Revise 4K Pages Performance Impact For DPDK Applications

LEI YAO
JIAYU HU
Agenda

• Why We Try To enable 4K-Page in DPDK

• The Performance Bottleneck using 4K-Page Memory

• Using 4K-Page Memory With Different Workload

• Improve the Performance
Benefit Using 4K Page Memory

• Flexible: 4K page can be allocated on demand, no memory will be preserved when system start up

• Security: No root permission need, it brings more security assurance

Why 4K page is rarely used in DPDK?
Performance Concern!
How To Use Pure 4K Page in DPDK

From DPDK 17.11 release, 4K page is supported in DPDK with VFIO-PCI driver. IOMMU can help for the IOVA to PA translation

1. **Turn on VT-d in BIOS:**

2. **Turn off transparent hugepage and enable IOMMU in Grub**
   
   transparent_hugepage=never, intel_iommu=on

3. **Bind all NIC use in DPDK to vfio-pci, then launch DPDK application**

   `usertools/dpdk-devbind.py -b vfio-pci [BDF]`

   DPK will use IOVA as VA mode in this setting, then the 4K based IOVA address will be translated to PA by Intel IOMMU. Sample command:
   
   testpmd -l 1-3 -n 4 -m 1024 --no-huge -- -i
First Impression Using 4K Page in DPDK

- testpmd(IO fwd)
  - NIC(40G) -> Ixia
  - IMIX packets (64B:7, 570:4, 1518:1)

- 4K-Page vs 2M Hugepage

Graph showing performance comparison between 4K Page and 2M Hugepage in terms of mpps and Gbps.
Potential Performance Bottleneck: TLB, IOTLB, UPI

Diagram showing the potential performance bottleneck pathways between cores, MMUs, TLBs, IOTLBs, and NICs for sockets 0 and 1.
The TLB? The UPI?

The TLB? NO
Perf result show that the TLB miss event number in 4K is higher than 2M hugepage, but the total miss rate is still low.

4K Page:

<table>
<thead>
<tr>
<th>#</th>
<th>time</th>
<th>counts</th>
<th>unit events</th>
<th>% of all dTLB cache hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.000105834</td>
<td>26,414,244</td>
<td>dTLB-load-misses</td>
<td>0.43%</td>
<td></td>
</tr>
<tr>
<td>5.000105834</td>
<td>6,213,669,079</td>
<td>dTLB-loads</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2M Hugepage:

<table>
<thead>
<tr>
<th>#</th>
<th>time</th>
<th>counts</th>
<th>unit events</th>
<th>% of all dTLB cache hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.000104143</td>
<td>209</td>
<td>dTLB-load-misses</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>5.000104143</td>
<td>4,792,519,063</td>
<td>dTLB-loads</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The UPI? NO
Remote Memory vs Local Memory - 3.1%

* Result on Intel(R) Xeon(R) Platinum 8180 CPU @ 2.50GHz
IOTLB?

Yes.
IOMMU is per socket nor per core. On Intel latest Xeon Processor, Processor Counter Monitor (PCM) can trace IOTLB miss event.

/pcm/pcm-iio.x:

4K Page:

<table>
<thead>
<tr>
<th>IIO Stack 1 - PCIe0</th>
<th>Inbound write</th>
<th>Inbound read</th>
<th>Outbound read</th>
<th>Outbound write</th>
<th>VT-d Occupancy</th>
<th>TLB Miss</th>
<th>TLB1 Miss</th>
<th>TLB full</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part0 (1st x16/x8/x4)</td>
<td>2030 M</td>
<td>1204 M</td>
<td>0</td>
<td>1300 K</td>
<td>34 G</td>
<td>22 M</td>
<td>23 M</td>
<td>0</td>
</tr>
<tr>
<td>Part1 (2nd x4)</td>
<td>1639 M</td>
<td>1605 M</td>
<td>0</td>
<td>1120 K</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part2 (2nd x8/3rd x4)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part3 (4th x4)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2M Hugepage

<table>
<thead>
<tr>
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<th>Inbound read</th>
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<th>TLB full</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part0 (1st x16/x8/x4)</td>
<td>5122 M</td>
<td>4415 M</td>
<td>0</td>
<td>1840 K</td>
<td>30 G</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Part1 (2nd x4)</td>
<td>5120 M</td>
<td>4467 M</td>
<td>0</td>
<td>1841 K</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
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<tr>
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<td>0</td>
<td>0</td>
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* Result on Intel(R) Xeon(R) Platinum 8180 CPU @ 2.50GHz
Is IOMMU Bottleneck For All Scenario?

4K-page memory is not the bottleneck for most of the workload in real world.

* Result on Intel(R) Xeon(R) Platinum 8180 CPU @ 2.50GHz
Is 4K-Page Lack of Performance at All Packet Size?

The key performance gap comparing from 4K Page Memory is between packet size 64B ~ 256B.

* Result on Intel(R) Xeon(R) Platinum 8180 CPU @ 2.50GHz
How to Improve IO Performance for Small Packets

Reduce NIC txd/rxd to avoid too much IOTLB miss

**IMIX Packets:**
- Performance of 4K-page with rxd/txd = 1024:
- Performance of 4K-page with rxd/txd = 128: + 50%

**64B Packets:**
- Performance of 4K-page with rxd/txd = 1024:
- Performance of 4K-page with rxd/txd = 128: + 123%

**128B Packets:**
- Performance of 4K-page with rxd/txd = 1024:
- Performance of 4K-page with rxd/txd = 128: + 9%

**256B Packets:**
- Performance of 4K-page with rxd/txd = 1024:
- Performance of 4K-page with rxd/txd = 128: + 10%

It can work but not good idea. This method has some limitation.
How to Improve IO Performance for Small Packets

Limited the RX rate!
Option 1: Limit the Inject Packet Rate

PVP Performance with Different Inject Packet Rate

* Result on Intel(R) Xeon(R) Platinum 8180 CPU @ 2.50GHz
How to Improve IO Performance for Small Packets

Option 2. Slow down the frequency touching the NIC Rx

debug

Testpmd

NIC(40G)

rte_delay_us()

NIC(40G)

Ixia

Ixia

Performance Trend with Different CPU Stall Time

On my test bench, 2us is the best practice number to for IO fwd workload.

* Result on Intel(R) Xeon(R) Platinum 8180 CPU @ 2.50GHz
Can Transparent Hugepage help?

- No Performance Gain for IMIX Packets
- No IOTLB miss event improvement.
- Default is “madvise” in latest Kernel, not always
Conclusion

• Only in IO bound scenario, 4K-page has performance concern

• IOMMU is the performance bottleneck

• Reduce the RX rate can be helpful for system throughput

• Transparent hugepage can’t help throughput
Thank You!