Executive Summary

Data centers and cloud service providers are creating a technology shift with network function-based computing to effectively add new features, flexibly connect services while simultaneously reducing overall costs. NFV (Network Function Virtualization) is the paradigm shift that addresses the challenges associated with purpose built network appliances, such as routers and firewalls, by virtualizing network functions in software and running them on industry standard servers.

Telecommunications service providers are in the process of actively deploying NFV in their data centers due to the associated benefits: greater service agility through software, cost savings through utilizing general purpose servers and greater manageability and visibility. However, as NFV decouples the network functions and deploys them as software services on COTS (commercial off the shelf) hardware, analyzing and optimizing the performance of the virtual network functions becomes a critical prerequisite prior to production grade NFV deployments. See Table 1.

Table 1: Summary of the comparative performance analysis on EPYC and Broadwell processors.

<table>
<thead>
<tr>
<th>VNF</th>
<th>Type of Interfaces attached to VNFs</th>
<th>AMD EPYC Deployment Configuration (#VM Pairs launched, Cores)</th>
<th>Parameter measured and Performance Numbers</th>
<th>Intel Broadwell Deployment Configuration (#VM Pairs launched)</th>
<th>Parameter measured and Performance Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>vRouter</td>
<td>PCIe passthrough</td>
<td>1 VM Pair 8 Cores</td>
<td>Throughput: 50.6 Gbps</td>
<td>1VM Pair 8 Cores</td>
<td>Throughput: 50.7 Gbps</td>
</tr>
<tr>
<td></td>
<td>SRIOV</td>
<td>1 VM Pair 8 Cores</td>
<td>Throughput: 52.8 Gbps</td>
<td>1VM Pair 8 Cores</td>
<td>Throughput: 50.3 Gbps</td>
</tr>
<tr>
<td>vFirewall</td>
<td>OpenvSwitch</td>
<td>16 VM Pairs 8 Cores</td>
<td>Downloaded: 52.1 GB</td>
<td>16 VM Pair 8 Cores</td>
<td>Downloaded: 40.8 GB</td>
</tr>
<tr>
<td>OpenSSL</td>
<td>OpenvSwitch</td>
<td>8 VM Pairs 16 Cores</td>
<td>Connections Established: 117,175</td>
<td>5 VM Pair 16 Cores</td>
<td>Connections Established: 89,884</td>
</tr>
</tbody>
</table>

Though network functions are de-coupled from the underlying proprietary hardware elements, the NFV infrastructure plays a prominent role in deriving maximum performance from the software equivalents of the hardware appliances. Without an infrastructure that addresses the shortfalls in today's commodity hardware, it becomes very challenging to employ NFV in production grade deployments and the promising technology could be limited to areas such as network offloading at the edge.
**Executive Summary (cont.)**

AMD’s EPYC Processor is a highly scalable architecture with industry-leading eight memory channels of bandwidth capacity, and is ideally suited for addressing high performance NFV applications. In a dual socket server, the combined 16 memory channels can support up to 32 DDR4 DIMMs and deliver a combined memory capacity of up to four terabytes. This whitepaper summarizes comparative performance analysis for multiple NFV applications (vRouter, vFirewall, and vOpenSSL) deployed on the EPYC server and the Intel Broadwell server. The servers used in the benchmarking performance tests are an AMD-based server with EPYC 7601 processors and an Intel® Broadwell® server with E5-2699 v4 processors using 100 gigabit ethernet Mellanox Connect-X5 network interface cards. **The results validate the performance advantages of AMD EPYC processors over Intel Broadwell.** Due to the open source nature of the NFV software used, the software had scaling limitations relative to being able use the maximum number of cores on the AMD EPYC processor.

> The tests demonstrate that an AMD EPYC processor provides more compute and memory power to the virtual network functions and hence is a superior alternative for NFV deployments.

**vrRouter, vFirewall and vOpenSSL Test Validation Overview**

**Virtual Function Details**

The tests provide performance information on AMD EPYC and Intel Broadwell by testing:

1. vRouter’s L3 forwarding capacity,
2. vFirewall’s ability to support remote client connects performing a download, and
3. vOpenSSL’s capacity to support multiple SSL connections.

These tests provide additional insight on the NFV computing platform where a higher IO and higher total memory bandwidth can be a better host than one with a relatively low IO and low total memory bandwidth.

**Compute Environment Under Test**

Intel Broadwell system has two sockets with each socket providing 22 physical cores with Hyper threading enabled, Broadwell offers a total of 88 total threads. Each core on Intel is rated at 2.2GHz clock speed. The AMD EPYC-based two socket system has a total of 64 cores, providing a total of 128 threads. Each EPYC processor core is rated at 2.2GHz. Mellanox ConnectX-5 network adapters are used for the tests. The test VNFs are deployed, configured and made load ready using TCS OpenVNFManager. See Tables 2, 3 and 4.
## Compute Environment Under Test (cont.)

### Table 2: Systems Under Test

<table>
<thead>
<tr>
<th>Intel</th>
<th>Details</th>
<th>AMD</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadwell Model</td>
<td>E5-2699 v4</td>
<td>AMD Model</td>
<td>7601</td>
</tr>
<tr>
<td>Processor sockets</td>
<td>2</td>
<td>Processor sockets</td>
<td>2</td>
</tr>
<tr>
<td>Total physical CPUs</td>
<td>44</td>
<td>Total physical CPUs</td>
<td>64</td>
</tr>
<tr>
<td>Total CPUs when Hyper Threading enabled</td>
<td>88</td>
<td>Total CPUs when Hyper Threading enabled</td>
<td>128</td>
</tr>
<tr>
<td>RAM DDR4</td>
<td>256 GB</td>
<td>RAM DDR4</td>
<td>256 GB</td>
</tr>
<tr>
<td>Total number of NUMA nodes</td>
<td>2</td>
<td>Total number of NUMA nodes</td>
<td>8</td>
</tr>
<tr>
<td>NUMA0, NUMA1</td>
<td>128 GB each</td>
<td>NUMA0, NUMA1, NUMA2, NUMA3, NUMA4, NUMA5, NUMA6, NUMA7</td>
<td>32 GB each</td>
</tr>
<tr>
<td>L1 d Cache on each core</td>
<td>32K</td>
<td>L1 d Cache on each core</td>
<td>32K</td>
</tr>
<tr>
<td>L1 i Cache on each core</td>
<td>32K</td>
<td>L1 i Cache on each core</td>
<td>64K</td>
</tr>
<tr>
<td>L2 Cache on each core</td>
<td>256K</td>
<td>L2 Cache on each core</td>
<td>512K</td>
</tr>
<tr>
<td>L3 Cache per socket</td>
<td>56320K</td>
<td>L3 Cache per socket</td>
<td>65536K</td>
</tr>
<tr>
<td>PCIe negotiation speed</td>
<td>8Gtps</td>
<td>PCIe negotiation speed</td>
<td>8Gtps</td>
</tr>
<tr>
<td>PCIe connector</td>
<td>8X</td>
<td>PCIe connector</td>
<td>16X</td>
</tr>
<tr>
<td>Memory Channels</td>
<td>8</td>
<td>Memory Channels</td>
<td>16</td>
</tr>
<tr>
<td>NIC</td>
<td>Mellanox CX5</td>
<td>NIC</td>
<td>Mellanox CX5</td>
</tr>
</tbody>
</table>

### Table 3: Versions

- **Operating System:** CentOS 7.3
- **Kernel:** 4.10.10 Kernel
- **OpenStack:** Ocata
- **Cloud router:** 4.7.9
- **Libvirt:** 3.2.0
- **Mellanox OFED:** 4.1-1.0.2.0
- **Salt:** 2016.11.8
- **Tomcat:** 8
- **Qemu-KVM version:** 2.9.0
- **OVS version:** 2.7.2
- **Influx DB:** 1.3.5
- **Iperf:** 3

### Table 4: Software Stack

- VNFs & VMs
  - OpenStack
  - NFVI platform
  - Cent OS7
  - Operating System
  - Naples / Broadwell
  - Server
vRouter Benchmarking Tests

Test Topology for vRouter

These AMD EPYC and Intel Broadwell servers are configured as OpenStack multi-node hardware. In each of the benchmarking tests, we have ensured that the system under test (SUT) is always configured as an OpenStack compute node.

Traffic is generated through virtual machines, on which iperf3 is pre-loaded, from the OpenStack controller node. Two virtual machines, each acting as iperf server and client, are used for traffic generation. The traffic from the iperf client is forwarded through the vRouter, hosted on SUT, to the iperf server on the traffic generator host. See Figure 1.

![Traffic Generator](image)

**Figure 1**: Router Topology

Optimization on AMD EPYC Processors

Tests were performed on CloudRouter 4.0, an open-source vRouter. Benchmarking tests were performed on two specific configuration sets: PCIe pass-through, and SR-IOV.

The vRouter on EPYC was pinned with eight cores for the VNF test. The IRQ balance service was disabled. The remaining logical threads were assigned to handle system interrupts allowing local NUMA memory to be available to every core under test. Table 5 summarizes the deployment optimization on AMD EPYC processors.
Table 5: Deployment Optimization on AMD EPYC Processors

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Configuration detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data plane optimization technique used</td>
<td>PCIe pass-through / SRIOV</td>
</tr>
<tr>
<td>#Cores Pinned</td>
<td>8</td>
</tr>
<tr>
<td>NUMA region</td>
<td>3</td>
</tr>
<tr>
<td>NUMA region that houses Mellanox Connect X5 NIC</td>
<td>3</td>
</tr>
<tr>
<td>Irq_balance information</td>
<td>OFF</td>
</tr>
<tr>
<td>MTU</td>
<td>9000</td>
</tr>
</tbody>
</table>

Optimization on Intel Broadwell

Intel Broadwell 2P server has two NUMA regions, and all of the cores are distributed on each of these NUMA regions. The test VNF, vRouter, is assigned only those cores that belong to the NUMA region connected with the PCIe slot.

vRouter Test Results

In this iteration, traffic is generated from AMD EPYC processors using iperf VMs, which is forwarded by the test VNF on SUT. See Table 6 and Figure 2.

Table 6: vRouter Test Results

<table>
<thead>
<tr>
<th>Traffic generator details</th>
<th>Data plane optimization technique used</th>
<th>SUT</th>
<th>Traffic generator host</th>
<th>Throughput Gb/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iperf version: iperf2</td>
<td>SRIOV</td>
<td>AMD EPYC</td>
<td>AMD EPYC</td>
<td>52.8</td>
</tr>
<tr>
<td>#simultaneous iperf threads used: 4</td>
<td>SRIOV</td>
<td>Intel Broadwell</td>
<td>AMD</td>
<td>50.3</td>
</tr>
<tr>
<td>Traffic type: L3</td>
<td>PCIe passthrough</td>
<td>AMD EPYC</td>
<td>Intel Broadwell</td>
<td>50.6</td>
</tr>
<tr>
<td></td>
<td>PCIe passthrough</td>
<td>Intel Broadwell</td>
<td>Intel IvyBridge</td>
<td>50.7</td>
</tr>
</tbody>
</table>

Table 6, testing done by TCS®, results not verified by AMD
vRouter Test Results (cont.)

AMD NFV Performance Work Bench | vRouter Results with SR-IOV & IRQ Pinning

<table>
<thead>
<tr>
<th>Intel Broadwell</th>
<th>Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cores</td>
<td>8</td>
</tr>
<tr>
<td>vCPU to CPU Ratio</td>
<td>1:1</td>
</tr>
<tr>
<td>VM pairs</td>
<td>1</td>
</tr>
<tr>
<td>vmCPU assigned</td>
<td>3</td>
</tr>
<tr>
<td>VM HDD size</td>
<td>14 GB</td>
</tr>
<tr>
<td>Traffic time</td>
<td>120 Seconds</td>
</tr>
<tr>
<td>Traffic Generator</td>
<td>AMD Naples</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AMD Naples</th>
<th>Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cores</td>
<td>128</td>
</tr>
<tr>
<td>vCPU to CPU Ratio</td>
<td>1:1</td>
</tr>
<tr>
<td>VM pairs</td>
<td>1</td>
</tr>
<tr>
<td>vmCPU assigned</td>
<td>6</td>
</tr>
<tr>
<td>VM HDD size</td>
<td>14 GB</td>
</tr>
<tr>
<td>Traffic time</td>
<td>120 Seconds</td>
</tr>
<tr>
<td>Traffic Generator</td>
<td>AMD Naples</td>
</tr>
</tbody>
</table>

Configuration Details:
- Openstack v- Ocate
- PCIe devices Mellanox 100GbE
- Traffic generator: Iperf3
- VNF: CloudRouter 4.0
- SR-IOV
- Hyper Threading: enabled
- IOMMU: enabled
- MTU: 9000

Cloudrouter VM:
- Flavour: centOS7
- RAM: 16GB
- HDD space: 14GB

Iperf VM
- Flavour: centOS7
- RAM: 8GB
- HDD space: 14GB
- CPUs: 4 per VM

Difference:
+ 2.5 Gbps
+ 4.97%

Figure 2: vRouter Test Results

Figure 2, testing done by TCS®, results not verified by AMD

vFirewall Benchmarking Tests

vFirewall Test Details

CloudRouter 4.0 was used as the vFirewall for the tests. The test setups, include content servers – virtual machines - that hold a file of a pre-defined size. Each of the content servers is accessed by the respective client through the vFirewall. Multiple clients simultaneously download the file from the content server that is assigned to it. The tests were performed in multiple iterations to check the performance of the device being tested. The total downloaded content was measured over a period of 5 minutes.

vFirewall Test Topology

For AMD, two EPYC servers were configured as an OpenStack multi-node setup. vFirewall and all the content servers were launched on the OpenStack compute node, which is the SUT, and all the download clients are launched on the controller node. All the virtual machines, vFirewall, content servers and the download clients are launched on openvSwitch interfaces provided by OpenStack Neutron. The same tests were performed on Intel Broadwell (SUT). See Figure 3.
vFirewall Test Topology (cont.)

Since the AMD processor has more cores compared to Intel Broadwell, we were able to deploy two firewalls on each of the physical sockets and were able to launch a greater number of content servers and download clients than the number of each that could be launched on Intel Broadwell based servers. See Table 7 for a summary of the test configuration, and Table 8 for the test results.

Table 7: vFirewall Test Configuration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Configuration detail</th>
</tr>
</thead>
<tbody>
<tr>
<td># Cores Pinned</td>
<td>8</td>
</tr>
<tr>
<td>NUMA region that houses Mellanox Connect X5 NIC</td>
<td>3</td>
</tr>
<tr>
<td>Irq_balance information</td>
<td>OFF</td>
</tr>
<tr>
<td>File Size</td>
<td>3 GB</td>
</tr>
<tr>
<td>MTU</td>
<td>1500</td>
</tr>
</tbody>
</table>

Table 8: vFirewall Test Results

<table>
<thead>
<tr>
<th>SUT</th>
<th>Traffic generator host</th>
<th>Total data downloaded</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD EPYC</td>
<td>AMD EPYC</td>
<td>52.1</td>
</tr>
<tr>
<td>Intel Broadwell</td>
<td>AMD EPYC</td>
<td>40.8</td>
</tr>
</tbody>
</table>

Table 8, testing done by TCS	extsuperscript{1}, results not verified by AMD
**vOpenSSL Benchmarking Tests**

**vOpenSSL Test Details**

vOpenSSL tests are aimed at establishing the maximum number of OpenSSL connections, using an RSA crypto system that a vOpenSSL server can support.

**Test Topology for vOpenSSL**

A multi-node OpenStack setup was created using two servers. Multiple OpenSSL servers are launched on the SUT, which is the OpenStack compute node. Through the OpenStack controller node, OpenSSL clients are launched and secured TLS connections are triggered for a specific interval of time. The number of OpenSSL clients is dependent on the performance of the server. The total number of connections that are made to the server through the clients is compared in each of the attempts between the AMD EPYC and Intel Broadwell systems. See Figure 4.

![Figure 4: vOpenSSL Test Topology](image)

See Table 9 for a summary of the test configuration, and Table 10 for the test results.

**Table 9: vOpenSSL Test Configuration**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Configuration detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>#Cores Pinned for server</td>
<td>16</td>
</tr>
<tr>
<td>#Cores Pinned for client</td>
<td>4</td>
</tr>
<tr>
<td>Irq_balance information</td>
<td>OFF</td>
</tr>
<tr>
<td>MTU on VM interfaces</td>
<td>1500</td>
</tr>
</tbody>
</table>

**Table 10: vOpenSSL Test Results**

<table>
<thead>
<tr>
<th>SUT</th>
<th>Traffic generator host</th>
<th># of concurrent connections established</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD</td>
<td>AMD</td>
<td>117,175.37</td>
</tr>
<tr>
<td>Intel Broadwell</td>
<td>AMD</td>
<td>89,883.69</td>
</tr>
</tbody>
</table>

*Table 10, testing done by TCS¹, results not verified by AMD
Conclusion

Performance testing with a number of VNF’s was successfully completed on AMD EPYC processors. Performance on an AMD EPYC processor with NFV applications such as vRouter, vFirewell, and vOpen SSL was demonstrated to be higher than Intel Broadwell. The higher performance on AMD EPYC processor is primarily attributed to the increased memory bandwidth. Open source software used to perform the tests had limitations in terms of utilizing the maximum available cores on AMD EPYC. Commercial NFV applications would be able to fully utilize the high core count on AMD EPYC and thereby demonstrate industry leading performance.

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FOOTNOTES

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