervisor and the VM. The following diagram outlines the set-up for benchmarking VNF forwarding capability:



**Methodology to benchmark Platform/VNF forwarding capability**

The recommended methodology for the platform/VNF validation and benchmark is: - Run RFC2889 Maximum Forwarding Rate test, this test will produce maximum forwarding rate and latency results that will serve as the expected values. These expected values can be used in subsequent steps or compared with in subsequent validation tests. - Transmit bidirectional traffic at line rate/max forwarding rate (whichever is higher) for at least 72 hours, measure throughput (fps) and latency. - Note: Traffic should be bidirectional. - Establish a baseline forwarding rate for what the platform can achieve. - Additional validation: After the test has completed for 72 hours run bidirectional traffic at the maximum forwarding rate once more to see if the system is still functional and measure throughput (fps) and latency. Compare the measure the new obtained values with the expected values.

**NOTE 1:** How the Platform is configured for its forwarding capability test (BIOS settings, GRUB configuration, runlevel...) is how the platform should be configured for every test after this

**NOTE 2:** How the VNF is configured for its forwarding capability test (# of vCPUs, vNICs, Memory, affinitization...) is how it should be configured for every test that uses a VNF after this.

### RFCs for testing virtual switch performance

The starting point for defining the suite of tests for benchmarking the performance of a virtual switch is to take existing RFCs and standards that were designed to test their physical counterparts and adapting them for testing virtual switches. The rationale behind this is to establish a fair comparison between the performance of virtual and physical switches. This section outlines the RFCs that are used by this specification.

#### RFC 1242 Benchmarking Terminology for Network Interconnection

Devices RFC 1242 defines the terminology that is used in describing performance benchmarking tests and their results. Definitions and discussions covered include: Back-to-back, bridge, bridge/router, constant load, data link frame size, frame loss rate, inter frame gap, latency, and many more.

#### RFC 2544 Benchmarking Methodology for Network Interconnect Devices

RFC 2544 outlines a benchmarking methodology for network Interconnect Devices. The methodology results in performance metrics such as latency, frame loss percentage, and maximum data throughput.

In this document network “throughput” (measured in millions of frames per second) is based on RFC 2544, unless otherwise noted. Frame size refers to Ethernet frames ranging from smallest frames of 64 bytes to largest frames of 9K bytes.

Types of tests are:

1. Throughput test defines the maximum number of frames per second that can be transmitted without any error.
2. Latency test measures the time required for a frame to travel from the originating device through the network to the destination device. Please note that RFC2544 Latency measurement will be superseded with a measurement of average latency over all successfully transferred packets or frames.
3. Frame loss test measures the network’s response in overload conditions - a critical indicator of the network’s ability to support real-time applications in which a large amount of frame loss will rapidly degrade service quality.
4. Burst test assesses the buffering capability of a virtual switch. It measures the maximum number of frames received at full line rate before a frame is lost. In carrier Ethernet networks, this measurement validates the excess information rate (EIR) as defined in many SLAs.
5. System recovery to characterize speed of recovery from an overload condition.
6. Reset to characterize speed of recovery from device or software reset. This type of test has been updated by [RFC6201](#) as such, the methodology defined by this specification will be that of RFC 6201.

Although not included in the defined RFC 2544 standard, another crucial measurement in Ethernet networking is packet delay variation. The definition set out by this specification comes from [RFC5481](#).

#### RFC 2285 Benchmarking Terminology for LAN Switching Devices

RFC 2285 defines the terminology that is used to describe the terminology for benchmarking a LAN switching device. It extends RFC 1242 and defines: DUTs, SUTs, Traffic orientation and distribution, bursts, loads, forwarding rates, etc.

### **RFC 2889 Benchmarking Methodology for LAN Switching**

RFC 2889 outlines a benchmarking methodology for LAN switching, it extends RFC 2544. The outlined methodology gathers performance metrics for forwarding, congestion control, latency, address handling and finally filtering.

### **RFC 3918 Methodology for IP Multicast Benchmarking**

RFC 3918 outlines a methodology for IP Multicast benchmarking.

### **RFC 4737 Packet Reordering Metrics**

RFC 4737 describes metrics for identifying and counting re-ordered packets within a stream, and metrics to measure the extent each packet has been re-ordered.

### **RFC 5481 Packet Delay Variation Applicability Statement**

RFC 5481 defined two common, but different forms of delay variation metrics, and compares the metrics over a range of networking circumstances and tasks. The most suitable form for vSwitch benchmarking is the “PDV” form.

### **RFC 6201 Device Reset Characterization**

RFC 6201 extends the methodology for characterizing the speed of recovery of the DUT from device or software reset described in RFC 2544.

## **Details of the Test Report**

There are a number of parameters related to the system, DUT and tests that can affect the repeatability of a test results and should be recorded. In order to minimise the variation in the results of a test, it is recommended that the test report includes the following information:

- Hardware details including:
  - Platform details.
  - Processor details.
  - Memory information (see below)
  - Number of enabled cores.
  - Number of cores used for the test.
  - Number of physical NICs, as well as their details (manufacturer, versions, type and the PCI slot they are plugged into).
  - NIC interrupt configuration.
  - BIOS version, release date and any configurations that were modified.
- Software details including:
  - 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 parameterised.
- Memory allocation to the vSwitch – which NUMA node it is using, and how many memory channels.
- Where the vswitch is built from source: compiler details including versions and the flags that were used to compile the vSwitch.
- DPDK or any other SW dependency version number or commit id used.
- Memory allocation to a VM - if it's from Hupages/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 vNIC interrupt configuration.
- 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).
- Memory Details
  - Total memory
  - Type of memory
  - Used memory
  - Active memory
  - Inactive memory
  - Free memory
  - Buffer memory
  - Swap cache
  - Total swap
  - Used swap
  - Free swap
- Test duration.
- Number of flows.
- Traffic Information:
  - Traffic type - UDP, TCP, IMIX / Other.
  - Packet Sizes.
- Deployment Scenario.

**Note:** Tests that require additional parameters to be recorded will explicitly specify this.



## 4.2.3 Test identification

### Throughput tests

The following tests aim to determine the maximum forwarding rate that can be achieved with a virtual switch. The list is not exhaustive but should indicate the type of tests that should be required. It is expected that more will be added.

#### Test ID: LTD.Throughput.RFC2544.PacketLossRatio

**Title:** RFC 2544 X% packet loss Throughput and Latency Test

**Prerequisite Test:** N/A

**Priority:**

**Description:**

This test determines the DUT's maximum forwarding rate with X% traffic loss for a constant load (fixed length frames at a fixed interval time). The default loss percentages to be tested are: - X = 0% - X = 10<sup>-7</sup>%

Note: Other values can be tested if required by the user.

The selected frame sizes are those previously defined under *Default Test Parameters*. The test can also be used to determine the average latency of the traffic.

Under the [RFC2544](#) test methodology, the test duration will include a number of trials; each trial should run for a minimum period of 60 seconds. A binary search methodology must be applied for each trial to obtain the final result.

**Expected Result:** At the end of each trial, the presence or absence of loss determines the modification of offered load for the next trial, converging on a maximum rate, or [RFC2544](#) Throughput with X% loss. The Throughput load is re-used in related [RFC2544](#) tests and other tests.

**Metrics Collected:**

The following are the metrics collected for this test:

- The maximum forwarding rate in Frames Per Second (FPS) and Mbps of the DUT for each frame size with X% packet loss.
- The average latency of the traffic flow when passing through the DUT (if testing for latency, note that this average is different from the test specified in Section 26.3 of [RFC2544](#)).
- CPU and memory utilization may also be collected as part of this test, to determine the vSwitch's performance footprint on the system.

#### Test ID: LTD.Throughput.RFC2544.PacketLossRatioFrameModification

**Title:** RFC 2544 X% packet loss Throughput and Latency Test with packet modification

**Prerequisite Test:** N/A

**Priority:**

**Description:**

This test determines the DUT's maximum forwarding rate with X% traffic loss for a constant load (fixed length frames at a fixed interval time). The default loss percentages to be tested are: - X = 0% - X = 10<sup>-7</sup>%

Note: Other values can be tested if required by the user.

The selected frame sizes are those previously defined under *Default Test Parameters*. The test can also be used to determine the average latency of the traffic.

Under the [RFC2544](#) test methodology, the test duration will include a number of trials; each trial should run for a minimum period of 60 seconds. A binary search methodology must be applied for each trial to obtain the final result.

During this test, the DUT must perform the following operations on the traffic flow:

- Perform packet parsing on the DUT's ingress port.
- Perform any relevant address look-ups on the DUT's ingress ports.
- Modify the packet header before forwarding the packet to the DUT's egress port. Packet modifications include:
  - Modifying the Ethernet source or destination MAC address.
  - Modifying/adding a VLAN tag. (**Recommended**).
  - Modifying/adding a MPLS tag.
  - Modifying the source or destination ip address.
  - Modifying the TOS/DSCP field.
  - Modifying the source or destination ports for UDP/TCP/SCTP.
  - Modifying the TTL.

**Expected Result:** The Packet parsing/modifications require some additional degree of processing resource, therefore the [RFC2544](#) Throughput is expected to be somewhat lower than the Throughput level measured without additional steps. The reduction is expected to be greatest on tests with the smallest packet sizes (greatest header processing rates).

**Metrics Collected:**

The following are the metrics collected for this test:

- The maximum forwarding rate in Frames Per Second (FPS) and Mbps of the DUT for each frame size with X% packet loss and packet modification operations being performed by the DUT.
- The average latency of the traffic flow when passing through the DUT (if testing for latency, note that this average is different from the test specified in Section 26.3 of [RFC2544](#)).
- The [RFC5481](#) PDV form of delay variation on the traffic flow, using the 99th percentile.
- CPU and memory utilization may also be collected as part of this test, to determine the vSwitch's performance footprint on the system.

**Test ID: LTD.Throughput.RFC2544.Profile**

**Title:** RFC 2544 Throughput and Latency Profile

**Prerequisite Test:** N/A

**Priority:**

**Description:**

This test reveals how throughput and latency degrades as the offered rate varies in the region of the DUT's maximum forwarding rate as determined by LTD.Throughput.RFC2544.PacketLossRatio (0%

Packet Loss). For example it can be used to determine if the degradation of throughput and latency as the offered rate increases is slow and graceful or sudden and severe.

The selected frame sizes are those previously defined under *Default Test Parameters*.

The offered traffic rate is described as a percentage delta with respect to the DUT's RFC 2544 Throughput as determined by LTD.Throughput.RFC2544.PacketLoss Ratio (0% Packet Loss case). A delta of 0% is equivalent to an offered traffic rate equal to the RFC 2544 Throughput; A delta of +50% indicates an offered rate half-way between the Throughput and line-rate, whereas a delta of -50% indicates an offered rate of half the maximum rate. Therefore the range of the delta figure is naturally bounded at -100% (zero offered traffic) and +100% (traffic offered at line rate).

The following deltas to the maximum forwarding rate should be applied:

- -50%, -10%, 0%, +10% & +50%

**Expected Result:** For each packet size a profile should be produced of how throughput and latency vary with offered rate.

**Metrics Collected:**

The following are the metrics collected for this test:

- The forwarding rate in Frames Per Second (FPS) and Mbps of the DUT for each delta to the maximum forwarding rate and for each frame size.
- The average latency for each delta to the maximum forwarding rate and for each frame size.
- CPU and memory utilization may also be collected as part of this test, to determine the vSwitch's performance footprint on the system.
- Any failures experienced (for example if the vSwitch crashes, stops processing packets, restarts or becomes unresponsive to commands) when the offered load is above Maximum Throughput MUST be recorded and reported with the results.

**Test ID: LTD.Throughput.RFC2544.SystemRecoveryTime**

**Title:** RFC 2544 System Recovery Time Test

**Prerequisite Test** LTD.Throughput.RFC2544.PacketLossRatio

**Priority:**

**Description:**

The aim of this test is to determine the length of time it takes the DUT to recover from an overload condition for a constant load (fixed length frames at a fixed interval time). The selected frame sizes are those previously defined under *Default Test Parameters*, traffic should be sent to the DUT under normal conditions. During the duration of the test and while the traffic flows are passing through the DUT, at least one situation leading to an overload condition for the DUT should occur. The time from the end of the overload condition to when the DUT returns to normal operations should be measured to determine recovery time. Prior to overloading the DUT, one should record the average latency for 10,000 packets forwarded through the DUT.

The overload condition SHOULD be to transmit traffic at a very high frame rate to the DUT (150% of the maximum 0% packet loss rate as determined by LTD.Throughput.RFC2544.PacketLossRatio or line-rate whichever is lower), for at least 60 seconds, then reduce the frame rate to 75% of the maximum 0% packet loss rate. A number of time-stamps should be recorded: - Record the time-stamp at which the frame rate was reduced and record a second time-stamp at the time of the last frame lost. The recovery time is the difference between the two timestamps. - Record the average latency for 10,000 frames after the last

frame loss and continue to record average latency measurements for every 10,000 frames, when latency returns to within 10% of pre-overload levels record the time-stamp.

**Expected Result:**

**Metrics collected**

The following are the metrics collected for this test:

- The length of time it takes the DUT to recover from an overload condition.
- The length of time it takes the DUT to recover the average latency to pre-overload conditions.

**Deployment scenario:**

- Physical → virtual switch → physical.

**Test ID: LTD.Throughput.RFC2544.BackToBackFrames**

**Title:** RFC2544 Back To Back Frames Test

**Prerequisite Test:** N

**Priority:**

**Description:**

The aim of this test is to characterize the ability of the DUT to process back-to-back frames. For each frame size previously defined under *Default Test Parameters*, a burst of traffic is sent to the DUT with the minimum inter-frame gap between each frame. If the number of received frames equals the number of frames that were transmitted, the burst size should be increased and traffic is sent to the DUT again. The value measured is the back-to-back value, that is the maximum burst size the DUT can handle without any frame loss. Please note a trial must run for a minimum of 2 seconds and should be repeated 50 times (at a minimum).

**Expected Result:**

Tests of back-to-back frames with physical devices have produced unstable results in some cases. All tests should be repeated in multiple test sessions and results stability should be examined.

**Metrics collected**

The following are the metrics collected for this test:

- The average back-to-back value across the trials, which is the number of frames in the longest burst that the DUT will handle without the loss of any frames.
- CPU and memory utilization may also be collected as part of this test, to determine the vSwitch's performance footprint on the system.

**Deployment scenario:**

- Physical → virtual switch → physical.

**Test ID: LTD.Throughput.RFC2889.MaxForwardingRateSoak**

**Title:** RFC 2889 X% packet loss Max Forwarding Rate Soak Test

**Prerequisite Test** LTD.Throughput.RFC2544.PacketLossRatio

**Priority:**

**Description:**

The aim of this test is to understand the Max Forwarding Rate stability over an extended test duration in order to uncover any outliers. To allow for an extended test duration, the test should ideally run for 24 hours or, if this is not possible, for at least 6 hours. For this test, each frame size must be sent at the highest Throughput rate with X% packet loss, as determined in the prerequisite test. The default loss percentages to be tested are: - X = 0% - X = 10<sup>-7</sup>%

Note: Other values can be tested if required by the user.

**Expected Result:**

**Metrics Collected:**

The following are the metrics collected for this test:

- Max Forwarding Rate stability of the DUT.
  - This means reporting the number of packets lost per time interval and reporting any time intervals with packet loss. The [RFC2889](#) Forwarding Rate shall be measured in each interval. An interval of 60s is suggested.
- CPU and memory utilization may also be collected as part of this test, to determine the vSwitch's performance footprint on the system.
- The [RFC5481](#) PDV form of delay variation on the traffic flow, using the 99th percentile.

**Test ID: LTD.Throughput.RFC2889.MaxForwardingRateSoakFrameModification**

**Title:** RFC 2889 Max Forwarding Rate Soak Test with Frame Modification

**Prerequisite Test:** LTD.Throughput.RFC2544.PacketLossRatioFrameModification (0% Packet Loss)

**Priority:**

**Description:**

The aim of this test is to understand the Max Forwarding Rate stability over an extended test duration in order to uncover any outliers. To allow for an extended test duration, the test should ideally run for 24 hours or, if this is not possible, for at least 6 hour. For this test, each frame size must be sent at the highest Throughput rate with 0% packet loss, as determined in the prerequisite test.

During this test, the DUT must perform the following operations on the traffic flow:

- Perform packet parsing on the DUT's ingress port.
- Perform any relevant address look-ups on the DUT's ingress ports.
- Modify the packet header before forwarding the packet to the DUT's egress port. Packet modifications include:
  - Modifying the Ethernet source or destination MAC address.
  - Modifying/adding a VLAN tag (**Recommended**).
  - Modifying/adding a MPLS tag.
  - Modifying the source or destination ip address.
  - Modifying the TOS/DSCP field.
  - Modifying the source or destination ports for UDP/TCP/SCTP.
  - Modifying the TTL.

**Expected Result:**

**Metrics Collected:**

The following are the metrics collected for this test:

- Max Forwarding Rate stability of the DUT.
  - This means reporting the number of packets lost per time interval and reporting any time intervals with packet loss. The [RFC2889](#) Forwarding Rate shall be measured in each interval. An interval of 60s is suggested.
- CPU and memory utilization may also be collected as part of this test, to determine the vSwitch’s performance footprint on the system.
- The [RFC5481](#) PDV form of delay variation on the traffic flow, using the 99th percentile.

**Test ID: LTD.Throughput.RFC6201.ResetTime**

**Title:** RFC 6201 Reset Time Test

**Prerequisite Test:** N/A

**Priority:**

**Description:**

The aim of this test is to determine the length of time it takes the DUT to recover from a reset.

Two reset methods are defined - planned and unplanned. A planned reset requires stopping and restarting the virtual switch by the usual ‘graceful’ method defined by it’s documentation. An unplanned reset requires simulating a fatal internal fault in the virtual switch - for example by using kill -SIGKILL on a Linux environment.

Both reset methods SHOULD be exercised.

For each frame size previously defined under *Default Test Parameters*, traffic should be sent to the DUT under normal conditions. During the duration of the test and while the traffic flows are passing through the DUT, the DUT should be reset and the Reset time measured. The Reset time is the total time that a device is determined to be out of operation and includes the time to perform the reset and the time to recover from it (cf. [RFC6201](#)).

[RFC6201](#) defines two methods to measure the Reset time:

- **Frame-Loss Method:** which requires the monitoring of the number of lost frames and calculates the Reset time based on the number of frames lost and the offered rate according to the following formula:

$\text{Reset\_time} = \frac{\text{Frames\_lost (packets)}}{\text{Offered\_rate (packets per second)}}$
--

- **Timestamp Method:** which measures the time from which the last frame is forwarded from the DUT to the time the first frame is forwarded after the reset. This involves time-stamping all transmitted frames and recording the timestamp of the last frame that was received prior to the reset and also measuring the timestamp of the first frame that is received after the reset. The Reset time is the difference between these two timestamps.

According to [RFC6201](#) the choice of method depends on the test tool’s capability; the Frame-Loss method SHOULD be used if the test tool supports:

- Counting the number of lost frames per stream.

- Transmitting test frame despite the physical link status.

whereas the **Timestamp method SHOULD be used if the test tool supports:**

- Timestamping each frame.
- Monitoring received frame's timestamp.
- Transmitting frames only if the physical link status is up.

**Expected Result:**

**Metrics collected**

The following are the metrics collected for this test:

- Average Reset Time over the number of trials performed.

Results of this test should include the following information:

- The reset method used.
- Throughput in Fps and Mbps.
- Average Frame Loss over the number of trials performed.
- Average Reset Time in milliseconds over the number of trials performed.
- Number of trials performed.
- Protocol: IPv4, IPv6, MPLS, etc.
- Frame Size in Octets
- Port Media: Ethernet, Gigabit Ethernet (GbE), etc.
- Port Speed: 10 Gbps, 40 Gbps etc.
- Interface Encapsulation: Ethernet, Ethernet VLAN, etc.

**Deployment scenario:**

- Physical → virtual switch → physical.

**Test ID: LTD.Throughput.RFC2889.MaxForwardingRate**

**Title:** RFC2889 Forwarding Rate Test

**Prerequisite Test:** LTD.Throughput.RFC2544.PacketLossRatio

**Priority:**

**Description:**

This test measures the DUT's Max Forwarding Rate when the Offered Load is varied between the throughput and the Maximum Offered Load for fixed length frames at a fixed time interval. The selected frame sizes are those previously defined under *Default Test Parameters*. The throughput is the maximum offered load with 0% frame loss (measured by the prerequisite test), and the Maximum Offered Load (as defined by RFC2285) is *"the highest number of frames per second that an external source can transmit to a DUT/SUT for forwarding to a specified output interface or interfaces"*.

Traffic should be sent to the DUT at a particular rate (TX rate) starting with TX rate equal to the throughput rate. The rate of successfully received frames at the destination counted (in FPS). If the RX rate is equal to the TX rate, the TX rate should be increased by a fixed step size and the RX rate measured again until the Max Forwarding Rate is found.

The trial duration for each iteration should last for the period of time needed for the system to reach steady state for the frame size being tested. Under RFC2889 (Sec. 5.6.3.1) test methodology, the test duration should run for a minimum period of 30 seconds, regardless whether the system reaches steady state before the minimum duration ends.

**Expected Result:** According to RFC2889 The Max Forwarding Rate is the highest forwarding rate of a DUT taken from an iterative set of forwarding rate measurements. The iterative set of forwarding rate measurements are made by setting the intended load transmitted from an external source and measuring the offered load (i.e what the DUT is capable of forwarding). If the Throughput == the Maximum Offered Load, it follows that Max Forwarding Rate is equal to the Maximum Offered Load.

**Metrics Collected:**

The following are the metrics collected for this test:

- The Max Forwarding Rate for the DUT for each packet size.
- CPU and memory utilization may also be collected as part of this test, to determine the vSwitch's performance footprint on the system.

**Deployment scenario:**

- Physical → virtual switch → physical. Note: Full mesh tests with multiple ingress and egress ports are a key aspect of RFC 2889 benchmarks, and scenarios with both 2 and 4 ports should be tested. In any case, the number of ports used must be reported.

**Test ID: LTD.Throughput.RFC2889.ForwardPressure**

**Title:** RFC2889 Forward Pressure Test

**Prerequisite Test:** LTD.Throughput.RFC2889.MaxForwardingRate

**Priority:**

**Description:**

The aim of this test is to determine if the DUT transmits frames with an inter-frame gap that is less than 12 bytes. This test overloads the DUT and measures the output for forward pressure. Traffic should be transmitted to the DUT with an inter-frame gap of 11 bytes, this will overload the DUT by 1 byte per frame. The forwarding rate of the DUT should be measured.

**Expected Result:** The forwarding rate should not exceed the maximum forwarding rate of the DUT collected by LTD.Throughput.RFC2889.MaxForwardingRate.

**Metrics collected**

The following are the metrics collected for this test:

- Forwarding rate of the DUT in FPS or Mbps.
- CPU and memory utilization may also be collected as part of this test, to determine the vSwitch's performance footprint on the system.

**Deployment scenario:**

- Physical → virtual switch → physical.

**Test ID: LTD.Throughput.RFC2889.ErrorFramesFiltering**

**Title:** RFC2889 Error Frames Filtering Test

**Prerequisite Test:** N/A



**Priority:****Description:**

The aim of this test is to determine whether the DUT will propagate any erroneous frames it receives or whether it is capable of filtering out the erroneous frames. Traffic should be sent with erroneous frames included within the flow at random intervals. Illegal frames that must be tested include: - Oversize Frames. - Undersize Frames. - CRC Errored Frames. - Dribble Bit Errored Frames - Alignment Errored Frames

The traffic flow exiting the DUT should be recorded and checked to determine if the erroneous frames were passed through the DUT.

**Expected Result:** Broken frames are not passed!

**Metrics collected**

No Metrics are collected in this test, instead it determines:

- Whether the DUT will propagate erroneous frames.
- Or whether the DUT will correctly filter out any erroneous frames from traffic flow with out removing correct frames.

**Deployment scenario:**

- Physical → virtual switch → physical.

**Test ID: LTD.Throughput.RFC2889.BroadcastFrameForwarding**

**Title:** RFC2889 Broadcast Frame Forwarding Test

**Prerequisite Test:** N

**Priority:****Description:**

The aim of this test is to determine the maximum forwarding rate of the DUT when forwarding broadcast traffic. For each frame previously defined under *Default Test Parameters*, the traffic should be set up as broadcast traffic. The traffic throughput of the DUT should be measured.

The test should be conducted with at least 4 physical ports on the DUT. The number of ports used MUST be recorded.

As broadcast involves forwarding a single incoming packet to several destinations, the latency of a single packet is defined as the average of the latencies for each of the broadcast destinations.

The incoming packet is transmitted on each of the other physical ports, it is not transmitted on the port on which it was received. The test MAY be conducted using different broadcasting ports to uncover any performance differences.

**Expected Result:**

**Metrics collected:**

The following are the metrics collected for this test:

- The forwarding rate of the DUT when forwarding broadcast traffic.
- The minimum, average & maximum packets latencies observed.

**Deployment scenario:**

- Physical → virtual switch 3x physical. In the Broadcast rate testing, four test ports are required. One of the ports is connected to the test device, so it can send broadcast frames and listen for miss-routed frames.

**Test ID: LTD.Throughput.RFC2544.WorstN-BestN**

**Title:** Modified RFC 2544 X% packet loss ratio Throughput and Latency Test

**Prerequisite Test:** N/A

**Priority:**

**Description:**

This test determines the DUT's maximum forwarding rate with X% traffic loss for a constant load (fixed length frames at a fixed interval time). The default loss percentages to be tested are: X = 0%, X = 10<sup>-7</sup>%

Modified RFC 2544 throughput benchmarking methodology aims to quantify the throughput measurement variations observed during standard RFC 2544 benchmarking measurements of virtual switches and VNFs. The RFC2544 binary search algorithm is modified to use more samples per test trial to drive the binary search and yield statistically more meaningful results. This keeps the heart of the RFC2544 methodology, still relying on the binary search of throughput at specified loss tolerance, while providing more useful information about the range of results seen in testing. Instead of using a single traffic trial per iteration step, each traffic trial is repeated N times and the success/failure of the iteration step is based on these N traffic trials. Two types of revised tests are defined - *Worst-of-N* and *Best-of-N*.

**Worst-of-N**

*Worst-of-N* indicates the lowest expected maximum throughput for ( packet size, loss tolerance) when repeating the test.

1. Repeat the same test run N times at a set packet rate, record each result.
2. Take the WORST result (highest packet loss) out of N result samples, called the Worst-of-N sample.
3. If Worst-of-N sample has loss less than the set loss tolerance, then the step is successful - increase the test traffic rate.
4. If Worst-of-N sample has loss greater than the set loss tolerance then the step failed - decrease the test traffic rate.
5. Go to step 1.

**Best-of-N**

*Best-of-N* indicates the highest expected maximum throughput for ( packet size, loss tolerance) when repeating the test.

1. Repeat the same traffic run N times at a set packet rate, record each result.
2. Take the BEST result (least packet loss) out of N result samples, called the Best-of-N sample.
3. If Best-of-N sample has loss less than the set loss tolerance, then the step is successful - increase the test traffic rate.
4. If Best-of-N sample has loss greater than the set loss tolerance, then the step failed - decrease the test traffic rate.
5. Go to step 1.

Performing both Worst-of-N and Best-of-N benchmark tests yields lower and upper bounds of expected maximum throughput under the operating conditions, giving a very good indication to the user of the deterministic performance range for the tested setup.

**Expected Result:** At the end of each trial series, the presence or absence of loss determines the modification of offered load for the next trial series, converging on a maximum rate, or RFC2544 Throughput with X% loss. The Throughput load is re-used in related RFC2544 tests and other tests.

**Metrics Collected:**

The following are the metrics collected for this test:

- The maximum forwarding rate in Frames Per Second (FPS) and Mbps of the DUT for each frame size with X% packet loss.
- The average latency of the traffic flow when passing through the DUT (if testing for latency, note that this average is different from the test specified in Section 26.3 of RFC2544).
- Following may also be collected as part of this test, to determine the vSwitch's performance footprint on the system:
  - CPU core utilization.
  - CPU cache utilization.
  - Memory footprint.
  - System bus (QPI, PCI, ...) utilization.
  - CPU cycles consumed per packet.

## Packet Latency tests

These tests will measure the store and forward latency as well as the packet delay variation for various packet types through the virtual switch. The following list is not exhaustive but should indicate the type of tests that should be required. It is expected that more will be added.

### Test ID: LTD.PacketLatency.InitialPacketProcessingLatency

**Title:** Initial Packet Processing Latency

**Prerequisite Test:** N/A

**Priority:**

**Description:**

In some virtual switch architectures, the first packets of a flow will take the system longer to process than subsequent packets in the flow. This test determines the latency for these packets. The test will measure the latency of the packets as they are processed by the flow-setup-path of the DUT. There are two methods for this test, a recommended method and a nalternative method that can be used if it is possible to disable the fastpath of the virtual switch.

**Recommended method:** This test will send 64,000 packets to the DUT, each belonging to a different flow. Average packet latency will be determined over the 64,000 packets.

**Alternative method:** This test will send a single packet to the DUT after a fixed interval of time. The time interval will be equivalent to the amount of time it takes for a flow to time out in the virtual switch plus 10%. Average packet latency will be determined over 1,000,000 packets.

This test is intended only for non-learning virtual switches; For learning virtual switches use RFC2889.

For this test, only unidirectional traffic is required.

**Expected Result:** The average latency for the initial packet of all flows should be greater than the latency of subsequent traffic.

**Metrics Collected:**

The following are the metrics collected for this test:

- Average latency of the initial packets of all flows that are processed by the DUT.

**Deployment scenario:**

- Physical → Virtual Switch → Physical.

**Test ID: LTD.PacketDelayVariation.RFC3393.Soak**

**Title:** Packet Delay Variation Soak Test

**Prerequisite Tests:** LTD.Throughput.RFC2544.PacketLossRatio (0% Packet Loss)

**Priority:**

**Description:**

The aim of this test is to understand the distribution of packet delay variation for different frame sizes over an extended test duration and to determine if there are any outliers. To allow for an extended test duration, the test should ideally run for 24 hours or, if this is not possible, for at least 6 hour. For this test, each frame size must be sent at the highest possible throughput with 0% packet loss, as determined in the prerequisite test.

**Expected Result:**

**Metrics Collected:**

The following are the metrics collected for this test:

- The packet delay variation value for traffic passing through the DUT.
- The RFC5481 PDV form of delay variation on the traffic flow, using the 99th percentile, for each 60s interval during the test.
- CPU and memory utilization may also be collected as part of this test, to determine the vSwitch's performance footprint on the system.

## Scalability tests

The general aim of these tests is to understand the impact of large flow table size and flow lookups on throughput. The following list is not exhaustive but should indicate the type of tests that should be required. It is expected that more will be added.

**Test ID: LTD.Scalability.RFC2544.0PacketLoss**

**Title:** RFC 2544 0% loss Scalability throughput test

**Prerequisite Test:** LTD.Throughput.RFC2544.PacketLossRatio, IF the delta Throughput between the single-flow RFC2544 test and this test with a variable number of flows is desired.

**Priority:**

**Description:**

The aim of this test is to measure how throughput changes as the number of flows in the DUT increases. The test will measure the throughput through the fastpath, as such the flows need to be installed on the DUT before passing traffic.

For each frame size previously defined under *Default Test Parameters* and for each of the following number of flows:

- 1,000
- 2,000
- 4,000
- 8,000
- 16,000
- 32,000
- 64,000
- Max supported number of flows.

This test will be conducted under two conditions following the establishment of all flows as required by RFC 2544, regarding the flow expiration time-out:

1. The time-out never expires during each trial.
- 2) The time-out expires for all flows periodically. This would require a short time-out compared with flow re-appearance for a small number of flows, and may not be possible for all flow conditions.

The maximum 0% packet loss Throughput should be determined in a manner identical to LTD.Throughput.RFC2544.PacketLossRatio.

**Expected Result:**

**Metrics Collected:**

The following are the metrics collected for this test:

- The maximum number of frames per second that can be forwarded at the specified number of flows and the specified frame size, with zero packet loss.

**Test ID: LTD.MemoryBandwidth.RFC2544.0PacketLoss.Scalability**

**Title:** RFC 2544 0% loss Memory Bandwidth Scalability test

**Prerequisite Tests:** LTD.Throughput.RFC2544.PacketLossRatio, IF the delta Throughput between an undisturbed RFC2544 test and this test with the Throughput affected by cache and memory bandwidth contention is desired.

**Priority:**

**Description:**

The aim of this test is to understand how the DUT's performance is affected by cache sharing and memory bandwidth between processes.

During the test all cores not used by the vSwitch should be running a memory intensive application. This application should read and write random data to random addresses in unused physical memory. The random nature of the data and addresses is intended to consume cache, exercise main memory access (as opposed to cache) and exercise all memory buses equally. Furthermore:

- the ratio of reads to writes should be recorded. A ratio of 1:1 SHOULD be used.
- the reads and writes MUST be of cache-line size and be cache-line aligned.
- in NUMA architectures memory access SHOULD be local to the core's node. Whether only local memory or a mix of local and remote memory is used MUST be recorded.

- the memory bandwidth (reads plus writes) used per-core MUST be recorded; the test MUST be run with a per-core memory bandwidth equal to half the maximum system memory bandwidth divided by the number of cores. The test MAY be run with other values for the per-core memory bandwidth.
- the test MAY also be run with the memory intensive application running on all cores.

Under these conditions the DUT's 0% packet loss throughput is determined as per LTD.Throughput.RFC2544.PacketLossRatio.

**Expected Result:**

**Metrics Collected:**

The following are the metrics collected for this test:

- The DUT's 0% packet loss throughput in the presence of cache sharing and memory bandwidth between processes.

## Activation tests

The general aim of these tests is to understand the capacity of the and speed with which the vswitch can accommodate new flows.

### Test ID: LTD.Activation.RFC2889.AddressCachingCapacity

**Title:** RFC2889 Address Caching Capacity Test

**Prerequisite Test:** N/A

**Priority:**

**Description:**

Please note this test is only applicable to virtual switches that are capable of MAC learning. The aim of this test is to determine the address caching capacity of the DUT for a constant load (fixed length frames at a fixed interval time). The selected frame sizes are those previously defined under *Default Test Parameters*.

In order to run this test the aging time, that is the maximum time the DUT will keep a learned address in its flow table, and a set of initial addresses, whose value should be  $\geq 1$  and  $\leq$  the max number supported by the implementation must be known. Please note that if the aging time is configurable it must be longer than the time necessary to produce frames from the external source at the specified rate. If the aging time is fixed the frame rate must be brought down to a value that the external source can produce in a time that is less than the aging time.

Learning Frames should be sent from an external source to the DUT to install a number of flows. The Learning Frames must have a fixed destination address and must vary the source address of the frames. The DUT should install flows in its flow table based on the varying source addresses. Frames should then be transmitted from an external source at a suitable frame rate to see if the DUT has properly learned all of the addresses. If there is no frame loss and no flooding, the number of addresses sent to the DUT should be increased and the test is repeated until the max number of cached addresses supported by the DUT determined.

**Expected Result:**

**Metrics collected:**

The following are the metrics collected for this test:

- Number of cached addresses supported by the DUT.

- CPU and memory utilization may also be collected as part of this test, to determine the vSwitch's performance footprint on the system.

**Deployment scenario:**

- Physical → virtual switch → 2 x physical (one receiving, one listening).

**Test ID: LTD.Activation.RFC2889.AddressLearningRate****Title:** RFC2889 Address Learning Rate Test**Prerequisite Test:** LTD.Memory.RFC2889.AddressCachingCapacity**Priority:****Description:**

Please note this test is only applicable to virtual switches that are capable of MAC learning. The aim of this test is to determine the rate of address learning of the DUT for a constant load (fixed length frames at a fixed interval time). The selected frame sizes are those previously defined under *Default Test Parameters*, traffic should be sent with each IPv4/IPv6 address incremented by one. The rate at which the DUT learns a new address should be measured. The maximum caching capacity from LTD.Memory.RFC2889.AddressCachingCapacity should be taken into consideration as the maximum number of addresses for which the learning rate can be obtained.

**Expected Result:** It may be worthwhile to report the behaviour when operating beyond address capacity - some DUTs may be more friendly to new addresses than others.

**Metrics collected:**

The following are the metrics collected for this test:

- The address learning rate of the DUT.

**Deployment scenario:**

- Physical → virtual switch → 2 x physical (one receiving, one listening).

**Coupling between control path and datapath Tests**

The following tests aim to determine how tightly coupled the datapath and the control path are within a virtual switch. The following list is not exhaustive but should indicate the type of tests that should be required. It is expected that more will be added.

**Test ID: LTD.CPDPCouplingFlowAddition****Title:** Control Path and Datapath Coupling**Prerequisite Test:****Priority:****Description:**

The aim of this test is to understand how exercising the DUT's control path affects datapath performance.

Initially a certain number of flow table entries are installed in the vSwitch. Then over the duration of an RFC2544 throughput test flow-entries are added and removed at the rates specified below. No traffic is 'hitting' these flow-entries, they are simply added and removed.

The test MUST be repeated with the following initial number of flow-entries installed: - < 10 - 1000 - 100,000 - 10,000,000 (or the maximum supported number of flow-entries)

The test MUST be repeated with the following rates of flow-entry addition and deletion per second: - 0 - 1 (i.e. 1 addition plus 1 deletion) - 100 - 10,000

**Expected Result:**

**Metrics Collected:**

The following are the metrics collected for this test:

- The maximum forwarding rate in Frames Per Second (FPS) and Mbps of the DUT.
- The average latency of the traffic flow when passing through the DUT (if testing for latency, note that this average is different from the test specified in Section 26.3 of [RFC2544](#)).
- CPU and memory utilization may also be collected as part of this test, to determine the vSwitch's performance footprint on the system.

**Deployment scenario:**

- Physical → virtual switch → physical.

## CPU and memory consumption

The following tests will profile a virtual switch's CPU and memory utilization under various loads and circumstances. The following list is not exhaustive but should indicate the type of tests that should be required. It is expected that more will be added.

**Test ID: LTD.CPU.RFC2544.0PacketLoss**

**Title:** RFC 2544 0% Loss Compute Test

**Prerequisite Test:**

**Priority:**

**Description:**

The aim of this test is to understand the overall performance of the system when a CPU intensive application is run on the same DUT as the Virtual Switch. For each frame size, an LTD.Throughput.RFC2544.PacketLossRatio (0% Packet Loss) test should be performed. Throughout the entire test a CPU intensive application should be run on all cores on the system not in use by the Virtual Switch. For NUMA system only cores on the same NUMA node are loaded.

It is recommended that stress-ng be used for loading the non-Virtual Switch cores but any stress tool MAY be used.

**Expected Result:**

**Metrics Collected:**

The following are the metrics collected for this test:

- CPU utilization of the cores running the Virtual Switch.
- The number of identity of the cores allocated to the Virtual Switch.
- The configuration of the stress tool (for example the command line parameters used to start it.)



## Summary List of Tests

1. Throughput tests
  - Test ID: LTD.Throughput.RFC2544.PacketLossRatio
  - Test ID: LTD.Throughput.RFC2544.PacketLossRatioFrameModification
  - Test ID: LTD.Throughput.RFC2544.Profile
  - Test ID: LTD.Throughput.RFC2544.SystemRecoveryTime
  - Test ID: LTD.Throughput.RFC2544.BackToBackFrames
  - Test ID: LTD.Throughput.RFC2889.Soak
  - Test ID: LTD.Throughput.RFC2889.SoakFrameModification
  - Test ID: LTD.Throughput.RFC6201.ResetTime
  - Test ID: LTD.Throughput.RFC2889.MaxForwardingRate
  - Test ID: LTD.Throughput.RFC2889.ForwardPressure
  - Test ID: LTD.Throughput.RFC2889.ErrorFramesFiltering
  - Test ID: LTD.Throughput.RFC2889.BroadcastFrameForwarding
2. Packet Latency tests
  - Test ID: LTD.PacketLatency.InitialPacketProcessingLatency
  - Test ID: LTD.PacketDelayVariation.RFC3393.Soak
3. Scalability tests
  - Test ID: LTD.Scalability.RFC2544.0PacketLoss
  - Test ID: LTD.MemoryBandwidth.RFC2544.0PacketLoss.Scalability
4. Activation tests
  - Test ID: LTD.Activation.RFC2889.AddressCachingCapacity
  - Test ID: LTD.Activation.RFC2889.AddressLearningRate
5. Coupling between control path and datapath Tests
  - Test ID: LTD.CPDPCouplingFlowAddition
6. CPU and memory consumption
  - Test ID: LTD.CPU.RFC2544.0PacketLoss



## 5.1 OPNFV Brahma Putra Release

Supports both OVS and OVS with DPDK.

Available tests:

- phy2phy\_tput: LTD.Throughput.RFC2544.PacketLossRatio
- back2back: LTD.Throughput.RFC2544.BackToBackFrames
- phy2phy\_tput\_mod\_vlan:LTD.Throughput.RFC2544.PacketLossRatioFrameModification
- phy2phy\_cont: Phy2Phy Continuous Stream
- pvp\_cont: PVP Continuous Stream
- pvvp\_cont: PVVP Continuous Stream
- phy2phy\_scalability:LTD.Scalability.RFC2544.0PacketLoss
- pvp\_tput: LTD.Throughput.RFC2544.PacketLossRatio
- pvp\_back2back: LTD.Throughput.RFC2544.BackToBackFrames
- pvvp\_tput: LTD.Throughput.RFC2544.PacketLossRatio
- pvvp\_back2back: LTD.Throughput.RFC2544.BackToBackFrames
- phy2phy\_cpu\_load: LTD.CPU.RFC2544.0PacketLoss
- phy2phy\_mem\_load: LTD.Memory.RFC2544.0PacketLoss

Supported deployment scenarios:

- Physical port -> vSwitch -> Physical port.
- Physical port -> vSwitch -> VNF -> vSwitch -> Physical port.
- Physical port -> vSwitch -> VNF -> vSwitch -> VNF -> vSwitch -> Physical port.

Loopback applications in the Guest can be:

- DPDK testpmd.
- Linux Bridge.
- l2fwd Kernel Module.

Supported traffic generators:

- Ixia: IxOS and IxNet.
- Spirent.

- Dummy.

### 5.1.1 Release Data

<b>Project</b>	vswitchperf
<b>Repo/tag</b>	brahmaputra.1.0
<b>Release designation</b>	Brahmaputra base release
<b>Release date</b>	February 26 2016
<b>Purpose of the delivery</b>	Brahmaputra base release

## 5.2 November 2015

- Support of opnfv\_test\_dashboard

## 5.3 October 2015

- Support of PVP and PVVP deployment scenarios using Vanilla OVS

## 5.4 September 2015

- Implementation of system statistics based upon pidstat command line tool.
- Support of PVVP deployment scenario using vhost-cuse and vhost user access methods

## 5.5 August 2015

- Backport and enhancement of reporting
- PVP deployment scenario testing using vhost-cuse as guest access method
- Implementation of LTD.Scalability.RFC2544.PacketLoss testcase
- Support for background load generation with command line tools like stress and stress-ng

## 5.6 July 2015

- PVP deployment scenario testing using vhost-user as guest access method - Verified on CentOS7 and Fedora 20  
- Requires QEMU 2.2.0 and DPDK 2.0

## 5.7 May 2015

This is the initial release of a re-designed version of the software based on community feedback. This initial release supports only the Phy2Phy deployment scenario and the LTD.Throughput.RFC2544.PacketLossRatio test - both described in the OPNFV vswitchperf 'CHARACTERIZE VSWITCH PERFORMANCE FOR TELCO NFV USE

CASES LEVEL TEST DESIGN'. The intention is that more test cases will follow once the community has digested the initial release.

- Performance testing with continuous stream
- Vanilla OVS support added.
  - Support for non-DPDK OVS build.
  - Build and installation support through Makefile will be added via next patch(Currently it is possible to manually build ovs and setting it in vsperf configuration files).
  - PvP scenario is not yet implemented.
- CentOS7 support
- Verified on CentOS7
- Install & Quickstart documentation
- Better support for mixing tests types with Deployment Scenarios
- Re-work based on community feedback of TOIT
- Framework support for other vSwitches
- Framework support for non-Ixia traffic generators
- Framework support for different VNFs
- Python3
- Support for biDirectional functionality for ixnet interface
- xmlunit output is currently disabled



## VSPERF RESULTS

### 6.1 OPNFV Brahma Putra Scenarios

Available Tests and aspects of scenarios:

Framework Test	Definition
phy2phy_tput	PacketLossRatio for Phy2Phy
back2back	BackToBackFrames for Phy2Phy
phy2phy_tput_mod_vlan	PacketLossRatioFrameModification for Phy2Phy
phy2phy_cont	Phy2Phy blast vswitch at x% TX rate and measure throughput
pvp_cont	PVP blast vswitch at x% TX rate and measure throughput
pvvp_cont	PVVP blast vswitch at x% TX rate and measure throughput
phy2phy_scalability	Scalability0PacketLoss for Phy2Phy
pvp_tput	PacketLossRatio for PVP
pvp_back2back	BackToBackFrames for PVP
pvvp_tput	PacketLossRatio for PVVP
pvvp_back2back	BackToBackFrames for PVVP
phy2phy_cpu_load	CPU0PacketLoss for Phy2Phy
phy2phy_mem_load	Same as CPU0PacketLoss but using a memory intensive app

Supported deployment scenarios:

- **Phy2Phy**: Physical port -> vSwitch -> Physical port.
- **PVP**: Physical port -> vSwitch -> VNF -> vSwitch -> Physical port.
- **PVVP**: Physical port -> vSwitch -> VNF -> vSwitch -> VNF -> vSwitch -> Physical port.

Loopback applications in the Guest can be:

- **DPDK testpmd**.
- **Linux Bridge**.
- **l2fwd**.

Supported traffic generators:

- **Ixia**: IxOS and IxNet.
- **Spirent**.
- **Dummy**.

## 6.2 OPNFV Brahmaputra Results

The vsperf CI jobs that were used to obtain the results can be found at [https://wiki.opnfv.org/wiki/vsperf\\_results](https://wiki.opnfv.org/wiki/vsperf_results).



**INDICES**

- search