# Revision History

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<th>Revision</th>
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1.0 Audience and Purpose

Intel® Open Network Platform Server (Intel ONP Server) is a Reference Architecture that provides engineering guidance and ecosystem-enablement support to encourage widespread adoption of Software-Defined Networking (SDN) and Network Functions Virtualization (NFV) solutions in Telco, Enterprise, and Cloud. Intel® Open Network Platform Server Reference Architecture Guides and Release Notes are available on 01.org.

The primary audiences for this test report are architects and engineers implementing the Intel® ONP Server Reference Architecture using open-source software ingredients that include:

- DevStack*
- OpenStack*
- OpenDaylight*
- Data Plane Development Kit (DPDK)*
- Open vSwitch* with DPDK-netdev
- Fedora*

This test report provides a guide to packet processing performance testing of the Intel® ONP Server. The report includes baseline performance data and provides system configuration and test cases relevant to SDN/NFV. The purpose of documenting these configurations and methods is not to imply a single “correct” approach, but rather to provide a baseline of well-tested configurations and test procedures. This will help guide architects and engineers who are evaluating and implementing SDN/NFV solutions more generally and can greatly assist in achieving optimal system performance.

Intel aims to use identical hardware platform specifications and software versions for Intel® ONP Server Reference Architecture Guide and Performance Test Reports. Exceptions can however occur due to software issues, version revisions and other factors that occur during integration and benchmarking activities. Information on these exceptions is provided in Intel® ONP Server Release 1.5 Hardware and Software Specifications Application Note available on 01.org.
2.0 Summary

Benchmarking an SDN/NFV system is not trivial and requires expert knowledge of networking and virtualization technologies. Engineers also need benchmarking and debugging skills, as well as a good understanding of the device-under-test (DUT) across compute, networking, and storage domains. Knowledge of specific network protocols and hands-on experience with relevant open-source software, such as Linux, kernel-based virtual machine (KVM), quick emulator (QEMU), DPDK, OVS, etc., are also required.

Repeatability is essential when testing complex systems and can be difficult to achieve with manual methods. Scripted install procedures and automated test methods will be needed for developing SDN/NFV solutions. Future versions of Intel® ONP Server will address this critical aspect.

This report builds on earlier Intel® ONP Server test reports available on 01.org as archived documents. A previous report (Intel ONP Server 1.3) contains certain baseline throughput test data and procedures for Linux operating system setup, BIOS configurations, core-usage configuration for OVS, VM setup, and building DPDK and OVS.

This current test report includes the following:

- New versions of software ingredients
- vHost user for QEMU
- 40Gbps performance testing with the Intel® Ethernet X710-DA2 Adapter
- Latency performance metrics
- Virtual eXtensible LAN (VXLAN) performance tests
- Tuning methods and troubleshooting tips for OVS
- Information on related industry NFV test activities

Performance data include the following configurations:

- Host Tests
- Virtual Switching Tests
- PHY-to-VM Tests
- VM-to-VM Tests
- VXLAN Tests
3.0 Platform Specifications

3.1 Hardware Ingredients

Table 3-1. Hardware Ingredients

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
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<tr>
<td>Server Platform</td>
<td>Intel® Server Board S2600WT2 DP (Formerly Wildcat Pass) 2 x 1GbE integrated LAN ports Two processors per platform</td>
</tr>
<tr>
<td>Chipset</td>
<td>Intel® C610 series chipset (Formerly Wellsburg)</td>
</tr>
<tr>
<td>Memory</td>
<td>Micron 16 GB 1Rx4 PC4-2133MHz, 16 GB per channel, 8 Channels, 128 GB Total</td>
</tr>
<tr>
<td>Local Storage</td>
<td>500 GB HDD Seagate SATA Barracuda 7200.12 (SN:9VMKQZMT)</td>
</tr>
<tr>
<td>PCIe</td>
<td>Port 3a and Port 3c x8</td>
</tr>
<tr>
<td>NICs</td>
<td>2 x Intel® Ethernet CAN X710-DA2 Adapter (Total: 4 x 10GbE ports) (Formerly Fortville)</td>
</tr>
<tr>
<td>BIOS</td>
<td>Version: SE5C610.86B.01.01.0008.021120151325  Date: 02/11/2015</td>
</tr>
</tbody>
</table>
3.2 Software Version

Table 3-2. Software Versions

<table>
<thead>
<tr>
<th>System Capability</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host Operating System</td>
<td>Fedora 21 x86_64 (Server version)</td>
</tr>
<tr>
<td></td>
<td>Kernel version: 3.17.4-301.fc21.x86_64</td>
</tr>
<tr>
<td>VM Operating System</td>
<td>Fedora 21 (Server version)</td>
</tr>
<tr>
<td></td>
<td>Kernel version: 3.17.4-301.fc21.x86_64</td>
</tr>
<tr>
<td>libvirt</td>
<td>libvirt-1.2.9.3-2.fc21.x86_64</td>
</tr>
<tr>
<td>QEMU</td>
<td>QEMU-KVM version 2.2.1</td>
</tr>
<tr>
<td></td>
<td><a href="http://wiki.qemu-project.org/download/qemu-2.2.1.tar.bz2">http://wiki.qemu-project.org/download/qemu-2.2.1.tar.bz2</a></td>
</tr>
<tr>
<td>DPDK</td>
<td>DPDK 2.0.0</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.dpdk.org/browse/dpdk/snapshot/dpdk-2.0.0.tar.gz">http://www.dpdk.org/browse/dpdk/snapshot/dpdk-2.0.0.tar.gz</a></td>
</tr>
<tr>
<td>OVS with DPDK-netdev</td>
<td>Open vSwitch 2.4.0</td>
</tr>
<tr>
<td></td>
<td><a href="http://openvswitch.org/releases/openvswitch-2.4.0.tar.gz">http://openvswitch.org/releases/openvswitch-2.4.0.tar.gz</a></td>
</tr>
</tbody>
</table>

3.3 Boot Settings

Table 3-3. Boot Settings

<table>
<thead>
<tr>
<th>System Capability</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host Boot Settings</td>
<td>HugePage size = 1 G; no. of HugePages = 16</td>
</tr>
<tr>
<td></td>
<td>HugePage size = 2 MB; no. of HugePages = 2048</td>
</tr>
<tr>
<td></td>
<td>intel_iommu=off</td>
</tr>
<tr>
<td></td>
<td>Hyper-threading disabled: isolcpus = 1-13,15-27</td>
</tr>
<tr>
<td></td>
<td>Hyper-threading enabled: isolcpus = 1-13,15-27,29-41,43-55</td>
</tr>
<tr>
<td>VM Kernel Boot Parameters</td>
<td>GRUB_CMDLINE_LINUX=&quot;rd.lvm.lv=fedora-server/root</td>
</tr>
<tr>
<td></td>
<td>rd.lvm.lv=fedora-server/swap default_hugepagesz=1G hugepagesz=1G</td>
</tr>
</tbody>
</table>
|                           | hugepages=1 hugepagesz=2M hugepages=1024 isolcpus=1,2 rhgb quiet"
3.4 Compile Options

Table 3-4. Compile Option Configurations

<table>
<thead>
<tr>
<th>System Capability</th>
<th>Configuration</th>
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<tbody>
<tr>
<td>DPDK Compilation</td>
<td>CONFIG_RTE_BUILD_COMBINE_LIBS=y</td>
</tr>
<tr>
<td></td>
<td>CONFIG_RTE_LIBRTE_VHOST=y</td>
</tr>
<tr>
<td></td>
<td>CONFIG_RTE_LIBRTE_VHOST_USER=y</td>
</tr>
<tr>
<td></td>
<td>DPDK compiled with &quot;-Ofast -g&quot;</td>
</tr>
<tr>
<td>OVS Compilation</td>
<td>OVS configured and compiled as follows:</td>
</tr>
<tr>
<td></td>
<td># ./configure --with-dpdk=&lt;DPDK SDK PATH&gt;/x86_64-native-linuxapp \</td>
</tr>
<tr>
<td></td>
<td>CFLAGS=&quot;-Ofast -g&quot;</td>
</tr>
<tr>
<td></td>
<td>make CFLAGS=&quot;-Ofast -g -march=native&quot;</td>
</tr>
<tr>
<td>DPDK Forwarding Applications</td>
<td>Build L3fwd: (in l3fwd/main.c)</td>
</tr>
<tr>
<td></td>
<td>#define RTE_TEST_RX_DESC_DEFAULT 2048</td>
</tr>
<tr>
<td></td>
<td>#define RTE_TEST_TX_DESC_DEFAULT 2048</td>
</tr>
<tr>
<td></td>
<td>Build L2fwd: (in l2fwd/main.c)</td>
</tr>
<tr>
<td></td>
<td>#define NB_MBUF 16384</td>
</tr>
<tr>
<td></td>
<td>#define RTE_TEST_RX_DESC_DEFAULT 2048</td>
</tr>
<tr>
<td></td>
<td>#define RTE_TEST_TX_DESC_DEFAULT 2048</td>
</tr>
<tr>
<td></td>
<td>Build testpmd: (in test-pmd/testpmd.c)</td>
</tr>
<tr>
<td></td>
<td>#define RTE_TEST_RX_DESC_DEFAULT 2048</td>
</tr>
<tr>
<td></td>
<td>#define RTE_TEST_TX_DESC_DEFAULT 2048</td>
</tr>
</tbody>
</table>
### 3.5 Operating System Settings

**Table 3-5. Software Versions**

<table>
<thead>
<tr>
<th>System Capability</th>
<th>Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linux OS Services Settings</td>
<td># systemctl disable NetworkManager.service &lt;br&gt; # chkconfig network on &lt;br&gt; # systemctl restart network.service &lt;br&gt; # systemctl stop NetworkManager.service &lt;br&gt; # systemctl stop firewalld.service &lt;br&gt; # systemctl disable firewalld.service &lt;br&gt; # systemctl stop irqbalance.service &lt;br&gt; # killall irqbalance &lt;br&gt; # systemctl disable irqbalance.service &lt;br&gt; # service iptables stop &lt;br&gt; # echo 0 &gt; /proc/sys/kernel/randomize_va_space &lt;br&gt; # SELinux disabled &lt;br&gt; # net.ipv4.ip_forward=0</td>
</tr>
<tr>
<td>Uncore Frequency Settings</td>
<td>Set the uncore frequency to the max ratio.</td>
</tr>
<tr>
<td>PCI Settings</td>
<td># setpci -s 00:03.0 184.1 000000 &lt;br&gt; # setpci -s 00:03.2 184.1 000000 &lt;br&gt; # setpci -s 00:03.0 184.1=0x1408 &lt;br&gt; # setpci -s 00:03.2 184.1=0x1408</td>
</tr>
<tr>
<td>Linux Module Settings</td>
<td># rmmod ipmi_msghandler &lt;br&gt; # rmmod ipmi_si &lt;br&gt; # rmmod ipmi_devintf</td>
</tr>
</tbody>
</table>
4.0 Test Configurations

The test setup is shown in Figure 4-1. The system-under-test is Intel® ONP Server Reference Architecture (version 1.5). The traffic is generated by Ixia running RFC 2544 (IxNetwork 7.40.929.15 EA; Protocols: 4.40.1075.13; IxOS: IxOS 6.80.1100.7 EA). The maximum theoretical system forwarding throughput is 40Gbps aggregated across four 10GE ports, except for VXLAN tests which use two ports. Physical ports are paired (one ingress and one egress), i.e., one 10Gbps bidirectional flow “consumes” two ports. Unless otherwise stated, all tests are for zero packet loss.

The VM network interface used is vhost-user with DPDK acceleration. Vhost-user information is available at http://dpdk.readthedocs.org/en/latest/prog_guide/vhost_lib.html along with DPDK 2.0 documentation.

![Figure 4-1. High-Level Overview of Test Setup](image-url)
Allocation of cores has a large impact on performance. For tests in this document, core configurations include physical and hyper-threaded options. Tests showing the impact on performance when adding cores and using hyper-threading are included. Table 4-1 shows combinations of physical and hyper-threaded cores used for various test cases.

Table 4-1. Number of Cores Used for Each Test Category

<table>
<thead>
<tr>
<th>Test</th>
<th>Physical Cores</th>
<th>Hyper-Threaded Cores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Host Tests</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Virtual Switching Tests</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>PHY-to-VM Tests</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>VM-to-VM Tests</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>VXLAN Tests</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

4.1 Traffic Profiles

The IP traffic profile used conforms to RFC 2544.

- Frame sizes (bytes): 64, 128, 256, 512, 1024, 1280, and 1518
- L3 protocol: IPv4
- L4 protocol: UDP
- All tests are bidirectional with the same data rate being offered from each direction.
- Test duration (per packet size) is 60 seconds, except for latency and Packet Delay Variation (PDV) soak tests, which are run for 1 hour.
- For VXLAN, a header is used to encapsulate IP packets per RFC 7348.
5.0 Test Metrics

5.1 Packet Processing Performance Metrics

RFC 2544 is an Internet Engineering Task Force (IETF) RFC that outlines a benchmarking methodology for network interconnect devices. The methodology results in performance metrics (e.g., 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 the smallest frames of 64 bytes to the largest of 1518 bytes.

RFC 2544 types of tests are as follows:

- **Throughput tests** define the maximum number of frames per second that can be transmitted without any error. Throughput is the fastest rate at which the count of test frames transmitted by the DUT is equal to the number of test frames sent to it by the test equipment. Test time during which frames are transmitted must be at least 60 seconds.

- **Latency tests** measure the time required for a frame to travel from the originating device through the network to the destination device.

- **Frame loss tests** measure 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 rapidly degrades service quality.

- **Burst tests** assess the buffering capability of a switch. They measure 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 as defined in many service-level agreements (SLAs).

- **System recovery tests** characterize speed of recovery from an overload condition.

- **Reset tests** characterize the speed of recovery from device or software reset.

“Test duration” refers to the measurement period for, and particular packet size with, an offered load and assumes the system has reached a steady state. Using the RFC 2544 test methodology, this is specified as at least 60 seconds.
5.2 Throughput

The throughput test data provided in this document represents “platform throughput” as measured by the Ixia traffic generator. Switching performance metrics include the number of switching operations for the particular configuration. This is shown in Table 5-1 using two examples of configurations with two and three switching operations, respectively. Figure 5-1 shows the two configuration examples.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Configuration Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PHY-OVS-PHY (four ports)</td>
</tr>
<tr>
<td>Physical Ports</td>
<td>4</td>
</tr>
<tr>
<td>Flows per Port (in each direction)</td>
<td>1</td>
</tr>
<tr>
<td>Total Flows</td>
<td>4</td>
</tr>
<tr>
<td>Switching Operations</td>
<td>2</td>
</tr>
<tr>
<td>Throughput (packets/sec) 128B packets</td>
<td>33,783,781</td>
</tr>
<tr>
<td></td>
<td>100% of line rate</td>
</tr>
<tr>
<td>Switching Performance (packets/sec) 128B packets</td>
<td>67,567,562</td>
</tr>
<tr>
<td></td>
<td>200% of line rate</td>
</tr>
</tbody>
</table>

![Figure 5-1](image.png)

Figure 5-1. Examples of Configurations with Two and Three Switching Operations
5.2.1  **Layer 2 Throughput**

This test determines the DUT's maximum Layer 2 forwarding rate without traffic loss, as well as average and minimum-maximum latency for different packet sizes.

This test is performed full duplex with traffic transmitting in both directions.

The DUT must perform packet parsing and Layer 2 address lookups on the ingress port, and then modify the header before forwarding the packet on the egress port.

5.2.2  **Layer 3 Throughput**

This test determines the DUT's maximum IPv4 Layer 3 forwarding rate without packet loss, as well as average and minimum-maximum latency for different packet sizes.

This test is performed full duplex with traffic transmitting in both directions.

The DUT must perform packet parsing and route lookups for Layer 3 packets on the ingress port and then forward the packet on the egress port without modifying the header.

5.3  **Latency**

With latency (i.e., packet delay) and packet delay variation, it is generally the worst-case performance that must be considered. Outliers can create customer disappointment at the carrier scale and cost service providers.

The RFC 2544 measurement of latency is extensively used in traditional testing. NFV requires more information on latency, including packet delay variation. Ideally, the delay of all packets should be considered, but in practice some form of sampling is needed (this may not be periodic sampling).

Average and minimum-maximum latency numbers are usually collected with throughput tests; however, the distribution of latency is a more meaningful metric (i.e., a test that collects latency distribution for different packet sizes and over an extended duration to uncover outliers; latency tests should run for at least 1 hour and ideally for 24 hours). Collecting test data for all traffic conditions can take a long time. One approach is to use the highest throughput that has demonstrated zero packet loss for each packet size as determined with throughput tests.

RFC 2679 defines a metric for one-way delay of packets across Internet paths and describes a methodology for measuring “Type-P-One-way-Delay” from source to destination.

5.4  **Packet Delay Variation (PDV)**

RFC 3393 provides definitions of PDV metrics for IP packets and is based on RFC 2679. This RFC notes that variation in packet delay is sometimes called “jitter” and that this term causes confusion because it is used in different ways by different groups of people. The ITU Telecommunication Standardization Sector also recommends various delay variation metrics [Y.1540] [G.1020]. Most of these standards specify multiple ways to quantify PDV.

RFC 5481 specifies two forms of measuring variation of packet delay:

- Inter-Packet Delay Variation (IPDV) is where the reference is the previous packet in the stream (according to a sending sequence), and the reference changes for each packet in the stream. In this
formulation, properties of variation are coupled with packet sequence. This form was called Instantaneous Packet Delay Variation in early IETF contributions and is similar to the packet spacing difference metric used for inter-arrival jitter calculations in RFC 3550.

- Packet Delay Variation (PDV) is where a single reference is chosen from the stream based on specific criteria. The most common criterion for the reference is the packet with the minimum delay in the sample. This term derives its name from a similar definition for Cell Delay Variation, an ATM performance metric [1.356].

Both metrics are derived from “one-way-delay” metrics and, therefore, require knowledge of time at the source and destination. Results are typically represented by histograms showing statistical distribution of delay variation. Packet loss has great influence for results (extreme cases are described in the RFC). For reporting and SLA purposes, simplicity is important and PDV lends itself better (e.g., percentiles, median, mean, etc.). PDV metrics can also be used with different stream characteristics, such as Poisson streams [RFC 3393] and periodic streams [RFC 3432], depending on the purpose and testing environment.
6.0 Test Cases

A summary of test cases is shown in Table 6-1.

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Test Description</th>
<th>Metrics</th>
<th>Packet Size (Bytes)</th>
<th>Test Duration</th>
<th>Flows per Port in Both Directions</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1</td>
<td>L3 Fwd (no pkt modification) 4 ports</td>
<td>Throughput Latency (avg)</td>
<td>64, 128, 256, 512, 256, 512, 1024, 1280, 1518</td>
<td>60 sec</td>
<td>One flow/port in both directions</td>
</tr>
<tr>
<td>7.1</td>
<td>L2 Fwd (with pkt modification) 4 ports</td>
<td>Throughput Latency (avg)</td>
<td>64, 128, 256, 512, 256, 512, 1024, 1280, 1518</td>
<td>60 sec</td>
<td>One flow/port in both directions</td>
</tr>
<tr>
<td>7.2</td>
<td>L3 Fwd 4 ports</td>
<td>Throughput Latency (avg)</td>
<td>64, 128, 256, 512, 256, 512, 1024, 1280, 1518</td>
<td>60 sec</td>
<td>One flow/port in both directions</td>
</tr>
<tr>
<td>7.2</td>
<td>L3 Fwd 4 ports</td>
<td>Packet Delay Variation</td>
<td>64B</td>
<td>1 hr</td>
<td>One flow/port in both directions</td>
</tr>
<tr>
<td>7.3</td>
<td>L3 Fwd 4 ports Maximum load (from test-case 3) for zero packet loss. Core configuration chosen from test-case 3.</td>
<td>Throughput Latency (avg)</td>
<td>64, 128, 256, 512, 256, 512, 1024, 1280, 1518</td>
<td>60 sec</td>
<td>One flow/port in both directions</td>
</tr>
<tr>
<td>7.4</td>
<td>Single VM (vhost-user) L3 Fwd 4 ports</td>
<td>Throughput Latency (min, max, avg)</td>
<td>64, 128, 256, 512, 256, 512, 1024, 1280, 1518</td>
<td>60 sec</td>
<td>One flow/port in both directions</td>
</tr>
<tr>
<td>7.5</td>
<td>Two VMs in series (vhost-user) L3 Fwd 2 ports</td>
<td>Throughput Latency (min, max, avg)</td>
<td>64, 128, 256, 512, 256, 512, 1024, 1280, 1518</td>
<td>60 sec</td>
<td>One flow/port in both directions</td>
</tr>
<tr>
<td>7.6</td>
<td>VXLAN encap/decap using vSwitch TEP L3 Fwd 2 ports</td>
<td>Throughput Latency (min, max, avg)</td>
<td>64, 72, 128, 256, 512, 768, 1024, 1280, 1468</td>
<td>60 sec</td>
<td>One flow/port in both directions</td>
</tr>
</tbody>
</table>
7.0 Test Results

7.1 Host Throughput (PHY-PHY)

The test setup for the host is shown in Figure 7-1.

![Figure 7-1. Host Setup (PHY-PHY)](image)

As shown in Table 7-1, host tests attempt to achieve system throughput of 40Gbps, using the 4-port configuration with 4 physical cores.

Table 7-1. Host Test Configurations

<table>
<thead>
<tr>
<th>Test</th>
<th>Configuration Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ports</td>
</tr>
<tr>
<td>L2 Forwarding</td>
<td>4</td>
</tr>
<tr>
<td>L3 Forwarding</td>
<td>4</td>
</tr>
</tbody>
</table>
For **L2 tests**, the full-line rate is achieved for all packet sizes as shown in the results in **Table 7-2**.

**Table 7-2. L2 Test Results for Host**

<table>
<thead>
<tr>
<th>Packet Size</th>
<th>L2 Forwarding — Bidirectional Throughput Achieved with Zero Packet Loss</th>
<th>Average Latency (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mbps</td>
<td>Packets/sec</td>
</tr>
<tr>
<td>64</td>
<td>28,669</td>
<td>42,662,748</td>
</tr>
<tr>
<td>72</td>
<td>31,222</td>
<td>42,420,571</td>
</tr>
<tr>
<td>128</td>
<td>40,000</td>
<td>33,783,756</td>
</tr>
<tr>
<td>256</td>
<td>40,000</td>
<td>18,115,929</td>
</tr>
<tr>
<td>512</td>
<td>40,000</td>
<td>9,398,488</td>
</tr>
<tr>
<td>768</td>
<td>40,000</td>
<td>6,345,174</td>
</tr>
<tr>
<td>1024</td>
<td>40,000</td>
<td>4,789,270</td>
</tr>
<tr>
<td>1280</td>
<td>40,000</td>
<td>3,846,150</td>
</tr>
<tr>
<td>1518</td>
<td>40,000</td>
<td>3,250,973</td>
</tr>
</tbody>
</table>

**Affinity Details**

# ./l2fwd -c 1e -n 4 --socket-mem 1024,0 -- -p 0f

For **L3 tests**, the full-line rate is achieved for all packet sizes from 128 bytes as shown in **Table 7-3**.

**Table 7-3. L3 Test Results for Host**

<table>
<thead>
<tr>
<th>Packet Size</th>
<th>L3 Forwarding — Bidirectional Throughput Achieved with Zero Packet Loss</th>
<th>Average Latency (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mbps</td>
<td>Packets/sec</td>
</tr>
<tr>
<td>64</td>
<td>40,000</td>
<td>59,523,774</td>
</tr>
<tr>
<td>72</td>
<td>40,000</td>
<td>54,347,790</td>
</tr>
<tr>
<td>128</td>
<td>40,000</td>
<td>33,783,750</td>
</tr>
<tr>
<td>256</td>
<td>40,000</td>
<td>18,115,928</td>
</tr>
<tr>
<td>512</td>
<td>40,000</td>
<td>9,398,484</td>
</tr>
<tr>
<td>768</td>
<td>40,000</td>
<td>6,345,173</td>
</tr>
<tr>
<td>1024</td>
<td>40,000</td>
<td>4,789,268</td>
</tr>
<tr>
<td>1280</td>
<td>40,000</td>
<td>3,846,151</td>
</tr>
<tr>
<td>1518</td>
<td>40,000</td>
<td>3,250,971</td>
</tr>
</tbody>
</table>

**Affinity Details**

# ./l3fwd -c 1e -n 4 --socket-mem 1024,0 -- -p 0xf \ --config="(0,0,1),(1,0,2),(2,0,3),(3,0,4)"
7.2 Virtual Switching Throughput (PHY-OVS-PHY)

Figure 7-2 shows the test setup for PHY-OVS-PHY with four 10GbE ports. Maximum theoretical platform throughput is 40Gbps (four flows aggregated).
Virtual switching tests attempt to achieve aggregated system throughput of 40Gbps using 4 ports to compare the following configuration variables (Table 7-4 shows configurations tested for each type of test).

Configuration variables:

- Native OVS or OVS with DPDK-netdev
- 1, 2, or 4 physical cores
- One flow per port (total four flows) or 2K flows per port (total 8K flows)
- Hyper-threading or no hyper-threading i.e.
  - 1 physical core vs 2 hyper-threaded cores
  - 2 physical cores vs 4 hyper-threaded cores

All tests are L3 forwarding.

**Table 7-4. Configurations for Virtual Switching Tests**

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Configuration Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ports</td>
<td>TX/RX Queues per Core</td>
</tr>
<tr>
<td>Native OVS</td>
<td>4</td>
</tr>
<tr>
<td>OVS with DPDK-netdev</td>
<td>4</td>
</tr>
<tr>
<td>Core scaling (L3 Forwarding)</td>
<td>4</td>
</tr>
<tr>
<td>Core scaling (L3 Forwarding)</td>
<td>4</td>
</tr>
<tr>
<td>Impact of hyper-threading</td>
<td>4</td>
</tr>
<tr>
<td>Impact of hyper-threading</td>
<td>4</td>
</tr>
</tbody>
</table>
7.2.1 Native OVS and OVS with DPDK-netdev

This test compares Native OVS and OVS with DPDK-netdev.

**Table 7-5 Configuration variables for Native OVS and OVS with DPDK-netdev**

<table>
<thead>
<tr>
<th>Configuration variables</th>
<th>Physical Cores</th>
<th>Hyper-threaded cores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native OVS</td>
<td>1</td>
<td>none or 2</td>
</tr>
<tr>
<td>OVS with DPDK-netdev</td>
<td>1</td>
<td>none or 2</td>
</tr>
</tbody>
</table>

**Table 7-6. Native OVS, no hyper-threading**

<table>
<thead>
<tr>
<th>Packet Size</th>
<th>L3 Forwarding — Bidirectional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Throughput Achieved with Zero Packet Loss</td>
</tr>
<tr>
<td></td>
<td>Mbps</td>
</tr>
<tr>
<td>64</td>
<td>567</td>
</tr>
<tr>
<td>72</td>
<td>606</td>
</tr>
<tr>
<td>128</td>
<td>1,012</td>
</tr>
<tr>
<td>256</td>
<td>1,882</td>
</tr>
<tr>
<td>512</td>
<td>3,661</td>
</tr>
<tr>
<td>768</td>
<td>5,479</td>
</tr>
<tr>
<td>1024</td>
<td>7,238</td>
</tr>
<tr>
<td>1280</td>
<td>8,998</td>
</tr>
<tr>
<td>1518</td>
<td>10,680</td>
</tr>
</tbody>
</table>

**Affinity Details**

- 0% Loss resolution
- Port0 IRQ's Affinity to lcore2
- Port1 IRQ's Affinity to lcore3

**Table 7-7. Native OVS, with hyper-threading**

<table>
<thead>
<tr>
<th>Packet Size</th>
<th>L3 Forwarding — Bidirectional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Throughput Achieved with Zero Packet Loss</td>
</tr>
<tr>
<td></td>
<td>Mbps</td>
</tr>
<tr>
<td>64</td>
<td>741</td>
</tr>
<tr>
<td>256</td>
<td>2,424</td>
</tr>
</tbody>
</table>

**Affinity Details**

- 0% Loss resolution
- Port0 IRQ's Affinity to lcore2
- Port1 IRQ's Affinity to lcore3
Table 7-8. OVS with DPDK, no hyper-threading

<table>
<thead>
<tr>
<th>Packet Size</th>
<th>L3 Forwarding — Bidirectional</th>
<th>Throughput Achieved with Zero Packet Loss</th>
<th>Average Latency (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mbps</td>
<td>Packets/sec</td>
</tr>
<tr>
<td>64</td>
<td>11,267</td>
<td>16,766,108</td>
<td>28</td>
</tr>
<tr>
<td>72</td>
<td>12,311</td>
<td>16,726,835</td>
<td>31</td>
</tr>
<tr>
<td>128</td>
<td>19,852</td>
<td>16,766,876</td>
<td>50</td>
</tr>
<tr>
<td>256</td>
<td>36,984</td>
<td>16,749,871</td>
<td>92</td>
</tr>
<tr>
<td>512</td>
<td>40,000</td>
<td>9,398,497</td>
<td>100</td>
</tr>
<tr>
<td>768</td>
<td>40,000</td>
<td>6,345,179</td>
<td>100</td>
</tr>
<tr>
<td>1024</td>
<td>40,000</td>
<td>4,789,273</td>
<td>100</td>
</tr>
<tr>
<td>1280</td>
<td>40,000</td>
<td>3,846,154</td>
<td>100</td>
</tr>
<tr>
<td>1518</td>
<td>40,000</td>
<td>3,250,973</td>
<td>100</td>
</tr>
</tbody>
</table>

Affinity Details: 1PMD thread based OVS and 0% Loss resolution

# ./ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=4

4P from 2 cards

Table 7-9. OVS with DPDK-netdev, with hyper-threading

<table>
<thead>
<tr>
<th>Packet Size</th>
<th>L3 Forwarding — Bidirectional</th>
<th>Throughput Achieved with Zero Packet Loss</th>
<th>Average Latency (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mbps</td>
<td>Packets/sec</td>
</tr>
<tr>
<td>64</td>
<td>12,891</td>
<td>19,183,078</td>
<td>32</td>
</tr>
<tr>
<td>72</td>
<td>14,051</td>
<td>19,091,305</td>
<td>35</td>
</tr>
<tr>
<td>128</td>
<td>23,139</td>
<td>19,543,183</td>
<td>58</td>
</tr>
<tr>
<td>256</td>
<td>40,000</td>
<td>18,115,938</td>
<td>100</td>
</tr>
<tr>
<td>512</td>
<td>40,000</td>
<td>9,398,499</td>
<td>100</td>
</tr>
<tr>
<td>768</td>
<td>40,000</td>
<td>6,345,179</td>
<td>100</td>
</tr>
<tr>
<td>1024</td>
<td>40,000</td>
<td>4,789,273</td>
<td>100</td>
</tr>
<tr>
<td>1280</td>
<td>40,000</td>
<td>3,846,155</td>
<td>100</td>
</tr>
<tr>
<td>1518</td>
<td>40,000</td>
<td>3,250,976</td>
<td>100</td>
</tr>
</tbody>
</table>

Affinity Details: 2PMD thread based OVS and 0% Loss resolution

# ./ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=40000004

4P from 2 cards
Figure 7-3. Relative throughput performance of Native OVS and OVS with DPDK-netdev using one physical core
7.2.2 Core Scaling—One Flow per Port (Total 4 Flows)

Figure 7-4 shows scaling performance with 1, 2, and 4 physical cores using 4 flows. Maximum theoretical throughput is indicated by the "top purple line" (packets-per-second on the Y-axis).

![Figure 7-4. OVS with DPDK — Host Throughput with HT Disabled (4 Flows)]](image)

The test data in Table 7-10 shows the smallest packet size that achieves line rate when using 1, 2, and 4 physical cores, respectively.

**Table 7-10. Packet Sizes that Achieve Line Rate Using 1, 2, and 4 Cores (with 4 Flows)**

<table>
<thead>
<tr>
<th>No. of Physical Cores</th>
<th>Packet Size (Bytes)</th>
<th>Packet Size (Bytes)</th>
<th>Packet Size (Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Physical Core</td>
<td>128B</td>
<td>256B</td>
<td>512B</td>
</tr>
<tr>
<td>Throughput (packets/sec)</td>
<td>16,766,876 (49% of line rate)</td>
<td>16,749,871 (92% of line rate)</td>
<td>9,398,497 (100% of line rate)</td>
</tr>
<tr>
<td>2 Physical Cores</td>
<td>128B</td>
<td>256B</td>
<td>512B</td>
</tr>
<tr>
<td>Throughput (packets/sec)</td>
<td>30,387,023 (90% of line rate)</td>
<td>18,115,940 (100% of line rate)</td>
<td>9,398,496 (100% of line rate)</td>
</tr>
<tr>
<td>4 Physical Cores</td>
<td>128B</td>
<td>256B</td>
<td>512B</td>
</tr>
<tr>
<td>Throughput (packets/sec)</td>
<td>33,783,781 (100% of line-rate)</td>
<td>18,115,939 (100% of line rate)</td>
<td>9,398,490 (100% of line rate)</td>
</tr>
</tbody>
</table>
7.2.3 Core Scaling—2K Flows per Port (Total 8K Flows)

Figure 7-5 shows scaling performance with 1, 2, and 4 physical cores, using 8K flows. Maximum theoretical throughput is indicated by the top purple line (packets-per-second on the Y-axis).

![Figure 7-5. OVS with DPDK — Host Throughput with HT Disabled (8K flows)](image)

The test data shown in Table 7-11 shows the smallest packet size that achieves line rate when using 1, 2, and 4 physical cores, respectively.

**Table 7-11. Packet Sizes that Achieve Line Rate Using 1, 2, and 4 Cores (with 8K Flows)**

<table>
<thead>
<tr>
<th>No. of Physical Cores</th>
<th>128B</th>
<th>256B</th>
<th>768B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 Physical Core</strong></td>
<td>9,058,613 (27% of line rate)</td>
<td>9,043,478 (50% of line rate)</td>
<td>6,345,179 (100% of line rate)</td>
</tr>
<tr>
<td>Throughput (packets/sec)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2 Physical Cores</strong></td>
<td>19,085,895 (56% of line rate)</td>
<td>18,115,935 (100% of line rate)</td>
<td>6,345,178 (100% of line rate)</td>
</tr>
<tr>
<td>Throughput (packets/sec)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4 Physical Cores</strong></td>
<td>18,115,935 (100% of line-rate)</td>
<td>18,115,941 (100% of line rate)</td>
<td>6,345,177 (100% of line rate)</td>
</tr>
<tr>
<td>Throughput (packets/sec)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7.2.4 64-Byte Performance

7.2.3.1 Core Scalability for 64B Packets

Figure 7-6 shows scaling performance of 64-byte packets with 1, 2, and 4 physical cores with the following number of flows configured:

- 4 total flows (1 flow per port)
- 4K total flows (1K flows per port)
- 8K total flows (2K flows per port)

Figure 7-6. Core Scaling for 64B Packets with 4 Flows and 4K and 8K Flows
Test data for measured throughput for 64B packets in Table 7-12 shows fairly linear scaling when using 1, 2, or 4 cores up to 8K flows. Due to the current configuration of OVS hash lookup tables, significant degradation in performance is observed when using more than 8K flows. This is related to the size of the EMC (exact match cache), which is a hash table in OVS. The current size of the EMC is set to 8K (flows) by default. Using this default configuration, larger numbers of flows may use a slower data path (not the EMC).

In Table 7-12, there is ~46% performance drop from 4 flows to 8K flows for 1 physical core, while 4K flows show ~36% performance drop compared to 4 flows for 1 physical core.

### Table 7-12. 64B Performance Scaling with 1, 2, and 4 Cores

<table>
<thead>
<tr>
<th>Number of Flows</th>
<th>1 Physical Core Measured throughput</th>
<th>2 Physical Cores Measured throughput</th>
<th>4 Physical Cores Measured throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Packets/sec</td>
<td>Line Rate %</td>
<td>Packets/sec</td>
</tr>
<tr>
<td>4</td>
<td>16,766,108</td>
<td>28</td>
<td>30,347,400</td>
</tr>
<tr>
<td>4K</td>
<td>10,781,154</td>
<td>18</td>
<td>22,233,135</td>
</tr>
<tr>
<td>8K</td>
<td>9,054,720</td>
<td>15</td>
<td>19,067,981</td>
</tr>
</tbody>
</table>

#### 7.2.3.2 Performance with Hyper-Threading

Figure 7-7 shows that hyper-threading increases performance of one 64-byte flow by 14% when one core is used and 17% when two cores are used.
Figure 7-8 shows hyper-threading increases performance of 4K, 64-byte flows by 49% when 1 core is used and 37% when 2 cores are used.

![Figure 7-8. Performance Scaling with Hyper-Threading with 8K Flows (2K Flows per Port)](image)

The test data in Table 7-13 shows the measured throughput for 64B packets with 4-flow and 8K-flow configurations.

Table 7-13. 64B Performance with/without Hyper-Threadig for 4 Flows and 8K Flows

<table>
<thead>
<tr>
<th>Number of Flows</th>
<th>1 Physical Core Throughput (packets/sec)</th>
<th>2 Hyper-threaded Cores Throughput (packets/sec)</th>
<th>2 Physical Cores Throughput (packets/sec)</th>
<th>4 Hyper-threaded Cores Throughput (packets/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>16,766,108 pps (28% of maximum)</td>
<td>19,183,077 pps (32% of maximum)</td>
<td>30,347,400 pps (51% of maximum)</td>
<td>35,469,109 pps (60% of maximum)</td>
</tr>
<tr>
<td>8K</td>
<td>9,054,720 pps (15% of maximum)</td>
<td>13,485,897 pps (23% of maximum)</td>
<td>19,067,981 pps (32% of maximum)</td>
<td>26,088,780 pps (44% of maximum)</td>
</tr>
</tbody>
</table>
7.3 Virtual Switching Latency (PHY-OVS-PHY)

As described in section 5.4, RFC 5481 specifies two forms of packet delay variation (PDV). The Ixia packet generator used does not support RFC 4581 for PDV or the measurement of IPDV. The generator does provide a PDV measurement with three modes (FIFO, LILO, and FILO). The RFC 5481 metrics of PDV and IPDV, however, can be computed off-line, using data capture and post-processing. Techniques and tools for doing this will be discussed in a future Intel® ONP test document.

Figure 7-9 shows the DUT configuration used for measuring latency through the vSwitch.
Figure 7-10 shows PDV for 64B packets during a one hour test for each target load. The latency values represent the aggregate of latency measurements for all flows during the test run (i.e., for each target load). The target load is increased from 10% of line rate up to 80% of line-rate in 10% increments. The target load of 80% represents the maximum load without packet loss as determined by test case three (Virtual Switching Tests — Throughput).

To illustrate the results, the following is extrapolated from the graph:

- Target load is 60% of line rate (orange bars).
- Approximately 30% of packets during a one hour test have latency between 4 and 5.7 microseconds.
- Approximately 70% of packets during a one hour test have latency between 5.7 and 8 microseconds.
- Total number of packets is 100% of line rate.

![Packet Delay Variation with Varying Load (64B Packets, Zero Packet Loss)](image-url)
7.4 One VM Throughput (PHY-VM-PHY)

This test uses a single VM with two bidirectional flows (total 4 flows) using 4 10GE ports as shown in Figure 7-11. Maximum theoretical platform throughput is 40Gbps (four flows aggregated).

Note: Four switching operations take place while packets are being routed through the system.

VM tests attempt to achieve aggregated system throughput of 40Gbps using 4 ports to compare the following configuration variables (Figure 7-14 shows configurations tested for each type of test).

Configuration variables:

- Native OVS or OVS with DPDK-netdev
- 1 or 2 physical cores
- One flow per port (total four flows) or 1K flows per port (total 4K flows)
- Hyper-threading or no hyper-threading i.e. 1 physical core vs 2 hyper-threaded cores

All tests are L3 forwarding.
Table 7-14. Configurations for Virtual Switching Tests

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Configuration Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ports</td>
</tr>
<tr>
<td>Native OVS</td>
<td>4</td>
</tr>
<tr>
<td>OVS with DPDK-netdev</td>
<td>4</td>
</tr>
<tr>
<td>Core scaling - 1 flow per port</td>
<td>4</td>
</tr>
<tr>
<td>Core scaling - 2k flows per port</td>
<td>4</td>
</tr>
<tr>
<td>Impact of hyper-threading - 1 flow per port</td>
<td>4</td>
</tr>
<tr>
<td>Impact of hyper-threading - 2k flows per port</td>
<td>4</td>
</tr>
</tbody>
</table>
7.4.1 Native OVS and OVS with DPDK-netdev

This test compares Native OVS and OVS with DPDK-netdev. In the case of OVS with DPDK-netdev tests include one or two physical cores and with or without hyper-threading.

Table 7-15. Configuration variables for Native OVS and OVS with DPDK-netdev

<table>
<thead>
<tr>
<th>Configuration variables</th>
<th>Physical Cores</th>
<th>Hyper-threaded cores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native OVS</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>OVS with DPDK-netdev</td>
<td>1, 2</td>
<td>none or 2</td>
</tr>
</tbody>
</table>

Table 7-16. Native OVS, no hyper-threading (1 physical core)

<table>
<thead>
<tr>
<th>Packet Size (Bytes)</th>
<th>Throughput Achieved with Zero Packet Loss</th>
<th>Average Latency (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L3 Forwarding — Bidirectional</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Throughput Achieved with Zero Packet Loss</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mbps</td>
<td>Packets/sec</td>
</tr>
<tr>
<td>64</td>
<td>316</td>
<td>470,266</td>
</tr>
<tr>
<td>256</td>
<td>1031</td>
<td>467,145</td>
</tr>
</tbody>
</table>

Affinity Details
- 0% Loss resolution
- Port0 IRQ's Affinity to lcore2
- Port1 IRQ's Affinity to lcore3
- On a VM:
  # ./testpmd -c 0x6 -n 4 --burst=64 -i --txd=2048 --rxd=2048 --txqflags=0xf00

Table 7-17. OVS with DPDK-netdev, no hyper-threading (1 physical core)

<table>
<thead>
<tr>
<th>Packet size (Bytes)</th>
<th>Aggregate Throughput (Packets/sec)</th>
<th>Line Rate (%)</th>
<th>Minimum Latency (µs)</th>
<th>Average Latency (µs)</th>
<th>Maximum Latency (µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>4,796,202</td>
<td>8</td>
<td>13.7</td>
<td>57.2</td>
<td>892</td>
</tr>
<tr>
<td>72</td>
<td>4,746,944</td>
<td>9</td>
<td>9.3</td>
<td>97.6</td>
<td>1,638</td>
</tr>
<tr>
<td>128</td>
<td>4,681,890</td>
<td>14</td>
<td>11.4</td>
<td>59.0</td>
<td>708</td>
</tr>
<tr>
<td>256</td>
<td>4,367,109</td>
<td>24</td>
<td>9.4</td>
<td>43.1</td>
<td>157</td>
</tr>
<tr>
<td>512</td>
<td>4,064,758</td>
<td>43</td>
<td>12.9</td>
<td>104.9</td>
<td>1,420</td>
</tr>
<tr>
<td>768</td>
<td>2,915,991</td>
<td>46</td>
<td>12.7</td>
<td>133.7</td>
<td>2,198</td>
</tr>
<tr>
<td>1024</td>
<td>2,386,169</td>
<td>50</td>
<td>12.8</td>
<td>122.2</td>
<td>2,154</td>
</tr>
<tr>
<td>1280</td>
<td>2,076,170</td>
<td>54</td>
<td>14.8</td>
<td>99.8</td>
<td>908</td>
</tr>
<tr>
<td>1518</td>
<td>1,852,326</td>
<td>57</td>
<td>10.7</td>
<td>34.3</td>
<td>282</td>
</tr>
</tbody>
</table>
Table 7-18. OVS with DPDK-netdev, with hyper-threading (1 physical core)

<table>
<thead>
<tr>
<th>Packet Size</th>
<th>L3 Forwarding — Bidirectional</th>
<th>Throughput Achieved with Zero Packet Loss</th>
<th>Average Latency (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mbps</td>
<td>Packets/sec</td>
</tr>
<tr>
<td>64</td>
<td></td>
<td>4,113</td>
<td>6,119,796</td>
</tr>
<tr>
<td>72</td>
<td></td>
<td>4,074</td>
<td>5,535,093</td>
</tr>
<tr>
<td>128</td>
<td></td>
<td>6,781</td>
<td>5,727,081</td>
</tr>
<tr>
<td>256</td>
<td></td>
<td>11,808</td>
<td>5,347,922</td>
</tr>
<tr>
<td>512</td>
<td></td>
<td>19,697</td>
<td>4,628,118</td>
</tr>
<tr>
<td>768</td>
<td></td>
<td>18,150</td>
<td>2,879,185</td>
</tr>
<tr>
<td>1024</td>
<td></td>
<td>19,659</td>
<td>2,353,759</td>
</tr>
<tr>
<td>1280</td>
<td></td>
<td>21,824</td>
<td>2,098,483</td>
</tr>
<tr>
<td>1518</td>
<td></td>
<td>23,835</td>
<td>1,937,188</td>
</tr>
</tbody>
</table>

Affinity Details

2PMD thread based OVS and 0.0% Loss resolution

# ./ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=200002

# ./testpmd -c 0x3 -n 4 -- --burst=64 -- --txd=2048 -- --rxd=2048 -- --txqflags=0xf00

4P from 2 cards

![Graph](image)

Figure 7-12. Relative throughput performance with a single VM comparing Native OVS and OVS with DPDK-netdev using one physical core
Table 7-19 shows the VM L3fwd throughput performance of OVS with DPDK-netdev using 2 physical cores.

**Table 7-19. OVS with DPDK-netdev, no hyper-threading (2 physical cores)**

<table>
<thead>
<tr>
<th>Packet Size</th>
<th>Throughput Achieved with Zero Packet Loss</th>
<th>Average Latency (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L3 Forwarding — Bidirectional</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mbps</td>
<td>Packets/sec</td>
</tr>
<tr>
<td>64</td>
<td>5,775</td>
<td>8,594,338</td>
</tr>
<tr>
<td>256</td>
<td>18,576</td>
<td>8,412,957</td>
</tr>
</tbody>
</table>

**Affinity Details**
- 4P from two DUAL cards
- `# ./ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=cOn
- On a VM:
  - `# ./testpmd -c 0x6 -n 4 --burst=64 -i --txqflags=0xf00`
7.4.3 OVS with DPDK-netdev – 4k Flows

This test compares single VM throughput with DPDK-netdev using 1flow per port (total 4 flows) and 1k flows per port (total 4k flows).

Table 7-20. Configuration variables for OVS with DPDK-netdev

<table>
<thead>
<tr>
<th>Configuration variables</th>
<th>Physical Cores</th>
<th>Hyper-threaded cores</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVS with DPDK-netdev</td>
<td>1</td>
<td>none</td>
</tr>
</tbody>
</table>

Table 7-21 shows the L3fwd performance with 4K flows (1 OVS PMD thread).

Table 7-21. OVS with DPDK-netdev, 4k flows

<table>
<thead>
<tr>
<th>Packet size (Bytes)</th>
<th>Aggregate Throughput (Packets/sec)</th>
<th>Line Rate %</th>
<th>Minimum Latency (µs)</th>
<th>Average Latency (µs)</th>
<th>Maximum Latency (µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>3,069,777</td>
<td>5</td>
<td>8.2</td>
<td>73.7</td>
<td>1,003</td>
</tr>
<tr>
<td>72</td>
<td>3,013,002</td>
<td>6</td>
<td>10.6</td>
<td>92.1</td>
<td>1,713</td>
</tr>
<tr>
<td>128</td>
<td>3,016,125</td>
<td>9</td>
<td>11.0</td>
<td>87.2</td>
<td>1,567</td>
</tr>
<tr>
<td>256</td>
<td>2,948,439</td>
<td>16</td>
<td>8.7</td>
<td>105.6</td>
<td>1,760</td>
</tr>
<tr>
<td>512</td>
<td>2,738,137</td>
<td>29</td>
<td>10.5</td>
<td>106.1</td>
<td>1,701</td>
</tr>
<tr>
<td>768</td>
<td>1,977,414</td>
<td>31</td>
<td>12.6</td>
<td>557.6</td>
<td>3,835</td>
</tr>
<tr>
<td>1024</td>
<td>1,608,287</td>
<td>34</td>
<td>12.0</td>
<td>94.0</td>
<td>2,166</td>
</tr>
<tr>
<td>1280</td>
<td>1,455,189</td>
<td>38</td>
<td>11.0</td>
<td>155.3</td>
<td>3,173</td>
</tr>
<tr>
<td>1518</td>
<td>1,318,009</td>
<td>41</td>
<td>7.0</td>
<td>88.7</td>
<td>1,613</td>
</tr>
</tbody>
</table>

Figure 7-14 shows the L3 forwarding throughput performance of 4 flows and 4K flows with 1 core (without hyper-threading). There is an average of 33% performance decrease for 4K flows in comparison to 4 flows.
Figure 7-14. One-VM Throughput (PHY-VM-PHY) with 4 Flows and 4K Flows
7.5 Two VM Throughput (PHY-VM-VM-PHY)

Figure 7-15 shows the VM-VM test setup with 2 x 10GbE ports (maximum 20Gbps aggregate throughput) with packets being forwarded from the first VM to the second VM (total two flows).

**Note:** There are 3 switching operations taking place while packets are being routed through the system.

This test compares two VM throughput with DPDK-netdev using 1flow per port (total 2 flows) and 2k flows per port (total 4k flows).

**Table 7-22. Configuration variables for OVS with DPDK-netdev**

<table>
<thead>
<tr>
<th>Configuration variables</th>
<th>Physical Cores</th>
<th>Hyper-threaded cores</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVS with DPDK-netdev</td>
<td>1</td>
<td>none</td>
</tr>
</tbody>
</table>
Figure 7-16 shows packet throughput comparing 2 flows and 4K flows for 1 core running 1 OVS PMD thread.

Table 7-23 and Table 7-24 show the data plotted and the latency numbers for each packet size for 1 core running 1 OVS PMD thread.

Table 7-23. VM-to-VM Packet Throughput with 2 Flows

<table>
<thead>
<tr>
<th>Packet size (Bytes)</th>
<th>Aggregate throughput (packets/sec)</th>
<th>Line Rate %</th>
<th>Minimum latency (µs)</th>
<th>Average latency (µs)</th>
<th>Maximum latency (µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>2,858,482</td>
<td>9.6</td>
<td>11</td>
<td>72</td>
<td>1,009</td>
</tr>
<tr>
<td>72</td>
<td>2,820,089</td>
<td>10.4</td>
<td>12</td>
<td>125</td>
<td>1,288</td>
</tr>
<tr>
<td>128</td>
<td>2,830,877</td>
<td>16.8</td>
<td>18</td>
<td>210</td>
<td>1,504</td>
</tr>
<tr>
<td>256</td>
<td>2,726,504</td>
<td>30.1</td>
<td>12</td>
<td>144</td>
<td>1,225</td>
</tr>
<tr>
<td>512</td>
<td>2,486,700</td>
<td>52.9</td>
<td>15</td>
<td>218</td>
<td>1,454</td>
</tr>
<tr>
<td>768</td>
<td>2,046,907</td>
<td>64.5</td>
<td>20</td>
<td>141</td>
<td>1,210</td>
</tr>
<tr>
<td>1024</td>
<td>1,751,030</td>
<td>73.1</td>
<td>20</td>
<td>131</td>
<td>984</td>
</tr>
<tr>
<td>1280</td>
<td>1,512,187</td>
<td>78.6</td>
<td>24</td>
<td>151</td>
<td>1,147</td>
</tr>
<tr>
<td>1518</td>
<td>1,344,186</td>
<td>82.7</td>
<td>23</td>
<td>116</td>
<td>1,062</td>
</tr>
</tbody>
</table>
Table 7-24. VM-to-VM Packet Throughput with 4K Flows

<table>
<thead>
<tr>
<th>Packet size (Bytes)</th>
<th>Aggregate throughput (packets/sec)</th>
<th>Line Rate %</th>
<th>Minimum latency (µs)</th>
<th>Average latency (µs)</th>
<th>Maximum latency (µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>1,736,304</td>
<td>5.8</td>
<td>17</td>
<td>191</td>
<td>2,257</td>
</tr>
<tr>
<td>72</td>
<td>1,690,405</td>
<td>6.2</td>
<td>15</td>
<td>133</td>
<td>1,139</td>
</tr>
<tr>
<td>128</td>
<td>1,687,704</td>
<td>10.0</td>
<td>19</td>
<td>122</td>
<td>920</td>
</tr>
<tr>
<td>256</td>
<td>1,640,607</td>
<td>18.1</td>
<td>15</td>
<td>144</td>
<td>1,020</td>
</tr>
<tr>
<td>512</td>
<td>1,509,908</td>
<td>32.1</td>
<td>17</td>
<td>121</td>
<td>601</td>
</tr>
<tr>
<td>768</td>
<td>1,043,917</td>
<td>32.9</td>
<td>19</td>
<td>242</td>
<td>1,697</td>
</tr>
<tr>
<td>1024</td>
<td>903,695</td>
<td>37.7</td>
<td>12</td>
<td>32</td>
<td>1,554</td>
</tr>
<tr>
<td>1280</td>
<td>841,002</td>
<td>43.7</td>
<td>19</td>
<td>316</td>
<td>2,291</td>
</tr>
<tr>
<td>1518</td>
<td>787,867</td>
<td>48.5</td>
<td>12</td>
<td>275</td>
<td>1,782</td>
</tr>
</tbody>
</table>

Figure 7-17 compares packet throughput of PHY-to-VM case and VM-to-VM test case with 4K flows (without hyper-threading) for 1 core running 1 OVS PMD thread. There is an additional switching operation in the VM-to-VM setup for communicating between the two VMs.
7.6 **VXLAN (PHY-OVS-VM-OVS-PHY)**

This test case investigates performance of VXLAN ([https://tools.ietf.org/html/rfc7348](https://tools.ietf.org/html/rfc7348)) using regular Open vSwitch* and Open vSwitch* with DPDK-netdev. The performance data provides a baseline for scenarios using VXLAN Tunnel End Points (VTEPs) in the vSwitch and establishes a test methodology for future comparisons. The test data here cannot be compared directly with other data in this document because the test setups are not equivalent. Future tests will include realistic use-case scenarios where traffic passes through VMs. The methodology described here attempts to emulate the scenario in Figure 7-18. An important difference, however, is that traffic does not pass through a VM (described below).

Figure 7-18 shows a VXLAN scenario using 2 x 10GbE ports (maximum 20Gbps aggregate throughput using two flows). VXLAN decapsulation and encapsulation processing occurs in the vSwitch VTEP.

![Figure 7-18. VXLAN Scenario with 2 Physical Ports and VTEP in the vSwitch](image)
7.6.1 VXLAN Test Methodology

In this test methodology, 2 hosts are used with VTEPs in each host doing both encapsulation and decapsulation. Figure 7-19 shows the test setup with packet flows between each host using the VXLAN tunnel and between each host and the Ixia traffic generator.

Each host machine requires 2 x 10GbE network ports:

1. Port 1 (eth0) is used for the VXLAN tunnel connection between the host machines.
2. Port 2 (eth1) is used for IPv4 traffic to and from the Ixia traffic generator.

VXLAN test setup details are provided in section 13, VXLAN Test Setup.

![Figure 7-19. Test Setup Showing Packet Flows between Hosts and Ixia Traffic Generator](image)

In this setup, 2 identical hosts are used (if hosts are not identical bottlenecks can impact test measurements). The 2 hosts are connected using 10GbE ports to create a VXLAN tunnel. The following steps show the flow of packets between Host A and Host B:

1. Ixia generates IPV4 packets.
2. OVS in Host A receives the IPv4 packets through eth1.
3. VTEP configured at vxlan0 in Host A encapsulates the IPv4 packets.
4. OVS in Host A forwards the VXLAN packets to Host B via the VXLAN tunnel.
5. In Host B, OVS receives the packets at br0 and forwards the VXLAN packets to the VTEP configured at vxlan0.
6. The VXLAN packets are decapsulated into IPv4 packets and OVS sends the packets to the Ixia via eth1.
7. Step 1 – 6 are repeated for IPv4 traffic from IXIA to Host B and Host B forwards the encapsulated VXLAN packets to Host A, which would be decapsulated and sent back to IXIA.
If the flow is unidirectional, Host A would encapsulate the IPv4 packet and Host B decapsulate the VXLAN packet. This test methodology uses bidirectional flows in order to measure both encapsulation and decapsulation performance (which occurs in each host).

### 7.6.2 VXLAN Test Results

VXLAN tests attempt to achieve system throughput of 20Gbps using 2 physical ports and 1 flow per port in each direction (see Table 7-25). Performance data shows comparisons between:

1. Native OVS and OVS with DPDK-netdev
2. OVS with DPDK-netdev when using 1 and 2 physical cores

<table>
<thead>
<tr>
<th>Test</th>
<th>Configurations for VXLAN Tests</th>
<th>Configuration Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ports</td>
<td>TX/RX Queues per Core</td>
</tr>
<tr>
<td>Native OVS (encap/decap and L3 Forwarding)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>OVS with DPDK-netdev (encap/decap and L3 Forwarding)</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 7-20 shows VXLAN performance for 64B comparing Native OVS and OVS with DPDK-netdev for 1 core and 2 core configurations. Aggregate throughput and latency data are provided in Table 7-26.
Figure 7-20. VXLAN Performance for 64B Packets Comparing Native OVS and OVS with DPDK-netdev (1 and 2 Cores)

Table 7-26. Packet Throughput for 64B with Native OVS and OVS with DPDK-netdev

<table>
<thead>
<tr>
<th>Test Configuration</th>
<th>Aggregate Throughput (Packets/sec)</th>
<th>Line Rate %</th>
<th>Minimum Latency (µs)</th>
<th>Average Latency (µs)</th>
<th>Maximum Latency (µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVS</td>
<td>412,769</td>
<td>1</td>
<td>42.7</td>
<td>78.8</td>
<td>20,814</td>
</tr>
<tr>
<td>OVS with DPDK-netdev (1 core)</td>
<td>7,347,179</td>
<td>25</td>
<td>10.9</td>
<td>29.6</td>
<td>121</td>
</tr>
<tr>
<td>OVS with DPDK-netdev (2 cores)</td>
<td>12,699,097</td>
<td>43</td>
<td>10.6</td>
<td>16.0</td>
<td>323</td>
</tr>
</tbody>
</table>

Figure 7-21 shows VXLAN performance comparing Native OVS and OVS with DPDK-netdev for 1 core and 2 core configurations for all packet sizes. Aggregate throughput and latency data are provided in Table 7-27, Table 7-28, and Table 7-29, respectively.
Figure 7-21. VXLAN Performance (PHY-VM-PHY) Comparing Native OVS and OVS with DPDK-netdev (1 and 2 Cores)
### Table 7-27. Packet Throughput using Native OVS

<table>
<thead>
<tr>
<th>Packet size (Bytes)</th>
<th>Aggregate Throughput (Packets/sec)</th>
<th>Line Rate</th>
<th>Minimum Latency (µs)</th>
<th>Average Latency (µs)</th>
<th>Maximum Latency (µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>412,769</td>
<td>1</td>
<td>42.7</td>
<td>78.8</td>
<td>20,814</td>
</tr>
<tr>
<td>72</td>
<td>411,534</td>
<td>1</td>
<td>42.4</td>
<td>79.8</td>
<td>19,944</td>
</tr>
<tr>
<td>128</td>
<td>413,938</td>
<td>2</td>
<td>41.6</td>
<td>86.5</td>
<td>21,123</td>
</tr>
<tr>
<td>256</td>
<td>432,179</td>
<td>5</td>
<td>39.8</td>
<td>187.4</td>
<td>26,929</td>
</tr>
<tr>
<td>512</td>
<td>333,262</td>
<td>7</td>
<td>32.0</td>
<td>66.4</td>
<td>20,488</td>
</tr>
<tr>
<td>768</td>
<td>304,744</td>
<td>9</td>
<td>33.6</td>
<td>64.4</td>
<td>19,718</td>
</tr>
<tr>
<td>1024</td>
<td>283,277</td>
<td>12</td>
<td>31.9</td>
<td>64.1</td>
<td>19,034</td>
</tr>
<tr>
<td>1280</td>
<td>225,635</td>
<td>12</td>
<td>30.7</td>
<td>61.9</td>
<td>20,169</td>
</tr>
<tr>
<td>1468</td>
<td>226,368</td>
<td>13</td>
<td>24.9</td>
<td>62.0</td>
<td>19,263</td>
</tr>
</tbody>
</table>

### Table 7-28. Packet Throughput using OVS with DPDK-netdev (1 Core)

<table>
<thead>
<tr>
<th>Packet size (Bytes)</th>
<th>Aggregate Throughput (Packets/sec)</th>
<th>Line Rate</th>
<th>Minimum Latency (µs)</th>
<th>Average Latency (µs)</th>
<th>Maximum Latency (µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>7,347,179</td>
<td>25</td>
<td>10.9</td>
<td>29.6</td>
<td>121.5</td>
</tr>
<tr>
<td>72</td>
<td>7,312,547</td>
<td>27</td>
<td>9.0</td>
<td>28.8</td>
<td>118.0</td>
</tr>
<tr>
<td>128</td>
<td>7,354,579</td>
<td>44</td>
<td>9.1</td>
<td>40.3</td>
<td>209.0</td>
</tr>
<tr>
<td>256</td>
<td>7,332,791</td>
<td>81</td>
<td>10.0</td>
<td>44.6</td>
<td>226.6</td>
</tr>
<tr>
<td>512</td>
<td>4,294,903</td>
<td>91</td>
<td>11.5</td>
<td>18.4</td>
<td>59.8</td>
</tr>
<tr>
<td>768</td>
<td>2,982,420</td>
<td>94</td>
<td>11.8</td>
<td>15.5</td>
<td>53.1</td>
</tr>
<tr>
<td>1024</td>
<td>2,283,510</td>
<td>95</td>
<td>11.9</td>
<td>14.4</td>
<td>50.1</td>
</tr>
<tr>
<td>1280</td>
<td>1,850,568</td>
<td>96</td>
<td>11.6</td>
<td>14.4</td>
<td>122.9</td>
</tr>
<tr>
<td>1468</td>
<td>1,624,881</td>
<td>97</td>
<td>11.3</td>
<td>14.2</td>
<td>79.0</td>
</tr>
</tbody>
</table>

### Table 7-29. Packet Throughput using OVS with DPDK-netdev (2 Cores)

<table>
<thead>
<tr>
<th>Packet size (Bytes)</th>
<th>Aggregate Throughput (Packets/sec)</th>
<th>Line Rate</th>
<th>Minimum Latency (µs)</th>
<th>Average Latency (µs)</th>
<th>Maximum Latency (µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>12,699,097</td>
<td>43</td>
<td>10.6</td>
<td>15.0</td>
<td>323.0</td>
</tr>
<tr>
<td>72</td>
<td>12,829,611</td>
<td>47</td>
<td>10.8</td>
<td>17.4</td>
<td>277.1</td>
</tr>
<tr>
<td>128</td>
<td>12,613,178</td>
<td>75</td>
<td>11.9</td>
<td>21.4</td>
<td>99.0</td>
</tr>
<tr>
<td>256</td>
<td>7,665,582</td>
<td>85</td>
<td>11.8</td>
<td>16.8</td>
<td>53.0</td>
</tr>
<tr>
<td>512</td>
<td>4,294,904</td>
<td>91</td>
<td>11.7</td>
<td>18.6</td>
<td>152.9</td>
</tr>
<tr>
<td>768</td>
<td>2,982,420</td>
<td>94</td>
<td>11.9</td>
<td>16.3</td>
<td>68.0</td>
</tr>
<tr>
<td>1024</td>
<td>2,283,510</td>
<td>95</td>
<td>11.7</td>
<td>14.8</td>
<td>112.0</td>
</tr>
<tr>
<td>1280</td>
<td>1,850,568</td>
<td>96</td>
<td>11.7</td>
<td>14.8</td>
<td>51.1</td>
</tr>
<tr>
<td>1468</td>
<td>1,624,881</td>
<td>97</td>
<td>11.4</td>
<td>15.2</td>
<td>120.0</td>
</tr>
</tbody>
</table>
8.0 Industry Benchmarks

8.1 ETSI NFV

The European Telecommunications Standards Institute (ETSI) NFV (Phase II) is developing test methodologies and test specifications relevant to performance testing. Certain draft specification documents are available publically here: https://docbox.etsi.org/ISG/NFV/Open/Drafts/. This includes a "NFV Pre-Deployment Validation" specification with the following:

1. Test methods for pre-deployment validation:
   a. Validating physical DUTs and systems-under-test:
      i. Data plane validation
      ii. Control plane validation
      iii. Management plane validation
   b. Impact of virtualization on test methods
   c. Considerations on choice of virtualized versus hardware based test appliances
2. Pre-deployment validation of NFV infrastructure
3. Pre-deployment validation of VNFs:
   a. VNF life-cycle testing:
      i. VNF instantiation testing
      ii. VNF termination
   b. VNF data plane benchmarking
4. Pre-deployment validation of network services
5. Reliability & resiliency requirements
6. Security considerations

8.2 IETF

The Benchmark Working Group (BMWG) is one of the longest-running working groups in IETF. This group was rechartered in 2014 to include benchmarking for virtualized network functions (VNFs) and their infrastructure.

An active Internet draft, "Considerations for Benchmarking Virtual Network Functions and Their Infrastructure," is available here: https://tools.ietf.org/html/draft-ietf-bmwg-virtual-net-00. Many RFCs referenced originated in the BMWG, including foundational RFC 1242 and RFC 2544:

- 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
Open Platform for NFV (OPNFV)

OPNFV is a carrier-grade, integrated, open-source platform to accelerate the introduction of new NFV products and services. As an open-source project, OPNFV is uniquely positioned to bring together the work of standards bodies, open-source communities, and commercial suppliers to deliver a de facto open-source NFV platform for the industry. By integrating components from upstream projects, the community can conduct performance and use case-based testing to ensure the platform’s suitability for NFV use cases.

As shown in Figure 8-1, many test projects within OPNFV are concerned with performance.

Base system testing:

- Infrastructure verification
- Platform performance benchmarking
- Characterize vSwitch performance for Telco
- Find system bottlenecks
- Storage performance benchmarking for NFVI
- Carrier grade requirements
- Controller performance testing

For more information, refer to OPNFV Wiki: https://wiki.opnfv.org/start.
vSwitch performance characterization is of particular relevance to this test report. An Internet draft for benchmarking vSwitches in OPNFV is available here: https://tools.ietf.org/html/draft-vesperf-bmwg-vswitch-opnfv-00. The draft describes the progress of the OPNFV project on vSwitch performance. This project intends to build on the current and completed work of the BMWG in IETF. The BMWG has traditionally conducted laboratory characterization of dedicated physical implementations of Internet-working functions. This memo begins to describe the additional considerations when vSwitches are implemented in general-purpose hardware.
9.0 Performance Tuning

9.1 Tuning Methods

There are a few important tuning methods that can improve throughput performance for PHY-PHY, PHY-VM, and VM-VM test cases:

- CPU core isolation for OVS-DPDK
- HugePage size 1 GB
- CPU core affinity for ovs-vswitchd and OVS PMD threads
- CPU core affinity for the VM (qemu-kvm)

This section provides some fundamental optimization and tunings for the OVS with DPDK setup. Refer to https://github.com/openvswitch/ovs/blob/master/INSTALL.DPDK.md#performance-tuning for more information on tuning-related optimization.

9.2 CPU Core Isolation for OVS-DPDK

While the threads used by OVS are pinned to logical cores on the system, the Linux scheduler can also run other tasks on those cores. To help prevent additional workloads from running on them, the isolcpus Linux* kernel parameter can be used to isolate the cores from the general Linux scheduler. Add the isolcpus Linux* parameter in the Linux boot kernel of the host machine. For example, if the OVS vswitchd and qemu-kvm process are to run on logical cores 2, 4, and 6, the following should be added to the kernel parameter list:

isolcpus=2,4,6

9.3 HugePage Size 1 GB

HugePage support is required for the large-memory pool allocation used for packet buffers. By using HugePage allocations, performance is increased because fewer pages are needed, and therefore less translation lookaside buffers (TLBs, high-speed translation caches). This reduces the time it takes to translate a virtual page address to a physical page address. Without HugePages, high TLB miss rates would occur with the standard 4K page size, slowing performance.

The allocation of HugePages should be done at boot time or as soon as possible after system boot to prevent memory from being fragmented in physical memory. To reserve HugePages at boot time, a parameter is passed to the Linux* kernel on the kernel command line. For example, to reserve 16G of HugePage memory in the form of 16 1G pages, the following options should be passed to the kernel:

default_hugepagesz=1G hugepagesz=1G hugepages=16

**Note:** For 1G HugePages, it is not possible to reserve the HugePage memory after the system has booted.

After the machine is up and running, mount the huge table file system:

```bash
# mount -t hugetlbfs -o pagesize=1G none /dev/hugepages
```
9.4 CPU Core Affinity for ovs-vswitchd and OVS PMD Threads

With PMD multi-threading support, OVS creates one PMD thread for each NUMA node as default. The PMD thread handles the I/O of all DPDK interfaces on the same NUMA node. The following command can be used to configure the multi-threading behavior:

```
# ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=<hex_string>
```

The above command asks for a CPU mask for setting the affinity of PMD threads. A set bit in the mask means a PMD thread is created and pinned to the corresponding CPU core. Ideally, for maximum throughput, the PMD thread should not be scheduled out, which temporarily halts its execution. Therefore, with the CPU core isolation being on the host machine during boot time, the CPU-isolated cores will be used to set the affinity of the PMD threads. For example, to configure PMD threads on core 2 and 3 using 'pmd-cpu-mask':

```
# ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=C
```

Check that the OVS PMD thread is set to the correct CPU1 and ovs-vswitchd threads are set to CPU2 and CPU3 using this command:

```
# top -p `pidof ovs-vswitchd` -H -d1
```

```
top - 17:31:09 up 2:46,  3 users,  load average: 0.40, 0.11, 0.08
Threads: 18 total,  1 running, 17 sleeping,  0 stopped,  0 zombie
%Cpu(s):  8.4 us, 0.0 sy, 0.0 ni, 91.6 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
KiB Mem: 32748524 total, 11233304 free, 21292684 used, 222536 buff/cache
KiB Swap:  4194300 total, 4194300 free,       0 used. 11237940 avail Mem

PID USER      PR NI    VIRT    RES    SHR S %CPU %MEM     TIME+ COMMAND
2150 root      20   0 3836184   8896   5140 R 99.0  0.0   0:28.55 pmd28
2152 root      20   0 3836184   8896   5140 R 99.0  0.0   0:28.55 pmd29
2041 root      20   0 3836184   8896   5140 S  0.0  0.0   0:13.47 ovs-vswitchd
2042 root      20   0 3836184   8896   5140 S  0.0  0.0   0:00.00 ovs-vswitchd
```

**Note:** The PMD threads on a NUMA node are created only if there is at least one DPDK interface from the NUMA node that has been added to OVS. To understand where most of the time is spent and whether the caches are effective, these commands can be used:

```
# ovs-appctl dpif-netdev/pmd-stats-clear #To reset statistics
# ovs-appctl dpif-netdev/pmd-stats-show
```
9.5 CPU Core Affinity for the Virtual Machine (qemu-kvm)

When configuring a PHY-VM test environment, it is important to set the CPU core affinity for the virtual machine (VM). Depending on the number of cores being assigned to the VM, the CPU core affinity should be set according to the QEMU threads. For example, to configure a VM with 4 cores, start the VM on CPU 4-6 (0x70):

```bash
# taskset 70 qemu-system-x86_64 -m 4096 -smp 4 -cpu host -hda /root/vm-images/vm-fc21.img -boot c -enable-kvm -pidfile /tmp/vm1.pid -monitor unix:/tmp/vm1monitor,server,nowait -name 'FC21-VM1' -net none -no-reboot -object memory-backend-file,id=mem,size=4096M,mem-path=/dev/hugepages,share=on - numa node,memdev=mem -mem-prepare -net none \  -chardev socket,id=char1,path=/usr/local/var/run/openvswitch/vhost-user0 \  -netdev type=vhost-user,id=net1,chardev=char1,vhostforce -device virtio-net-pci,netdev=net1,mac=00:00:00:00:00:01,csum=off,gso=off,guest_tso4=off,guest_tso6=off,guest_ecn=off,mrg_rxbuf=off \  -chardev socket,id=char2,path=/usr/local/var/run/openvswitch/vhost-user1 \  -netdev type=vhost-user,id=net2,chardev=char2,vhostforce -device virtio-net-pci,netdev=net2,mac=00:00:00:00:00:02,csum=off,gso=off,guest_tso4=off,guest_tso6=off,guest_ecn=off,mrg_rxbuf=off \  --nographic -vnc :14
```

Once the VM is running, there will be multiple QEMU threads that are spawned running on the host. Check the main QEMU thread process ID (PID) to track the spawned threads:

```bash
# ps -e |grep qemu
2511 pts/3  22:27:53 qemu-system-x86
```
Use the `top` command to provide a list of the main and child process QEMU threads. The main QEMU thread PID 2511 is always active with utilization close to 100% of CPU:

```
# top -p 2511 -H -d1
```

```
top - 17:06:42 up 1 day, 3:03, 3 users, load average: 2.00, 2.01, 2.02
Threads: 6 total, 1 running, 5 sleeping, 0 stopped, 0 zombie
%Cpu(s): 16.7 us, 0.0 sy, 0.0 ni, 83.3 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
KiB Mem: 32748524 total, 10566116 free, 21308332 used, 874076 buff/cache
KiB Swap: 4194300 total, 4194300 free, 0 used. 11189840 avail Mem

<table>
<thead>
<tr>
<th>PID</th>
<th>USER</th>
<th>PR</th>
<th>NI</th>
<th>VIRT</th>
<th>RES</th>
<th>SHR</th>
<th>%CPU</th>
<th>%MEM</th>
<th>TIME+</th>
<th>COMMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>2520</td>
<td>root</td>
<td>20</td>
<td>0</td>
<td>4704308</td>
<td>24944</td>
<td>6848 R</td>
<td>99.9</td>
<td>0.1</td>
<td>1339:34</td>
<td>qemu-system-x86</td>
</tr>
<tr>
<td>2511</td>
<td>root</td>
<td>20</td>
<td>0</td>
<td>4704308</td>
<td>24944</td>
<td>6848 S</td>
<td>0.0</td>
<td>0.1</td>
<td>0:11.69</td>
<td>qemu-system-x86</td>
</tr>
<tr>
<td>2518</td>
<td>root</td>
<td>20</td>
<td>0</td>
<td>4704308</td>
<td>24944</td>
<td>6848 S</td>
<td>0.0</td>
<td>0.1</td>
<td>2:11.77</td>
<td>qemu-system-x86</td>
</tr>
<tr>
<td>2519</td>
<td>root</td>
<td>20</td>
<td>0</td>
<td>4704308</td>
<td>24944</td>
<td>6848 S</td>
<td>0.0</td>
<td>0.1</td>
<td>0:11.13</td>
<td>qemu-system-x86</td>
</tr>
<tr>
<td>2521</td>
<td>root</td>
<td>20</td>
<td>0</td>
<td>4704308</td>
<td>24944</td>
<td>6848 S</td>
<td>0.0</td>
<td>0.1</td>
<td>7:57.56</td>
<td>qemu-system-x86</td>
</tr>
<tr>
<td>2523</td>
<td>root</td>
<td>20</td>
<td>0</td>
<td>4704308</td>
<td>24944</td>
<td>6848 S</td>
<td>0.0</td>
<td>0.1</td>
<td>0:03.76</td>
<td>qemu-system-x86</td>
</tr>
</tbody>
</table>
```

Then, use `htop` to check the % CPU usage in runtime for each QEMU child thread and determine the active QEMU threads:

```
# htop -p 2520,2511,2518,2519,2521,2523
```

Output:

![Figure 9-1. Output from htop showing high CPU usage for active QEMU threads](image)

From the `htop` screen, you can view two active QEMU threads that have a high CPU usage. In this example, PID 2511 and PID 2520 (screen output) are using 100% CPU. We have to set these two active threads to specific CPU logical cores. We are going to set PID 2511 to CPU4 (0x10), and PID 2520 to CPU 5 (0x20). The other 4 threads (PID: 2518, 2519, 2521, 2523) are going to be set to CPU6 (0x40).

It is important to assign each active (100% CPU) QEMU thread to separate CPU cores to sustain good optimal throughput performance. If the active QEMU threads are not core-affinitized, the overall throughput performance is impacted.
9.6 Troubleshooting Tips for OVS

In the OVS controller, there are a few management tools in ovs-vswitchd that are useful to monitor the status of ports and OpenFlow activities:

- `ovs-vsctl` manages the switch through interaction with ovsdb-server.
- `ovs-ofctl` is a management utility for OpenFlow.
- `ovs-appctl` is a utility for managing logging levels.

After creating and configuring the ports, the `ovs-vsctl` command tool is useful to check the overall view of the bridges and ports created in the ovsdb-server database:

```
# ovs-vsctl show
7bdd3285-c5db-4944-b963-3ecedf661a41
  Bridge "br0"
    Port "br0"
      Interface "br0"
      type: internal
    Port "dpdk0"
      Interface "dpdk0"
      type: dpdk
    Port "dpdk1"
      Interface "dpdk1"
      type: dpdk
```
The ovs-ofctl command tool is useful to check the OpenFlow flow configuration and port statistics. To check port information on a particular bridge, such as the port’s media access control (MAC) address and number, ovs-ofctl show <bridge-name> or ovs-ofctl dump-ports-desc <bridge-name> provides the following information on all ports:

```
OFPT_FEATURES_REPLY (xid=0x2): dpid:0000001b21a272e4
  n_tables:254, n_buffers:256
  capabilities: FLOW_STATS TABLE_STATS PORT_STATS QUEUE_STATS ARP_MATCH_IP
  actions: output enqueue set_vlan_vid strip_vlan mod_dl_src mod_dl_dst
           mod_nw_dst mod_nw_tos mod_tp_src mod_tp_dst
1(dpdk0): addr:00:1b:21:a2:72:e4
  config:     0
  state:      LINK_DOWN
  current:    AUTO_NEG
  speed: 0 Mbps now, 0 Mbps max
2(vxlan0): addr:c2:7a:99:d6:01:e2
  config:     0
  state:      0
  speed: 0 Mbps now, 0 Mbps max
LOCAL(br-int): addr:00:1b:21:a2:72:e4
  config:     0
  state:      0
  current:    10MB-FD COPPER
  speed: 10 Mbps now, 0 Mbps max
```

When the test is running, you can monitor packets sending and receiving at the ports configured in OVS by checking the flow and port statistics. For example, if you want to check if the packets are being received and sent in a flow, ovs-ofctl dump-flows <bridge-name> prints all the configured flow statistics. The figure below shows the flows configured for sending and receiving exist and are being used with n_packets equal to non-zero.

```
# /root/ovs/utilities/ovs-ofctl dump-flows br-int
NXST_FLOW reply (xid=0x4): cookie=0x0, duration=177593.242s, table=0,
n_packets=1300667542, n_bytes=78040052520, idle_age=65534, hard_age=65534,
  ip, in_port=2 actions=output:1
```
The `ovs-ofctl dump-ports <bridge-name>` command prints port statistics for RX/TX packets, packets that are dropped, and packet errors (if they occur). In this example, there are packet errors in port 1. One of the reasons may be that the packet rate being received at port 1 is too high and beyond the port’s capacity. The packet sending rate to the port, therefore, needs to be reduced to fix the packet error. If there is a packet drop in the OVS, check the CPU core affinitization for the QEMU threads for the PHY-VM test case, and if the HugePage size is set correctly, and the ovs-vswitchd and OVS PMD threads are running on isolated cores.

```
# /root/ovs/utilities/ovs-ofctl dump-ports br-int
OFPST_PORT reply (xid=0x2): 3 ports
  port 2: rx pkts=0, bytes=0, drop=0, errs=0, frame=0, over=0, crc=0
  tx pkts=8, bytes=648, drop=0, errs=0, coll=0
  port 1: rx pkts=578932881, bytes=37051704384, drop=0, errs=176810889, frame=0,
          over=0, crc=0
  tx pkts=130667551, bytes=83242723450, drop=0, errs=0, coll=0
  port LOCAL: rx pkts=14, bytes=1156, drop=0, errs=0, frame=0, over=0, crc=0
  tx pkts=0, bytes=0, drop=0, errs=0, coll=0
```

To check the Address Resolution Protocol (ARP) cache content, `ovs-appctl tnl/arp/show` prints the learned MAC address and IP address.

```
# /root/ovs/utilities/ovs-appctl tnl/arp/show
IP MAC                 Bridge
=============================================
2.2.2.1 00:1b:21:a2:72:e5   br0
2.2.2.2 00:1b:21:a2:72:e6   br0
```
10.0 OVS Test Setup

10.1 Configure the Host Machine

1. Disable the following services:
   a. The interruption request (IRQ) balance:
      # killall irqbalance
      # systemctl stop irqbalance.service
      # systemctl disable irqbalance.service
   b. Firewall and iptables:
      # systemctl stop firewalld.service
      # systemctl disable firewalld.service
      # systemctl stop iptables.service
   c. Security-enhanced Linux (SELinux):
      [root@localhost ~]# vi /etc/selinux/config
      SELINUX=disabled
   d. Address space layout randomization:
      # echo "# Disable Address Space Layout Randomization (ASLR)" > /etc/\sysctl.d/aslr.conf
      # echo "kernel.randomize_va_space=0" >> /etc/sysctl.d/aslr.conf
   e. IPv4 forwarding:
      # echo "# Enable IPv4 Forwarding" > /etc/sysctl.d/ip_forward.conf
      # echo "net.ipv4.ip_forward=0" >> /etc/sysctl.d/ip_forward.conf
      # systemctl restart systemd-sysct1.service
      # cat /proc/sys/kernel/randomize_va_space
      0
      # cat /proc/sys/net/ipv4/ip_forward
      0

2. Set the uncore frequency:
   # rdmsr -p 0 0x620
c1e
   # rdmsr -p 14 0x620
c1e
   # wrmsr -p 0 0x620 0x1e1e
   # wrmsr -p 14 0x620 0x1e1e

3. Set the PCI configuration:
   # setpci -s 00:03.0 184.1
   0000000
   # setpci -s 00:03.2 184.1
4. Remove the following modules:

   # rmmod ipmi_msghandler
   # rmmod ipmi_si
   # rmmod ipmi_devintf

## 10.2  Set the Kernel Boot Parameters

1. With hyper-threading enabled, add the following to the kernel boot parameters
   `/etc/default/grub` for 2 sockets:

   ```
   GRUB_CMDLINE_LINUX="rd.lvm.lv=fedora-server/root rd.lvm.lv=fedora-server/swap
   default_hugepagesz=1G hugepagesz=1G hugepages=16 hugepagesz=2M hugepages=2048
   intel_iommu=off isolcpus=1-13,15-27,29-41,43-55 rhgb quiet"
   ```

2. With hyper-threading disabled, add the following to the kernel boot parameters
   `/etc/default/grub` for 2 sockets:

   ```
   GRUB_CMDLINE_LINUX="rd.lvm.lv=fedora-server/root rd.lvm.lv=fedora-server/swap
   default_hugepagesz=1G hugepagesz=1G hugepages=16 hugepagesz=2M hugepages=2048
   intel_iommu=off isolcpus=1-13,15-27 rhgb quiet"
   ```

3. Save the file and update the GRUB config file:

   ```
   # grub2-mkconfig -o /boot/grub2/grub.cfg
   ```

4. Reboot the host machine and check to make sure 1GB and 2MB HugePage sizes are created.
   You should see 16 1GB HugePages and 2048 2MB HugePages:

   ```
   # ls /sys/devices/system/node/node0/hugepages/hugepages-*
  hugepages-1048576kB/ hugepages-2048kB/
   # cat /sys/devices/system/node/node0/hugepages/hugepages-1048576kB/nr_hugepages
   16
   # cat /sys/devices/system/node/node0/hugepages/hugepages-2048kB/nr_hugepages
   2048
   ```

## 10.3  Compile DPDK 2.0

1. Go to the DPDK-2.0.0 directory and run the following:

   ```
   # make install T=x86_64-ivshmem-linuxapp-gcc
   # cd x86_64-ivshmem-linuxapp-gcc
   ```

2. Edit the config file (`vim .config`) and set the configuration options:

   ```
   CONFIG_RTE_BUILD_COMBINE_LIBS=y
   CONFIG_RTE_LIBRTE_VHOST=y
   CONFIG_RTE_LIBRTE_VHOST_USER=y
   ```

3. Save the config file and run `make`:

   ```
   # EXTRA_CFLAGS="-g -Ofast"
   ```
10.4 Install OVS

Go to the OVS directory and run:

```
# ./boot.sh
# ./configure --with-dpdk=/root/dpdk-2.0.0/x86_64-ivshmem-linuxapp-gcc \
    CFLAGS="-Ofast -g"
# make 'CFLAGS=-g -Ofast -march=native' -j10
```

10.5 Prepare to Start OVS

1. Mount the 1GB HugePage and 2MB HugePage:

```
# mkdir -p /mnt/huge
# mkdir -p /mnt/huge_2mb
# mount -t hugetlbfs nodev /mnt/huge
# mount -t hugetlbfs nodev /mnt/huge_2mb -o pagesize=2MB
```

2. Check that HugePages are mounted:

```
# mount
nodev on /mnt/huge type hugetlbfs (rw,relatime)
nodev on /mnt/huge_2mb type hugetlbfs (rw,relatime,pagesize=2MB)
```

3. Remove the following Linux modules and load the modules for OVS:

```
# rmmod ixgbe
# rmmod igb_uio
# rmmod cuse
# rmmod fuse
# rmmod openvswitch
# rmmod uio
# rmmod eventfd_link
# rmmod ioeventfd
# rm -rf /dev/vhost-net
# modprobe uio
# insmod $DPDK_BUILD/kmod/igb_uio.ko
```

4. Check the PCI ID for the 10GbE NIC ports:

```
# lspci | grep Ethernet
01:00.0 Ethernet controller: Intel Corporation Ethernet Controller X710 for 10GbE SFP+ (rev 01)
01:00.1 Ethernet controller: Intel Corporation Ethernet Controller X710 for 10GbE SFP+ (rev 01)
02:00.0 Ethernet controller: Intel Corporation Ethernet Controller X710 for 10GbE SFP+ (rev 01)
02:00.1 Ethernet controller: Intel Corporation Ethernet Controller X710 for 10GbE SFP+ (rev 01)
```
10.6 Bind 10GbE NIC Ports to the igb_uio Driver

To create a 4-port configuration:

```
# python $DPDK_DIR/tools/dpdk_nic_bind.py --bind=igb_uio 01:00.0
# python $DPDK_DIR/tools/dpdk_nic_bind.py --bind=igb_uio 01:00.1
# python $DPDK_DIR/tools/dpdk_nic_bind.py --bind=igb_uio 02:00.0
# python $DPDK_DIR/tools/dpdk_nic_bind.py --bind=igb_uio 02:00.1
# python $DPDK_DIR/tools/dpdk_nic_bind.py -status
```

Output:

```
Network devices using the DPDK-compatible driver:
============================================
0000:01:00.0 'Ethernet Controller X710 for 10GbE SFP+' drv=igb_uio unused=i40e
0000:01:00.1 'Ethernet Controller X710 for 10GbE SFP+' drv=igb_uio unused=i40e
0000:02:00.0 'Ethernet Controller X710 for 10GbE SFP+' drv=igb_uio unused=i40e
0000:02:00.1 'Ethernet Controller X710 for 10GbE SFP+' drv=igb_uio unused=i40e
Network devices using the kernel driver:
=====================================
0000:00:19.0 'Ethernet Connection I217-LM' if=enp0s25 drv=e1000e unused=igb_uio
*Active*
0000:05:00.0 'I210 Gigabit Network Connection' if=enp5s0 drv=igb unused=igb_uio
Other network devices:
=====================
<none>
```
10.7  Remove and Terminate Previous-Run OVS and Prepare

```
# pkill -9 ovs
# rm -rf /usr/local/var/run/openvswitch
# rm -rf /usr/local/etc/openvswitch/
# rm -f /tmp/conf.db
# mkdir -p /usr/local/etc/openvswitch
# mkdir -p /usr/local/var/run/openvswitch
```

10.8  Initialize the New OVS Database

1. Initialize the new OVS database:
```
# export OVS_DIR=/root/OVS/ovs
# cd $OVS_DIR
# ./ovsdb/ovsdb-tool create /usr/local/etc/openvswitch/conf.db \
    ./vswitchd/vswitch.ovsschema
```

2. Start the database server:
```
# ./ovsdb/ovsdb-server --remote=punix:/usr/local/var/run/openvswitch/db.sock \
    --remote=db:Open_vSwitch,Open_vSwitch,manager_options \
    --pidfile --detach
```

3. Initialize the OVS database:
```
# ./utilities/ovs-vsctl --no-wait init
```

10.9  Start OVS-vSwitchd

Start OVS with DPDK portion using 2GB on CPU2 (0x2):
```
# ./vswitchd/ovs-vswitchd --dpdk -c 0x2 -n 4 --socket-mem 2048 \
    --unix:/usr/local/var/run/openvswitch/db.sock --pidfile
```

10.10  Tune OVS-vswitchd

You can check the thread siblings list (when hyper-threading is enabled) with the following:
```
# cat /sys/devices/system/cpu/cpuN/topology/thread_siblings_list
```

Based on the core thread siblings, you can set/check the PMD mask so that the multiple logical cores are on the same physical core.
1 PMD Configuration
Set the default OVS PMD thread usage to CPU2 (0x4):

```bash
# ./ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=4
# ./ovs-vsctl set Open_vSwitch . other_config:max-idle=30000
```

2 PMD Configuration
For 1 physical core, 2 logical cores (2 PMDs) on a system with HT enabled, check the thread siblings:

```bash
# cat /sys/devices/system/cpu/cpu1/topology/thread_siblings_list
2,30
```

Then set the pmd-cpu-mask to CPU2 and CPU30 (0x40000004):

```bash
# ./ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=40000004
# ./ovs-vsctl set Open_vSwitch . other_config:max-idle=30000
```

For 2 physical cores and 2 logical cores (2 PMDs) on system HT disabled, set the default OVS PMD thread usage to CPU2 and CPU3 (0xC):

```bash
# ./ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=C
# ./ovs-vsctl set Open_vSwitch . other_config:max-idle=30000
```

4 PMD Configuration
For 2 physical cores, 2 logical cores (4PMDS) on system with HT enabled, check the thread siblings:

```bash
# cat /sys/devices/system/cpu/cpu2/topology/thread_siblings_list
2,30
# cat /sys/devices/system/cpu/cpu3/topology/thread_siblings_list
3,31
```

Then set the pmd-cpu-mask to CPU2, CPU3, CPU30, and CPU31 (0xC000000C).

```bash
# ./ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask= C000000C
# ./ovs-vsctl set Open_vSwitch . other_config:max-idle=30000
```

For 4 physical cores (4 PMDs) on system HT disabled, set the default OVS PMD thread usage and set the default OVS PMD thread usage to CPU2, CPU3, CPU4, and CPU5 (0x3C):

```bash
# ./ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=3C
# ./ovs-vsctl set Open_vSwitch . other_config:max-idle=30000
```
10.11 Create the Ports

4-Port Configuration

# cd /root/ovs
#.utilities/ovs-vsctl add-br br0 -- set bridge br0 datapath_type=netdev
#.utilities/ovs-vsctl add-port br0 dpdk0 -- set Interface dpdk0 type=dpdk
#.utilities/ovs-vsctl add-port br0 dpdk1 -- set Interface dpdk1 type=dpdk
#.utilities/ovs-vsctl add-port br0 dpdk2 -- set Interface dpdk2 type=dpdk
#.utilities/ovs-vsctl add-port br0 dpdk3 -- set Interface dpdk3 type=dpdk
#.utilities/ovs-vsctl show

10.12 Add the Port Flows

1. Clear current flows:
   # export OVS_DIR=/root/ovs
   # cd $OVS_DIR
   # ./utilities/ovs-ofctl del-flows br0

2. Add flow:
   # ./utilities/ovs-ofctl add-flow br0 \n   in_port=1,dl_type=0x800,idle_timeout=0,action=output:2
   # ./utilities/ovs-ofctl add-flow br0 \n   in_port=2,dl_type=0x800,idle_timeout=0,action=output:1
   # ./utilities/ovs-ofctl add-flow br0 \n   in_port=3,dl_type=0x800,idle_timeout=0,action=output:4
   # ./utilities/ovs-ofctl add-flow br0 \n   in_port=4,dl_type=0x800,idle_timeout=0,action=output:3
   # ./utilities/ovs-ofctl dump-flows br0
11.0 PHY-VM-PHY Test Setup

Follow the steps on the PHY-to-PHY test setup until section 10.10, Tune OVS-vswitchd, and set up 1 core with 1 PMD thread configuration (without hyper-threading) for the PHY-to-VM tests. Follow the instructions in this section to continue on the PHY-to-VM.

11.1 Create the Ports

4-Port configuration

```
# cd /root/ovs
# ./utilities/ovs-vsctl add-br br0 -- set bridge br0 datapath_type=netdev
# ./utilities/ovs-vsctl add-port br0 dpdk0 -- set Interface dpdk0 type=dpdk
# ./utilities/ovs-vsctl add-port br0 dpdk1 -- set Interface dpdk1 type=dpdk
# ./utilities/ovs-vsctl add-port br0 dpdk2 -- set Interface dpdk2 type=dpdk
# ./utilities/ovs-vsctl add-port br0 dpdk3 -- set Interface dpdk3 type=dpdk
# ./utilities/ovs-vsctl add-port br0 vhost-user0 
  -- set Interface vhost-user0 type=dpdkvhostuser
# ./utilities/ovs-vsctl add-port br0 vhost-user1 
  -- set Interface vhost-user1 type=dpdkvhostuser
# ./utilities/ovs-vsctl add-port br0 vhost-user2 
  -- set Interface vhost-user2 type=dpdkvhostuser
# ./utilities/ovs-vsctl add-port br0 vhost-user3 
  -- set Interface vhost-user3 type=dpdkvhostuser
# ./utilities/ovs-vsctl show
```

11.2 Add the Port Flows

```
# export OVS_DIR=/root/ovs
# cd $OVS_DIR

1. Clear current flows
   # ./utilities/ovs-ofctl del-flows br0

2. Add Flow
   # ./utilities/ovs-ofctl add-flow br0 
     in_port=1,dl_type=0x800,idle_timeout=0,action=output:5
   # ./utilities/ovs-ofctl add-flow br0 
     in_port=2,dl_type=0x800,idle_timeout=0,action=output:6
   # ./utilities/ovs-ofctl add-flow br0 
     in_port=3,dl_type=0x800,idle_timeout=0,action=output:7
   # ./utilities/ovs-ofctl add-flow br0 
     in_port=4,dl_type=0x800,idle_timeout=0,action=output:8
```
# ./utilities/ovs-ofctl add-flows br0 \
  in_port=5,dl_type=0x800,idle_timeout=0,action=output:1
# ./utilities/ovs-ofctl add-flow br0 \
  in_port=6,dl_type=0x800,idle_timeout=0,action=output:2
# ./utilities/ovs-ofctl add-flow br0 \
  in_port=7,dl_type=0x800,idle_timeout=0,action=output:3
# ./utilities/ovs-ofctl add-flow br0 \
  in_port=8,dl_type=0x800,idle_timeout=0,action=output:4
# ./utilities/ovs-ofctl dump-flows br0

### 11.3 Power on the VM

Start the VM on CPU 4, CPU 5, and CPU 6 (0x70) with the following configuration:

```bash
# taskset 70 qemu-system-x86_64 -m 4096 -smp 4 -cpu host -hda /root/vm-images/vm-fc21.img -boot c -enable-kvm -pidfile /tmp/vml.pid -monitor unix:/tmp/vmlmonitor,server,nowait -name 'FC21-VM1' -net none -no-reboot -object memory-backend-file,id=mem,size=4096M,mem-path=/dev/hugepages,share=on -numa node,memdev=mem -mem-prealloc \n  -chardev socket,id=char1,path=/usr/local/var/run/openvswitch/vhost-user0 \n  -netdev type=vhost-user,id=net1,chardev=char1,hostforce -device virtio-net-pci,netdev=net1,mac=00:00:00:00:00:01,csum=off,gso=off,guest_tso4=off,guest_tso6=off,guest_ecn=off,mrg_rxbuf=off \n  -chardev socket,id=char2,path=/usr/local/var/run/openvswitch/vhost-user1 \n  -netdev type=vhost-user,id=net2,chardev=char2,hostforce -device virtio-net-pci,netdev=net2,mac=00:00:00:00:00:02,csum=off,gso=off,guest_tso4=off,guest_tso6=off,guest_ecn=off,mrg_rxbuf=off \n  -chardev socket,id=char1,path=/usr/local/var/run/openvswitch/vhost-user0 \n  -netdev type=vhost-user,id=net1,chardev=char1,hostforce -device virtio-net-pci,netdev=net1,mac=00:00:00:00:00:01,csum=off,gso=off,guest_tso4=off,guest_tso6=off,guest_ecn=off,mrg_rxbuf=off \n  -chardev socket,id=char2,path=/usr/local/var/run/openvswitch/vhost-user1 \n  -netdev type=vhost-user,id=net2,chardev=char2,hostforce -device virtio-net-pci,netdev=net2,mac=00:00:00:00:00:02,csum=off,gso=off,guest_tso4=off,guest_tso6=off,guest_ecn=off,mrg_rxbuf=off \n  --nographic -vnc :14
```

### 11.4 Set the VM Kernel Boot Parameters

1. Add the following to the kernel boot parameters /etc/default/grub:

   ```bash
   GRUB_CMDLINE_LINUX="rd.lvm.lv=fedora-server/root rd.lvm.lv=fedora-server/swap default_hugepagesz=1G hugepagesz=1G hugepages=1 hugepagesz=2M hugepages=1024 isolcpus=1,2 rhgb quiet"
   ```

2. Save the file and update the GRUB config file:

   ```bash
   # grub2-mkconfig -o /boot/grub2/grub.cfg
   ```

3. Reboot the VM and check to make sure 1GB and 2MB HugePage sizes are created. You should see one 1GB HugePage and 1024 2MB HugePages:
# ls /sys/devices/system/node/node0/hugepages/hugepages-*/
hugepages-1048576kB/  hugepages-2048kB/
# cat /sys/devices/system/node/node0/hugepages/hugepages-1048576kB/nr_hugepages
1
# cat /sys/devices/system/node/node0/hugepages/hugepages-2048kB/nr_hugepages
1024

11.5 Set up the VM HugePages

Mount the HugePage for 1 GB and 2 MB:

```
# mount -t hugetlbfs hugetlbfs /mnt/huge
# mount -t hugetlbfs none /mnt/huge_2mb -o pagesize=2MB
```

11.6 Set up DPDK 2.0

1. Download DPDK 2.0.0 and compile it:

```
# make install T=x86_64-native-linuxapp-gcc
```

2. Edit the test-pmd apps input and output queue size to 2K for better throughput performance:

```
# vi /root/dpdk-2.0.0/app/test-pmd/test-pmd.c

/**
 * Configurable number of RX/TX ring descriptors.
 */

#define RTE_TEST_RX_DESC_DEFAULT 2048
#define RTE_TEST_TX_DESC_DEFAULT 2048
```

3. Save and build the test-pmd app:

```
# export RTE_SDK=/root/dpdk-2.0.0
# export RTE_TARGET=x86_64-native-linuxapp-gcc
# make
```
11.7  Set up the vHost Network in the VM

1. Load the UIO kernel module in the VM:
   # modprobe uio
   # insmod /root/dpdk-2.0.0/x86_64-native-linuxapp-gcc/kmod/igb_uio.ko

2. Check the PCI ID for the 10GbE NIC ports:
   # lspci -nn

   00:04.0 Ethernet controller [0200]: Red Hat, Inc Virtio network device [1af4:1000]
   00:05.0 Ethernet controller [0200]: Red Hat, Inc Virtio network device [1af4:1000]
   00:06.0 Ethernet controller [0200]: Red Hat, Inc Virtio network device [1af4:1000]
   00:07.0 Ethernet controller [0200]: Red Hat, Inc Virtio network device [1af4:1000]

3. Bind the user-side vhost network devices with the igb_uio driver:
   # /root/dpdk-2.0.0/tools/dpdk_nic_bind.py -b igb_uio 00:04.0
   # /root/dpdk-2.0.0/tools/dpdk_nic_bind.py -b igb_uio 00:05.0
   # /root/dpdk-2.0.0/tools/dpdk_nic_bind.py -b igb_uio 00:06.0
   # /root/dpdk-2.0.0/tools/dpdk_nic_bind.py -b igb_uio 00:07.0
   # /root/dpdk-2.0.0/tools/dpdk_nic_bind.py -status

   Network devices using DPDK-compatible driver
   ======================================================
   0000:00:04.0 'Virtio network device' drv=igb_uio unused=virtio_pci
   0000:00:05.0 'Virtio network device' drv=igb_uio unused=virtio_pci
   0000:00:06.0 'Virtio network device' drv=igb_uio unused=virtio_pci
   0000:00:07.0 'Virtio network device' drv=igb_uio unused=virtio_pci

   Network devices using kernel driver
   ================================
   <none>

11.8  Start the test-pmd Application in the VM

1. Run test-pmd app on vCPU1 and vCPU2 (0x6):
   # cd /root/dpdk-2.0.0/x86_64-native-linuxapp-gcc/build/app/test-pmd
   # ./testpmd -c 0x6 -n 4 -- --burst=32 -i --disable-hw-vlan --txd=2048 \ 
     --rxd=2048 --txqflags=0xf00

2. In the application, enter the fwd and mac_retry commands:
   testpmd> set fwd mac_retry

3. Set the mac_retry packet forwarding mode.
4. Start the PMD forwarding operation:

```
testpmd> start
mac_retry packet forwarding - CRC stripping disabled - packets/burst=32
nb forwarding cores=1 - nb forwarding ports=2
RX queues=1 - RX desc=2048 - RX free threshold=32
RX threshold registers: pthresh=8 hthresh=8 wthresh=0
TX queues=1 - TX desc=2048 - TX free threshold=0
TX threshold registers: pthresh=32 hthresh=0 wthresh=0
TX RS bit threshold=0 - TXQ flags=0xf00
```

## 11.9 CPU Affinity Tuning

The tables below show the host’s CPU core affinity settings for PHY-to-VM test configuration for 1 physical core (no hyper-threading). When the VM starts, there are multiple QEMU threads spawned. Refer to section 9.1.4, CPU Core Affinity for the Virtual Machine (qemu-kvm), to set the active QEMU threads to the correct core affinity.

### CPU Affinity Setting on the Host

<table>
<thead>
<tr>
<th>Logical Core</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ovs-vswitchd</td>
</tr>
<tr>
<td>2</td>
<td>PMD0</td>
</tr>
<tr>
<td>4, 5, 6</td>
<td>QEMU</td>
</tr>
</tbody>
</table>

### QEMU Threads CPU Affinity

<table>
<thead>
<tr>
<th>Logical Core</th>
<th>Process</th>
<th>CPU% (from htop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>QEMU (main thread)</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>QEMU</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>QEMU</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>QEMU</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>QEMU</td>
<td>0</td>
</tr>
</tbody>
</table>

**Note:** Two active threads (with 100% CPU) are set to 2 different logical cores
12.0 VM-VM Test Setup

Refer to section 11.0, PHY-VM-PHY Test Setup, to set up the host configurations until section 10.10, Tune OVS-vsctl, and then set up 1 core with 1 PMD thread configuration (without hyper-threading) for 2 VMs series tests. Follow the instructions below to continue on the VM-to-VM setup.

12.1 Create the Ports

```bash
# cd /root/ovs
# ./utilities/ovs-vsctl show
# ./utilities/ovs-vsctl add-br br0 -- set bridge br0 datapath_type=netdev
# ./utilities/ovs-vsctl add-port br0 dpdk0 -- set Interface dpdk0 type=dpdk
# ./utilities/ovs-vsctl add-port br0 dpdk1 -- set Interface dpdk1 type=dpdk
# ./utilities/ovs-vsctl add-port br0 vhost-user0 \
    -- set Interface vhost-user0 type=dpdkvhostuser
# ./utilities/ovs-vsctl add-port br0 vhost-user1 \
    -- set Interface vhost-user1 type=dpdkvhostuser
# ./utilities/ovs-vsctl add-port br0 vhost-user2 \
    -- set Interface vhost-user2 type=dpdkvhostuser
# ./utilities/ovs-vsctl add-port br0 vhost-user3 \
    -- set Interface vhost-user3 type=dpdkvhostuser
# ./utilities/ovs-vsctl show
```

12.2 Add the Port Flows

```bash
# export OVS_DIR=/root/ovs
# cd $OVS_DIR

1. Clear current flows

```bash
# ./utilities/ovs-ofctl del-flows br0
```

2. Add Flow

```bash
# ./utilities/ovs-ofctl add-flow br0 \
    in_port=1,dl_type=0x800,idle_timeout=0,action=output:3
# ./utilities/ovs-ofctl add-flow br0 \
    in_port=2,dl_type=0x800,idle_timeout=0,action=output:6
# ./utilities/ovs-ofctl add-flow br0 \
    in_port=3,dl_type=0x800,idle_timeout=0,action=output:1
# ./utilities/ovs-ofctl add-flow br0 \
    in_port=4,dl_type=0x800,idle_timeout=0,action=output:5
# ./utilities/ovs-ofctl add-flow br0 \
    in_port=6,dl_type=0x800,idle_timeout=0,action=output:2
# ./utilities/ovs-ofctl add-flow br0 \
    in_port=5,dl_type=0x800,idle_timeout=0,action=output:4
```
12.3 Power on the VM

Start the first VM on CPU 4, CPU 5, and CPU 6 (0x70) with the following configuration:

```bash
# taskset 70 qemu-system-x86_64 -m 4096 -smp 4 -cpu host -hda /root/vm-images/vm2-fc21.img -boot c -enable-kvm -pidfile /tmp/vml.pid -monitor unix:/tmp/vm2monitor,server,nowait --name 'FC21-VM2' -net none -no-reboot -object memory-backend-file,id=mem,size=4096M,mem-path=/dev/hugepages,share=on -numa node,memdev=mem -mem-prealloc \  
    -chardev socket,id=char1,path=/usr/local/var/run/openvswitch/vhost-user0 \  
    -netdev type=vhost-user,id=net1,chardev=char1,vhostforce -device virtio-net-pci,netdev=net1,mac=00:00:00:00:00:01,csnum=off,gso=off,guest_tso4=off,guest_tso6=off,guest_ecn=off,mrg_rxbuf=off \  
    -chardev socket,id=char2,path=/usr/local/var/run/openvswitch/vhost-user0 \  
    -netdev type=vhost-user,id=net2,chardev=char2,vhostforce -device virtio-net-pci,netdev=net2,mac=00:00:00:00:00:02,csnum=off,gso=off,guest_tso4=off,guest_tso6=off,guest_ecn=off,mrg_rxbuf=off \  
    --nographic 
```

12.3.1 VM Kernel Boot Parameters

1. Add the following to the kernel boot parameters `/etc/default/grub` in the VM:

   ```bash
   GRUB_CMDLINE_LINUX="rd.lvm.lv=fedora-server/root rd.lvm.lv=fedora-server/swap default_hugepagesz=1G hugepagesz=1G hugepages=1 hugepagesz=2M hugepages=1024 isolcpus=1,2 rhgb quiet"
   ```

2. Save the file and update the GRUB config file:

   ```bash
   # grub2-mkconfig -o /boot/grub2/grub.cfg
   ```

3. Reboot the VM and then check to make sure 1GB and 2MB HugePage sizes are created. You should see one 1GB HugePages and 1024 2MB HugePages:

   ```bash
   # ls /sys/devices/system/node/node0/hugepages/hugepages-*
   hugepages-1048576kB/ hugepages-2048kB/
   #cat /sys/devices/system/node/node0/hugepages/hugepages-1048576kB.nr_hugepages
   1
   #cat /sys/devices/system/node/node0/hugepages/hugepages-2048kB.nr_hugepages
   1024
   ```

4. Start the second VM by making a copy of the first VM. Start the second VM on CPU 7, CPU8, and CPU9 (0x380) with the following command:

   ```bash
   # taskset 380 qemu-system-x86_64 -m 4096 -smp 4 -cpu host -hda /root/vm-images/vm2-fc21.img -boot c -enable-kvm -pidfile /tmp/vml.pid -monitor unix:/tmp/vm2monitor,server,nowait --name 'FC21-VM2' -net none -no-reboot -object memory-backend-file,id=mem,size=4096M,mem-path=/dev/hugepages,share=on -numa node,memdev=mem -mem-prealloc \  
    -chardev socket,id=char1,path=/usr/local/var/run/openvswitch/vhost-user0 \  
    -netdev type=vhost-user,id=net1,chardev=char1,vhostforce -device virtio-net-pci,netdev=net1,mac=00:00:00:00:00:01,csnum=off,gso=off,guest_tso4=off,guest_tso6=off,guest_ecn=off,mrg_rxbuf=off \  
    -chardev socket,id=char2,path=/usr/local/var/run/openvswitch/vhost-user0 \  ```
12.4 Set up the VM HugePages

Mount the HugePage for 1GB and 2MB:

```bash
# mount -t hugetlbfs hugetlbfs /mnt/huge
# mount -t hugetlbfs none /mnt/huge_2mb -o pagesize=2MB
```

12.5 Set up DPDK 2.0

1. Download DPDK 2.0.0 and compile it:

   ```bash
   # make install T=x86_64-native-linuxapp-gcc
   ```

2. Edit the test-pmd app input and output queue size to 2K for better throughput performance:

   ```bash
   # vi /root/dpdk-2.0.0/app/test-pmd/test-pmd.c
   /*
   * Configurable number of RX/TX ring descriptors.
   */
   #define RTE_TEST_RX_DESC_DEFAULT 2048
   #define RTE_TEST_TX_DESC_DEFAULT 2048
   ```

3. Save and build the test-pmd app:

   ```bash
   # export RTE_SDK=/root/dpdk-2.0.0
   # export RTE_TARGET=x86_64-native-linuxapp-gcc
   # make
   ```
12.6 Set up the vHost Network in the VM

1. Load the UIO kernel module in the VM:
   ```
   # modprobe uio
   # insmod /root/dpdk-2.0.0/x86_64-native-linuxapp-gcc/kmod/igb_uio.ko
   ```

2. Check the PCI ID for the 10GbE NIC ports:
   ```
   # lscpi -nn
   00:04.0 Ethernet controller [0200]: Red Hat, Inc Virtio network device
   [1af4:1000]
   00:05.0 Ethernet controller [0200]: Red Hat, Inc Virtio network device
   [1af4:1000]
   ```

3. Bind the user side vhost network devices with the igb_uio driver:
   ```
   # /root/dpdk-2.0.0/tools/dpdk_nic_bind.py -b igb_uio 00:04.0
   # /root/dpdk-2.0.0/tools/dpdk_nic_bind.py -b igb_uio 00:05.0
   # /root/dpdk-2.0.0/tools/dpdk_nic_bind.py --status
   ```

   Network devices using DPDK-compatible driver
   ==============================================================
   0000:00:04.0 'Virtio network device' drv=igb_uio unused=virtio_pci
   0000:00:05.0 'Virtio network device' drv=igb_uio unused=virtio_pci

   Network devices using kernel driver
   ==============================================================
   <none>

12.7 Start test-pmd Application in the VM

1. Run the test-pmd app on vCPU1 and vCPU2 (0x6):
   ```
   # cd /root/dpdk-2.0.0/x86_64-native-linuxapp-gcc/build/app/test-pmd
   # ./testpmd -c 0x6 -n 4 -- --burst=32 -i --txd=2048 --rxd=2048
   --txqflags=0xf00 --disable-hw-vlan
   ```

2. In the application, enter the fwd and mac_retry commands:
   ```
   testpmd> set fwd mac_retry
   Set mac_retry packet forwarding mode
   ```

3. Start the PMD forwarding operation:
   ```
   testpmd> start
   mac_retry packet forwarding - CRC stripping disabled - packets/burst=32
   nb forwarding cores=1 - nb forwarding ports=2
   RX queues=1 - RX desc=2048 - RX free threshold=32
   RX threshold registers: pthresh=8 hthresh=8 wthresh=0
   TX queues=1 - TX desc=2048 - TX free threshold=0
   TX threshold registers: pthresh=32 hthresh=0 wthresh=0
   TX RS bit threshold=0 - TXQ flags=0xf00
   ```
12.8 CPU Affinity Tuning

The tables below show the host’s CPU core affinity settings for VM-to-VM tests configuration for 1 physical core (no hyper-threading). When the two VMs start, there will be multiple QEMU threads spawned. Refer to section 9.4, CPU Core Affinity for Virtual Machine (qemu-kvm), to set the active QEMU threads to the correct core affinity.

CPU affinity setting on the host

<table>
<thead>
<tr>
<th>Logical Core</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ovs-vswitchd</td>
</tr>
<tr>
<td>2</td>
<td>PMDO</td>
</tr>
<tr>
<td>4, 5, 6</td>
<td>QEMU (VM1)</td>
</tr>
<tr>
<td>7, 8, 9</td>
<td>QEMU (VM2)</td>
</tr>
</tbody>
</table>

QEMU threads CPU affinity

VM1 QEMU threads:

<table>
<thead>
<tr>
<th>Logical Core</th>
<th>Process</th>
<th>CPU% (from htop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>QEMU (main thread for VM1)</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>QEMU</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>QEMU</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>QEMU</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>QEMU</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>QEMU</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Two active threads (with 100% CPU) are set to 2 different logical cores

VM2 QEMU threads:

<table>
<thead>
<tr>
<th>Logical Core</th>
<th>Process</th>
<th>CPU% (from htop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>QEMU (main thread for VM2)</td>
<td>100</td>
</tr>
<tr>
<td>8</td>
<td>QEMU</td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>QEMU</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>QEMU</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>QEMU</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Two active threads (with 100% CPU) are set to 2 different logical cores
13.0 VXLAN Test Setup

Follow the instructions below to configure VXLAN test setup. Test setup configurations include using regular Native OVS and OVS with DPDK-netdev.

13.1 Native OVS Setup

To setup and start regular OVS in Host A and Host B, please refer to section 10.1 Configure the Host Machine and follow the instructions below.

13.1.1 Set the Kernel Boot Parameters

1. With hyper-threading disabled, add the following to the kernel boot parameters /etc/default/grub

```
grubzilla=run
```

```
GRUB_CMDLINE_LINUX="rd.lvm.lv=fedora-server/root rd.lvm.lv=fedora-server/swap
default_hugepagesz=1G hugepagesz=1G hugepages=16 hugepagesz=2M hugepages=2048
intel_iommu=off isolcpus=2-13,14-27 rhgb quiet"
```

2. Save the file and update the GRUB config file:

```
# grub2-mkconfig -o /boot/grub2/grub.cfg
```

3. Reboot the host machine and check to make sure 1GB and 2MB HugePage sizes are created. You should see 16 1GB HugePages and 2048 2MB HugePages:

```
# ls /sys/devices/system/node/node0/hugepages/hugepages-*
hugepages-1048576kB/ hugepages-2048kB/
# cat /sys/devices/system/node/node0/hugepages/hugepages-1048576kB/nr_hugepages
16
# cat /sys/devices/system/node/node0/hugepages/hugepages-2048kB/nr_hugepages
2048
```

13.1.2 Compile and Install OVS

Go to the OVS directory and run:

```
# ./boot.sh
# ./configure
# make -j10
# make install
# ./configure --with-linux=/lib/modules/3.17.4-301.fc21.x86_64/build 
    CFLAGS="-Ofast -g"
# make 'CFLAGS=-g -Ofast -march=native' -j10
```
13.1.3 Prepare to Start OVS

1. Mount the 1GB HugePage and 2MB HugePage:

   ```
   # mkdir -p /mnt/huge
   # mkdir -p /mnt/huge_2mb
   # mount -t hugetlbfs nodev /mnt/huge
   # mount -t hugetlbfs nodev /mnt/huge_2mb -o pagesize=2MB
   ```

2. Check that HugePages are mounted:

   ```
   # mount
   nodev on /mnt/huge type hugetlbfs (rw,relatime)
   nodev on /mnt/huge_2mb type hugetlbfs (rw,relatime,pagesize=2MB)
   ```

3. Load the modules:

   ```
   # modprobe openvswitch
   # modprobe i40e
   ```

4. Remove and terminate previous-run OVS and prepare:

   ```
   # pkill -9 ovs
   # rm -rf /usr/local/var/run/openvswitch
   # rm -rf /usr/local/etc/openvswitch/
   # rm -f /tmp/conf.db
   # mkdir -p /usr/local/etc/openvswitch
   # mkdir -p /usr/local/var/run/openvswitch
   ```

5. Initialize the new OVS database and start the server:

   ```
   # export OVS_DIR=/root/OVS-2.4_perf/ovs
   # cd $OVS_DIR
   # ./ovsdb/ovsdb-tool create /usr/local/etc/openvswitch/conf.db \\
   #  ./vswitchd/vswitch.ovsschema
   ```

6. Start the database server:

   ```
   # ./ovsdb/ovsdb-server --remote=punix:/usr/local/var/run/openvswitch/db.sock \\
   #  --remote=db:Open_vSwitch,Open_vSwitch,manager_options \\
   #  --pidfile -detach
   ```

7. Initialize the OVS database:

   ```
   # ./utilities/ovs-vsctl --no-wait init
   ```

8. Start OVS-vswitchd:

   ```
   # ./vswitchd/ovs-vswitchd
   ```
13.1.4 Create the Ports and VXLAN VTEP

**Host A Configuration**

1. Create the VXLAN tunnel between 2 hosts:

   ```
   # ./utilities/ovs-vsctl add-br br0
   # ifconfig br0 2.2.2.1/24
   # ./utilities/ovs-vsctl add-port br0 eth3
   # ./utilities/ovs-appctl ovs-route/add 2.2.2.2/24 br0
   ```

2. Create an internal bridge:

   ```
   # ./utilities/ovs-vsctl add-br br-int
   # ifconfig br-int 1.1.1.1/24
   # ./utilities/ovs-vsctl add-port br-int eth2
   ```

3. Add VXLAN VTEP:

   ```
   # ./utilities/ovs-vsctl add-port br-int vxlan0 -- set Interface \  
   vxlan0 type=vxlan options:remote_ip=2.2.2.2 options:key=1000
   # ./utilities/ovs-vsctl show
   # ./utilities/ovs-appctl ovs-route/show
   ```

**Host B Configuration**

1. Create a VXLAN tunnel between the 2 hosts:

   ```
   # ./utilities/ovs-vsctl add-br br0
   # ifconfig br0 2.2.2.2/24
   # ./utilities/ovs-vsctl add-port br0 eth3
   # ./utilities/ovs-appctl ovs-route/add 2.2.2.1/24 br0
   ```

2. Create an internal bridge:

   ```
   # ./utilities/ovs-vsctl add-br br-int
   # ifconfig br-int 1.1.1.2/24
   # ./utilities/ovs-vsctl add-port br-int eth2
   ```

3. Add VXLAN VTEP:

   ```
   # ./utilities/ovs-vsctl add-port br-int vxlan0 -- set Interface vxlan0 \  
   type=vxlan options:remote_ip=2.2.2.1 options:key=1000
   # ./utilities/ovs-vsctl show
   # ./utilities/ovs-appctl ovs-route/show
   ```

13.1.5 Add the Port Flows

**Host A and Host B Configuration**

1. Clear current flows:

   ```
   # cd $OVS_DIR
   # ./utilities/ovs-ofctl del-flows br-int
   ```
2. Add flow for port 1 (physical) to port 2 (VTEP):

```bash
# ./utilities/ovs-ofctl add-flow br-int \
in_port=1,dl_type=0x800,idle_timeout=0,action=output:2
# ./utilities/ovs-ofctl add-flow br-int \
in_port=2,dl_type=0x800,idle_timeout=0,action=output:1
# ./utilities/ovs-ofctl dump-flows br-int
```

### 13.2 OVS with DPDK Setup

To set up and start OVS with DPDK in Host A and Host B, refer to section 10.0, OVS Test Setup, and follow the step-by-step instructions until section 10.9 Start OVS-vSwitchd. Then follow the instructions below to configure the VXLAN test setup.

#### 13.2.1 Tune OVS-vSwitchd for VXLAN

Once the OVS-vSwitchd is running, we setup the CPU core affinity for the OVS PMD threads to 1 core, and 2 cores respectively.

**One-PMD Configuration**

Set the default OVS PMD thread usage to CPU2 (0x4):

```bash
# ./ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=4
# ./ovs-vsctl set Open_vSwitch . other_config:max-idle=30000
```

**Two-PMD Configuration**

For 2 physical cores and 2 logical cores (2 PMDs) on system HT disabled, set the default OVS PMD thread usage to CPU2 and CPU3 (0xC):

```bash
# ./ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=C
# ./ovs-vsctl set Open_vSwitch . other_config:max-idle=30000
```

#### 13.2.2 Create the Ports and VXLAN VTEP

**Host A Configuration**

1. Create the VXLAN tunnel between 2 hosts:

   ```bash
   # ./utilities/ovs-vsctl add-br br0 -- set bridge br0 datapath_type=netdev
   # ifconfig br0 2.2.2.1/24
   # ./utilities/ovs-vsctl add-port br0 dpdk0 -- set Interface dpdk0 type=dpdk
   # ./utilities/ovs-appctl ovs/route/add 2.2.2.2/24 br0
   ```

2. Create an internal bridge:

   ```bash
   # ./utilities/ovs-vsctl add-br br-int -- set bridge br-int datapath_type=netdev
   # ifconfig br-int 1.1.1.1/24
   ```
3. **Add VXLAN VTEP:**

```
# ./utilities/ovs-vsctl add-port br-int dpdk1 -- set Interface dpdk1 type=dpdk
# ./utilities/ovs-vsctl add-port br-int vxlan0 -- set Interface \
  vxlan0 type=vxlan options:remote_ip=2.2.2.2 options:key=1000
# ./utilities/ovs-vsctl show
# ./utilities/ovs-appctl ovs/route/show
```

**Host B Configuration**

1. **Create a VXLAN tunnel between the 2 hosts:**

```
# ./utilities/ovs-vsctl add-br br0 -- set bridge br0 datapath_type=netdev
# ifconfig br0 2.2.2.2/24
# ./utilities/ovs-vsctl add-port br0 dpdk0 -- set Interface dpdk0 type=dpdk
# ./utilities/ovs-appctl ovs/route/add 2.2.2.1/24 br0
```

2. **Create an internal bridge:**

```
# ./utilities/ovs-vsctl add-br br-int -- set bridge br-int datapath_type=netdev
# ifconfig br-int 1.1.1.2/24
# ./utilities/ovs-vsctl add-port br-int dpdk1 -- set Interface dpdk1 type=dpdk
```

3. **Add VXLAN VTEP:**

```
# ./utilities/ovs-vsctl add-port br-int vxlan0 -- set Interface vxlan0 \
  type=vxlan options:remote_ip=2.2.2.1 options:key=1000
# ./utilities/ovs-vsctl show
# ./utilities/ovs-appctl ovs/route/show
```

### 13.2.3 Add the Port Flows

**Host A and Host B Configuration**

1. **Clear current flows:**

```
# cd $OVS_DIR
# ./utilities/ovs-ofctl del-flows br-int
```

2. **Add flow for port 1 (physical) to port 2 (VTEP):**

```
# ./utilities/ovs-ofctl add-flow br-int \ 
  in_port=1,dl_type=0x800,idle_timeout=0,action=output:2
# ./utilities/ovs-ofctl add-flow br-int \ 
  in_port=2,dl_type=0x800,idle_timeout=0,action=output:1
# ./utilities/ovs-ofctl dump-flows br-int
```
# Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARP</td>
<td>Address Resolution Protocol</td>
</tr>
<tr>
<td>BMWG</td>
<td>Benchmark Working Group</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>DPDK</td>
<td>Data Plane Development Kit</td>
</tr>
<tr>
<td>DUT</td>
<td>Device-Under-Test</td>
</tr>
<tr>
<td>EMC</td>
<td>Exact Match Cache</td>
</tr>
<tr>
<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
</tr>
<tr>
<td>GbE</td>
<td>Gigabit Ethernet</td>
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<tr>
<td>GRUB</td>
<td>GRand Unified Bootloader</td>
</tr>
<tr>
<td>IETF</td>
<td>Internet Engineering Task Force</td>
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<tr>
<td>IPDV</td>
<td>Inter-Packet Delay Variation</td>
</tr>
<tr>
<td>IPv4</td>
<td>Internet Protocol version 4</td>
</tr>
<tr>
<td>IRQ</td>
<td>Interruption Request</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
</tr>
<tr>
<td>ITU-T</td>
<td>ITU Telecommunication Standardization Sector</td>
</tr>
<tr>
<td>KVM</td>
<td>Kernel-based Virtual Machine</td>
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<tr>
<td>LAN</td>
<td>Local Area Network</td>
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<tr>
<td>MAC</td>
<td>Media Access Control</td>
</tr>
<tr>
<td>NFV</td>
<td>Network Functions Virtualization</td>
</tr>
<tr>
<td>NIC</td>
<td>Network Interface Card</td>
</tr>
<tr>
<td>NUMA</td>
<td>Non-Uniform Memory Access</td>
</tr>
<tr>
<td>OPNFV</td>
<td>Open Platform for NFV</td>
</tr>
<tr>
<td>OVS</td>
<td>Open vSwitch</td>
</tr>
<tr>
<td>PCI</td>
<td>Peripheral Component Interconnect</td>
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<tr>
<td>PDV</td>
<td>Packet Delay Variation</td>
</tr>
<tr>
<td>PHY</td>
<td>Physical Layer</td>
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<tr>
<td>PID</td>
<td>Process ID</td>
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<tr>
<td>PMD</td>
<td>Poll Mode Driver</td>
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</tbody>
</table>
### Acronyms and Abbreviations (cont’d)

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>QEMU</td>
<td>Quick Emulator</td>
</tr>
<tr>
<td>RFC</td>
<td>Request for Comments</td>
</tr>
<tr>
<td>SDN</td>
<td>Software-Defined Networking</td>
</tr>
<tr>
<td>SELinux</td>
<td>Security-Enhanced Linux</td>
</tr>
<tr>
<td>SLA</td>
<td>Service-Level Agreement</td>
</tr>
<tr>
<td>TLB</td>
<td>Translation Lookaside Buffer</td>
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<tr>
<td>vhost</td>
<td>Virtual Host</td>
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<tr>
<td>VM</td>
<td>Virtual Machine</td>
</tr>
<tr>
<td>VNF</td>
<td>Virtualized Network Function</td>
</tr>
<tr>
<td>VTEP</td>
<td>VXLAN Tunnel End Point</td>
</tr>
<tr>
<td>VXLAN</td>
<td>Virtual eXtensible LAN</td>
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