DPDK

Understanding The Performance of DPDK as a Computer Architect

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Outlines

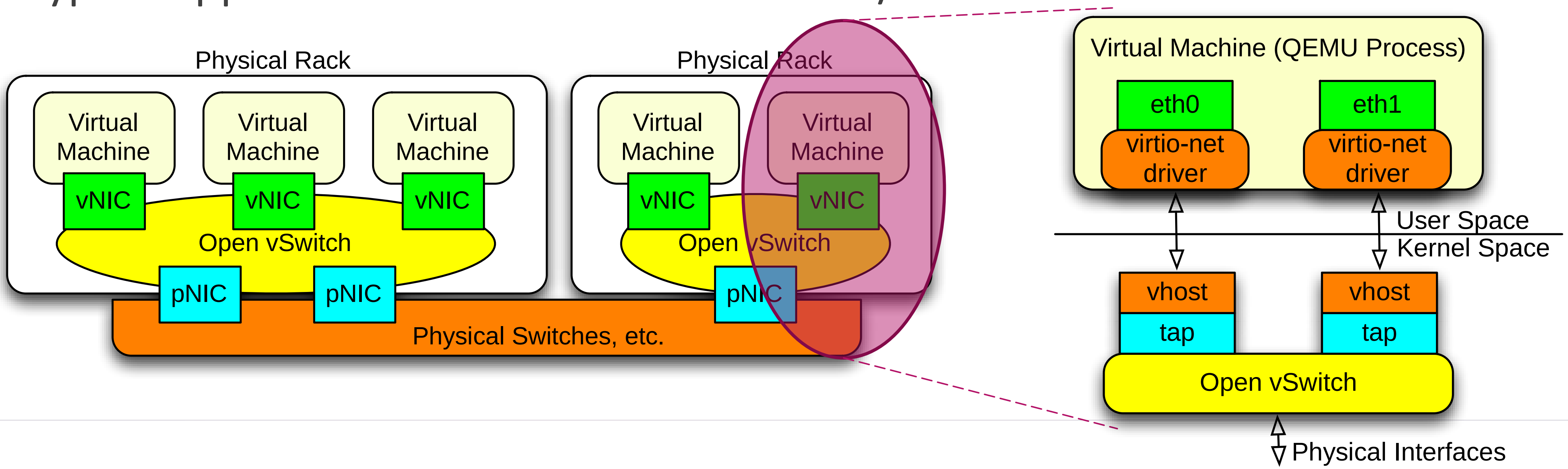
- Background & Motivations
- Introductions to OvS arch and memory hierarchy
- Experiment setup and test methodology
- OvS versus OvS-DPDK performance evaluation
- Multi-socket platform impact analysis
- Conclusion

Background & Motivations

- **Open vSwitch (OvS)**: key connectivity component in cloud/datacenter to provide network of virtualized machines. E.g. *OpenStack*, and *OpenNebula*.
- **Line rate increases** (10G→40G→100G): OvS is hard to keep up.
- DPDK accelerated OvS (OvS-DPDK): known to have higher performance. But why?
- We explain why OvS-DPDK has better performance over vanilla OvS from computer architecture's perspective. E.g. cache behaviors, context switches, etc.

Introduction: OvS Application Scenario

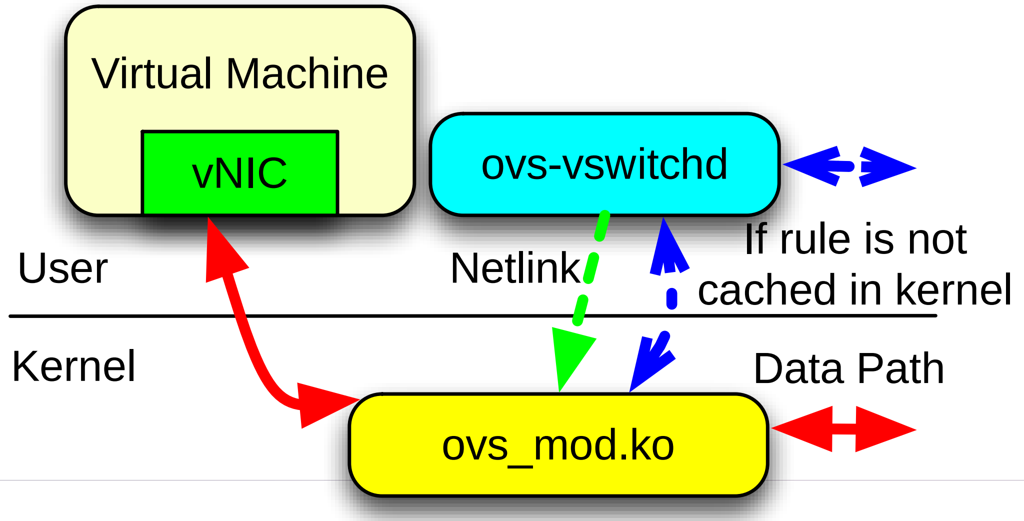
- A typical application scenario of OvS in cloud/datacenter.



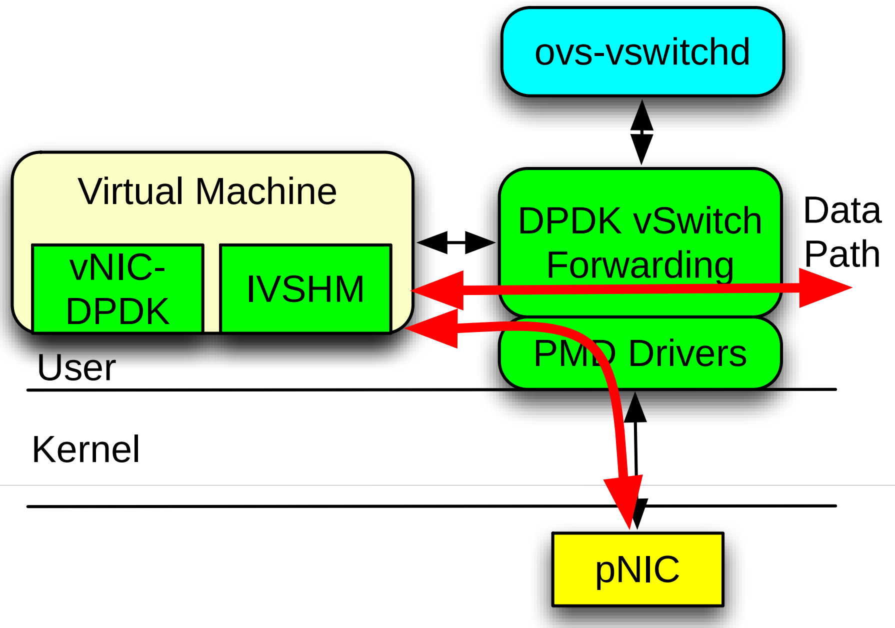
- Two communication scenarios:
  - VM → vNIC → VM (Same host)
  - VM → pNIC → VM (Different hosts)

Introduction: OvS, OvS-DPDK I/O Comparison

- OvS data path:

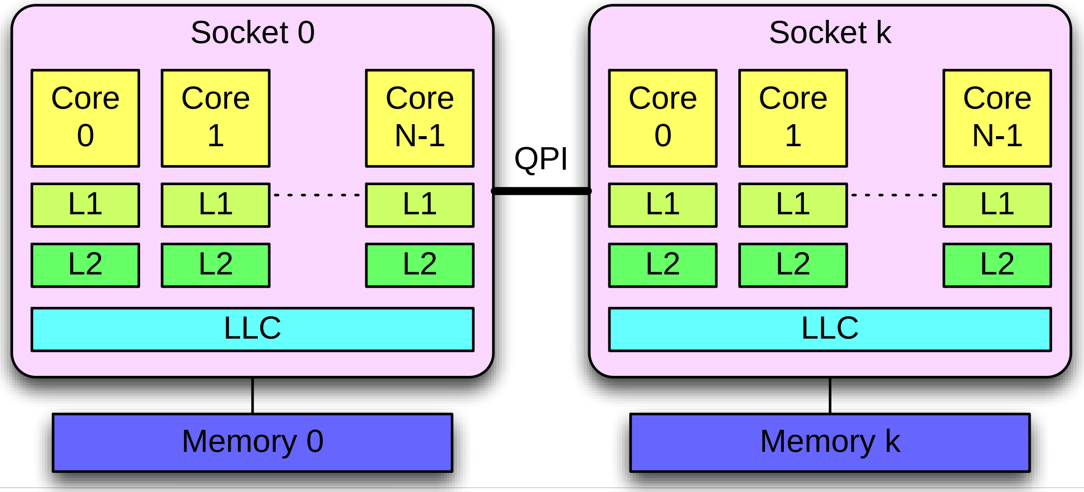


- OvS-DPDK data path:



Introduction: Memory Hierarchy

- For a typical Intel Skylake processor



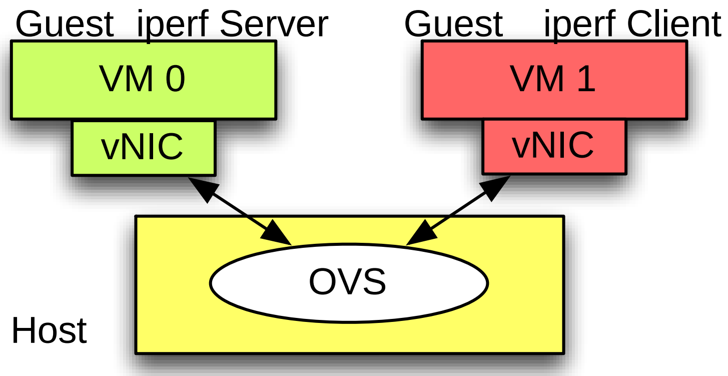
Parameters	Value
L1 Peak Bandwidth (bytes/cycle)	2x32 Load 1x32 Store
L2 Data Access (cycles)	12
L2 Peak Bandwidth (bytes/cycle)	64
Shared L3 Access (cycles)	44
L3 Peak Bandwidth (bytes/cycle)	32
Memory Access (cycles)	~ 140 (for 2.0 GHz)

Source: Intel 64 and IA-32 Architectures: Optimization Reference Manual

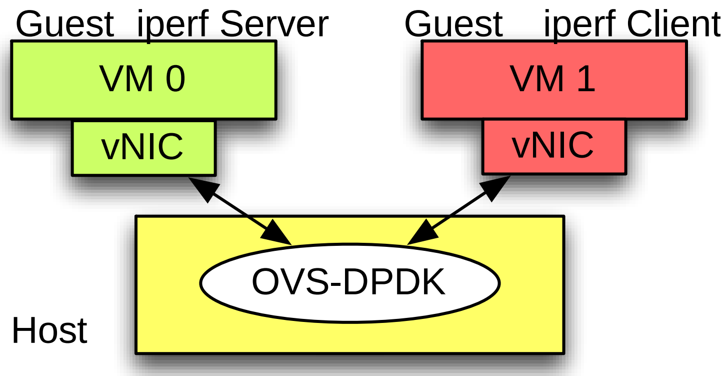
Experiment Setup Overview

- Guest-Guest (VM2VM)

Experiment 1

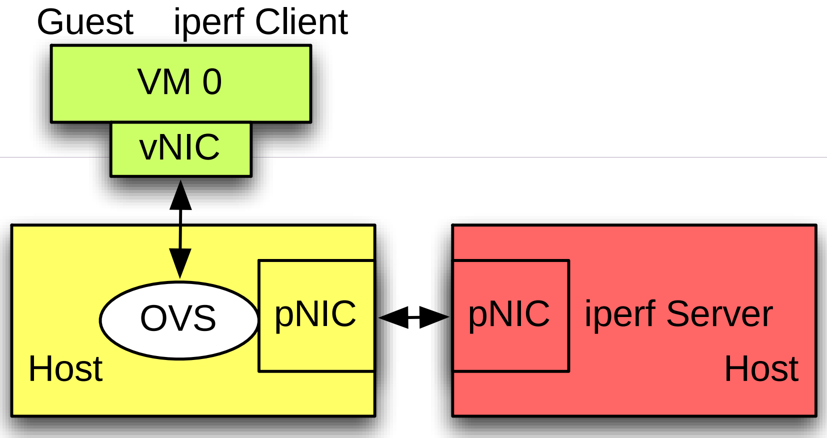


Experiment 2

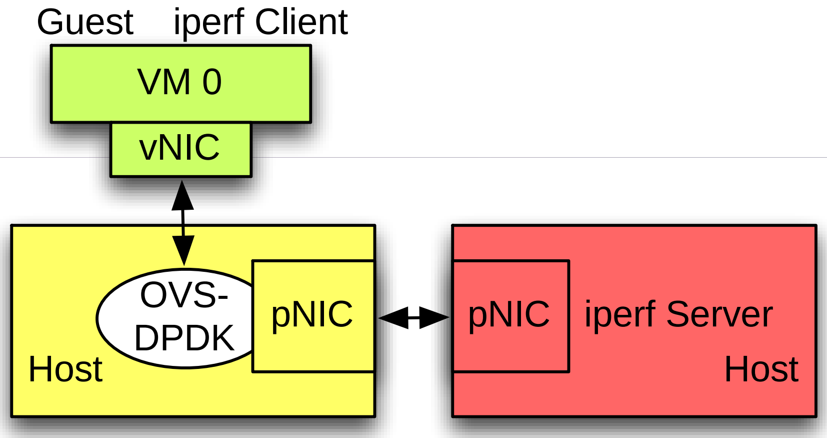


- Guest-Host (VM2Host)

Experiment 3



Experiment 4



Test Platform Specifications

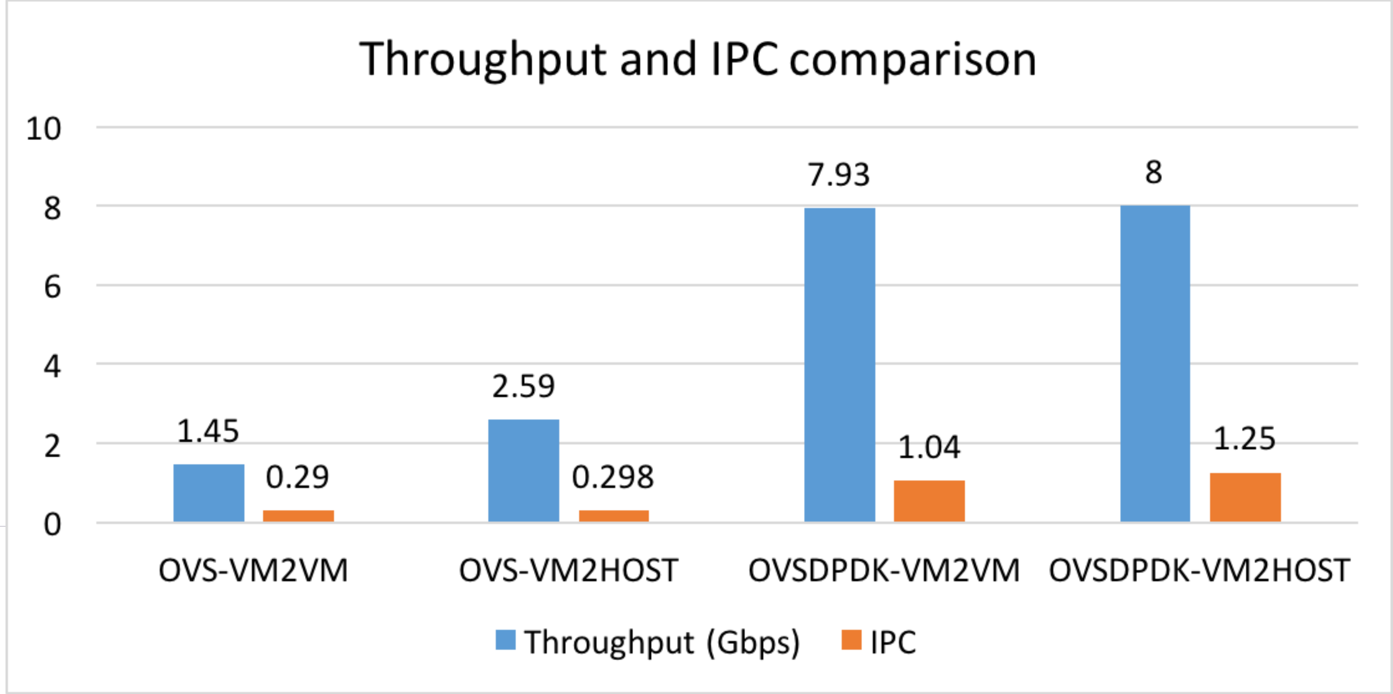
- ***Hardware*** - Intel SuperMicro Server
  - Intel Xeon D-1540, 8 Cores @ 2.0 GHz.
  - ***L1i***: 32 KB, ***L1d***: 32 KB, ***L2***: 256 KB, ***LLC***: 12 MB, ***Memory***: 64 GB.
  - ***NIC***: Intel 82599ES 10-Gigabit SFI/SFP+
- ***OS***: Ubuntu 16.04; ***OvS*** version: 2.5.0; ***DPDK*** version: 16.04
- All the VMs are created by KVM and emulated by QEMU.
- Run ***Iperf*** (version 2.0.5) test on the provided environment.
- Processor performance profiling tools:
  - Linux ***Perf*** version: 4.4.13
  - Intel ***VTune Amplifier XE*** version: 2016 Update 4

Iperf Test Setup

- Experiment 1 (***VM-OvS-VM***)
  - On VM0 (Iperf Server)
    - sudo iperf -s -w 512k -l 128k -p 1005 | grep SUM
  - On VM1 (Iperf Client)
    - iperf -c 10.0.0.1 -p 1005 -w 512k -l 128k -i2 –t60 -P4 | grep SUM
- Experiment 2 (***VM-OvSDPDK-VM***)
  - Same as experiment 1, but use OvS-DPDK
- Experiment 3 (***Host-OvS-VM***)
  - Same as experiment 1, but use another host machine as server
- Experiment 4 (***Host-OvSDPDK-VM***)
  - Same as experiment 3, but use OvS-DPDK.

Evaluation 1

- Throughput and IPC comparison for 4 different scenarios:

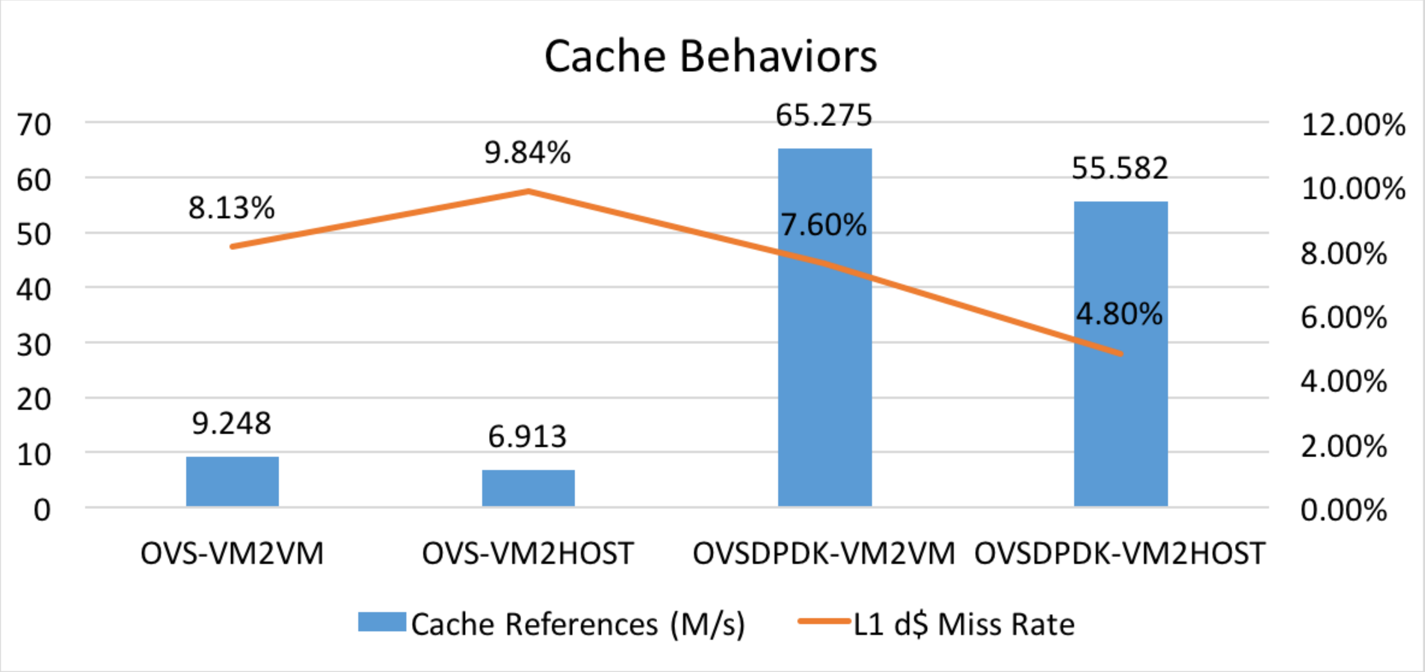


- ***5.5x*** throughput increase for VM2VM scenario
- ***3x*** throughput increase for the VM2HOST scenario
- OvS-DPDK scenarios render better IPC (ideal IPC is 4.0 for 4-issue arch) with pipeline.

5.5x higher throughput, IPC > 1.0

Evaluation 2

- Cache behavior comparison:

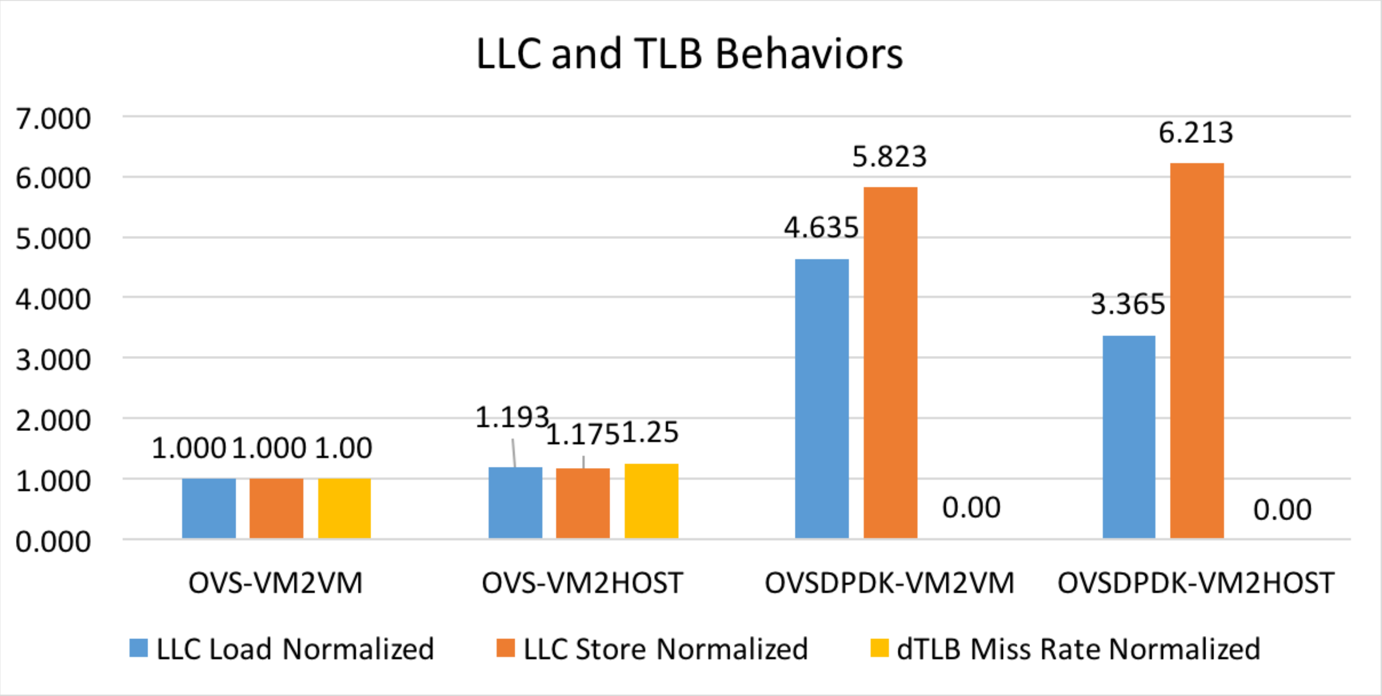


- OvS-DPDK achieves ***7x*** and ***8x*** more cache references for VM2VM and VM2HOST scenarios respectively.
- L1 data cache miss rate is less for both scenarios with OvS-DPDK. Cache miss reduced by ***50%*** for the VM2HOST case with OvSDPDK.

More cache refs, fewer L1 cache misses (SW prefetching)

Evaluation 3

- Last level cache and table lookaside buffer (TLB) behaviors



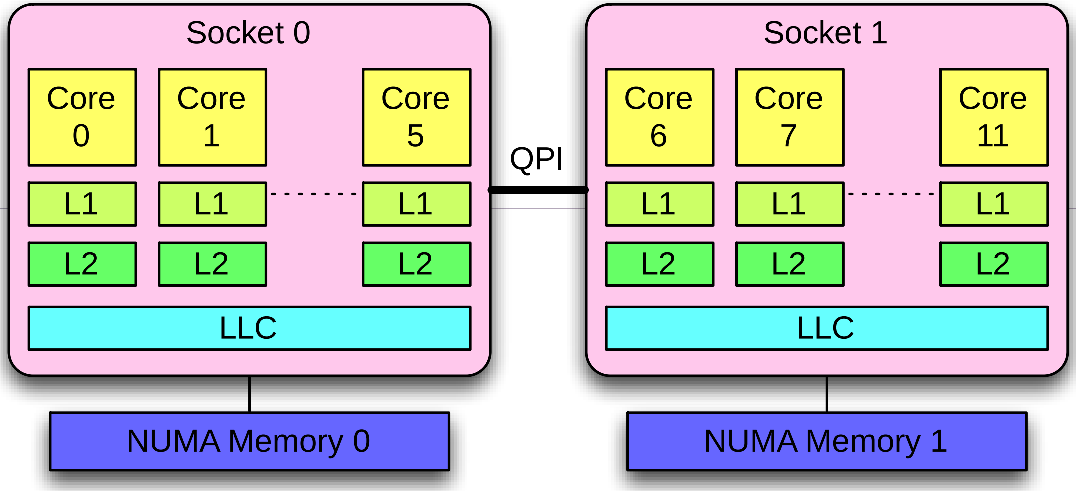
- Last level cache has ***3 ~ 6*** times more accesses with OvS-DPDK than with vanilla OvS.
- TLB miss rate is near perfect ***0.0 %*** if using OvS-DPDK.

More LLC accesses, 0% TLB miss (huge page)

Across Socket Communication Between VMs

DPDK

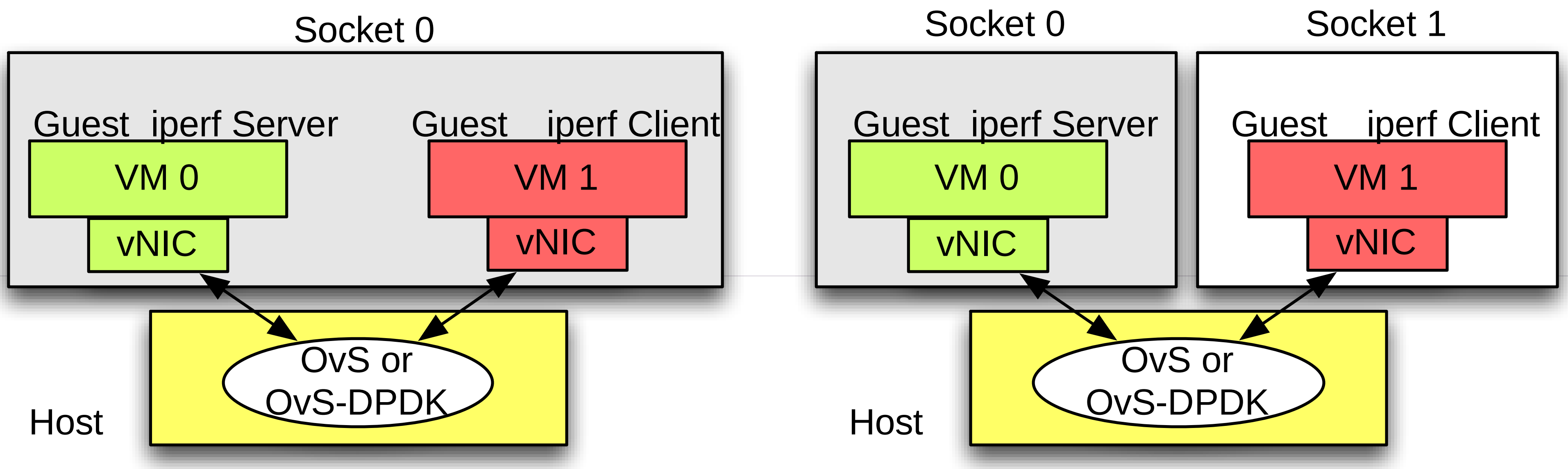
- Modern datacenter racks employ multi-socket platform design to scale up performance with the power budget.
- How OvS and OvS-DPDK behave on such multi-socket platform?
- Our multi-socket test platform:



- ***2-socket*** server
- **2 Intel Xeon** E5-2643 v3 Processors, 6 cores @ 3.4 GHz each socket
- ***L1i***: 32 KB; ***L1d***: 32 KB; ***L2***: 256 KB
- ***LLC*** (L3): 20 MB.
- NUMA Mem0: 8.0 GB; Mem1: 16 GB

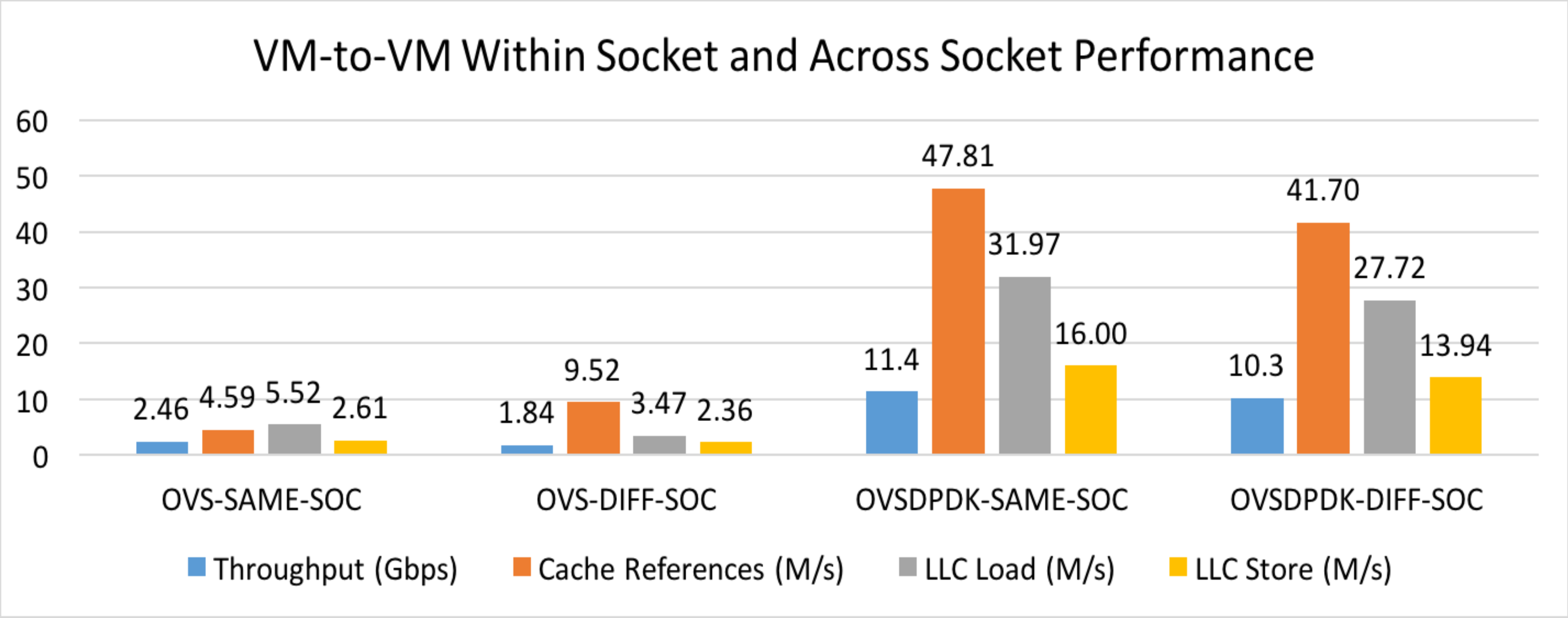
Across Socket Experiment Setup

- Within/Across socket with either OvS or OvS-DPDK: 4 different configurations.
- Run Iperf benchmark for each configuration.



Evaluation 4

- Throughput comparison and cache behaviors.

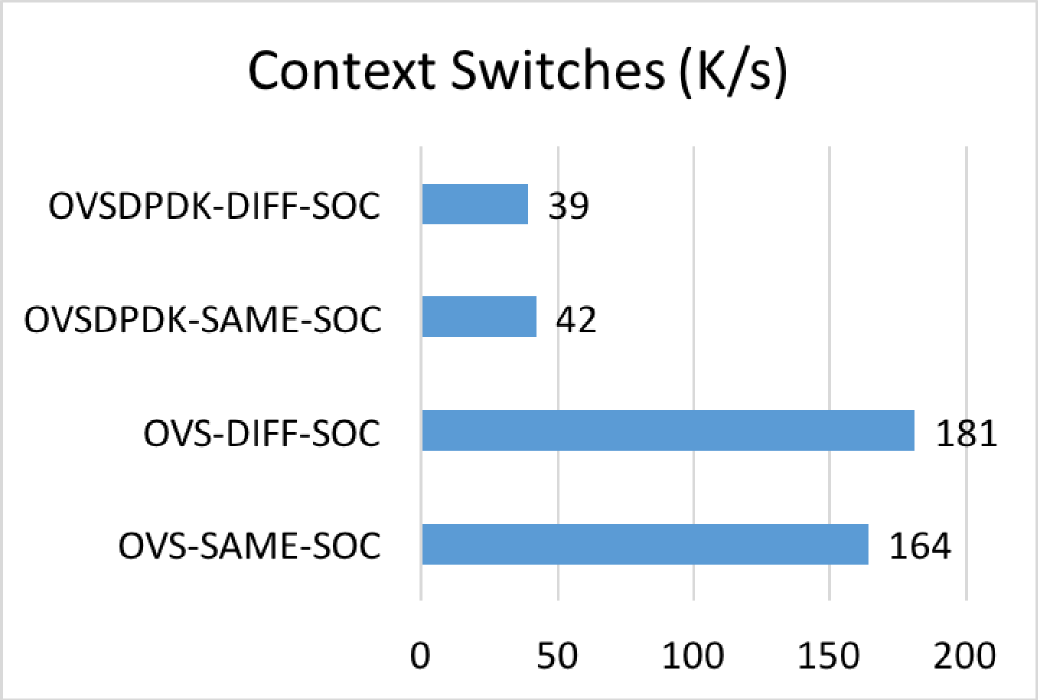


- Throughput difference:
  - OvS: **1.33x** if with same socket
  - OvS-DPDK: **1.1x** if with same socket
- LLC references: **>10%** less LLC references if running VMs across different socket.

Same socket: higher throughput, better LLC behavior

Evaluation 5

- Context switches comparison.



- If comparing OvS vs. OvS-DPDK:
  - Context switches drop dramatically if using OvS-DPDK
- If comparing Same/Diff socket:
  - Not big difference
  - Across socket communication is not the root cause of context switches

OvS-DPDK: fewer context switches.

Across socket: not the root cause of context switches.

Conclusion

- This work conducts a thorough performance analysis of vanilla OvS and OvS-DPDK from a computer architect's perspective.
- OvS-DPDK improves system performance by:
  - Increasing IPC, cache references;
  - Decreasing cache misses (*software prefetching*), TLB misses (*huge pages*), and context switches (*user-space driver*).
- A multi-socket platform may lead to:
  - Lower system throughput and less LLC accesses.
  - Across socket, however, is not the root cause of context switches.

Questions?

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