

虚拟化中的大页 (Hugapage)

——工程实践与科技创新 作业 4

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实验目的

1. 学习虚拟化中页式存储的原理
2. 认识页大小、页表大小、TLB 大小之间的关系与对性能的影响
3. 通过在不同页大小的情况下测试内存读写性能以更好地认识页大小对性能的影响

实验环境

1. 主机系统：Ubuntu 20.04
2. 虚拟机系统：Ubuntu 20.04
3. qemu 版本：5.2.0

实验内容

任务一：在主机上准备 Hugepage (1G 与 2M)

本部分主要介绍 Ubuntu 系统配置 Hugepage 的方法。在虚拟机与主机中使用同样的方式配置 Hugepage。本项目分别测试了主机 Hugepage 为 1G 与 2M 时的虚拟机内存性能。

更改默认 Hugepage 大小 (Optional)

Ubuntu 系统开机时按住 Shift 键进入 GNU GRUB，↑↓键选择要进入的操作系统。

按 e 键更改系统启动命令，在 `linux` 对应行加入参数`default_hugepagesz=`可以更改系统默认的 Hugepage 大小。下图是设置默认 Hugepage 大小为 1G 的例子：

```
GNU GRUB version 2.04

insmod ext2
set root='hd0,msdos5'
if [ x$feature_platform_search_hint = xy ]; then
  search --no-floppy --fs-uuid --set=root --hint-bios=hd0,msdos5\
--hint-efi=hd0,msdos5 --hint-baremetal=ahci0,msdos5 36646a65-be54-4c69\
-bcf7-b050d58ce3b0
else
  search --no-floppy --fs-uuid --set=root 36646a65-be54-4c69-bcf\
7-b050d58ce3b0
fi
linux /boot/vmlinuz-5.11.0-41-generic root=UUID=36646a65-\
be54-4c69-bcf7-b050d58ce3b0 ro find_preseed=/preseed.cfg auto noprompt p\
riority=critical locale=en_US quiet default_hugepagesz=1024M_
initrd /boot/initrd.img-5.11.0-41-generic

Minimum Emacs-like screen editing is supported. TAB lists
completions. Press Ctrl-x or F10 to boot, Ctrl-c or F2 for a
command-line or ESC to discard edits and return to the GRUB
menu.
```

为 Hugepage 分配空间并挂载文件系统

Step1: 使用 `cat /proc/meminfo` 指令查看 hugepage 的相关信息

```
HugePages_Total:      0
HugePages_Free:       0
HugePages_Rsvd:       0
HugePages_Surp:       0
Hugepagesize:       1048576 kB
Hugetlb:              0 kB
```

可见默认 Hugepage 大小为 1G

Step2: 使用 `echo 20 > /proc/sys/vm/nr_hugepage` 指令准备指定数量的 Hugepage。

```
root@ubuntu:/home/ubuntu-gry# echo 20 > /proc/sys/vm/nr_hugepages
```

```
HugePages_Total:      3
HugePages_Free:       3
HugePages_Rsvd:       0
HugePages_Surp:       0
Hugepagesize:       1048576 kB
Hugetlb:             3145728 kB
```

准备 20 个 1G hugepage 超过了最大内存，此时系统会根据内存大小调整 hugepage 数量，事实上指分配了三个 hugepage，使用 `cat /proc/meminfo` 查看到的 Hugepage 相关信息如上图所示：Hugepage 总数 (HugepageTotal) 为 3，未分配的 Hugepage (HugepageFree) 的数量为 3，Hugepage 总量 (Hugetlb) 为 3G。

Step3: 使用 `mount -t hugetlbfs hugetlbfs /dev/hugepage` 挂载 Hugepage 文件系统 (hugetlbfs: Linux 提供的基于 RAM 的文件系统)，挂载以后 `/dev/hugepages` 将使用 Hugepage 作为后备 (Backing Store)。使用 `mount` 指令确认挂载成功。

```
ubuntu-gry@ubuntu:~$ sudo mount -t hugetlbfs hugetlbfs /dev/hugepages
[sudo] password for ubuntu-gry:
hugetlbfs on /dev/hugepages type hugetlbfs (rw,relatime,pagesize=1024M)
```

附加步骤：关闭 Transparent Hugepage

打开 ubuntu_1 (使用 Hugepage) 以后，使用查看 Hugepage 使用情况，观察到 Transparent hugepage 的使用量大增，而没有使用预准备的 Hugepage，说明 Transparent Hugepage 会影响到预准备的 Hugepage

```
root@ubuntu:/home/ubuntu-gry# cat /proc/meminfo | grep -i hugepages
AnonHugePages:    1038336 kB
ShmemHugePages:    0 kB
FileHugePages:     0 kB
HugePages_Total:   2
HugePages_Free:    0
HugePages_Rsvd:    0
HugePages_Surp:    0
Hugepagesize:     1048576 kB
```

使用 `cat /sys/kernel/mm/transparent_hugepage/enabled` 命令查看 transparent hugepage 是否开启

```
root@ubuntu:/home/ubuntu-gry# cat /sys/kernel/mm/transparent_hugepage/enabled
always [madvice] never
```

结果是 madvice，即主机会动态决定是否使用 Transparent Hugepage，使用 `echo never > /sys/kernel/mm/transparent_hugepage/enabled` 指令在主机上关闭 Transparent Hugepage，如下图所示

```
root@ubuntu:/home/ubuntu-gry# echo never > /sys/kernel/mm/transparent_hugepage/enabled
root@ubuntu:/home/ubuntu-gry# cat /sys/kernel/mm/transparent_hugepage/enabled
always madvice [never]
```

分别创建使用/不使用 Hugepage 的虚拟机

虚拟机使用 Hugepage，意味着它将虚拟地址映射到主机的 `/dev/hugepages`，这并不是虚拟机在安装时就固化的。事实上，只需要在开启虚拟机时设置 `-mem-path` 参数为主机上的 Hugepage 文件系统 `/dev/hugepages` 即可。

在本次作业中为了将使用、不使用 Hugepage 的虚拟机在截图中加以区分，故分别创建两个虚拟机 ubuntu_1, ubuntu_2 用以代表是否使用 Hugepage。

```
ubuntu-gry@ubuntu:~/qemu-5.2.0/build/x86_64-softmmu$ sudo ./qemu-system-x86_64 -m 2048 -enable-kvm ubuntu_1.img -cdrom ./ubuntu-20.04.3-desktop-amd64.iso -mem-path /dev/hugepages/
```

```
ubuntu-gry@ubuntu:~/qemu-5.2.0/build/x86_64-softmmu$ sudo ./qemu-system-x86_64 -m 2048 -enable-kvm ubuntu_2.img -cdrom ./ubuntu-20.04.3-desktop-amd64.iso
```

在虚拟机中分配、使用 Hugepage

在虚拟机中分配、使用 Hugepage 的过程与上文“为 Hugepage 分配空间并挂载文件系统”所述过程一致, 区别仅在于: 上文例图中 hugepagesz=1G, 因此只需要分配 3 个 hugepage。而由于虚拟机的内存受限, 无法使用 1G 的 hugepage, 只能使用 2M 的 hugepage, 因此在虚拟机中需要分配更多数量的 hugepage。

虚拟机的内存总大小为 2G (在开启虚拟机指令中使用 -m 参数设置)。事实上, 在虚拟机中进行内存性能测试时, 为了控制使用 hugepage 与否时 sysbench 可使用的内存一致, 虚拟机分配了一半内存 (1G) 给 hugepage, 共 512 个 hugepage。

任务二：实验测试与分析

Hugepage 原理

$$\text{Page Hit Rate} = \text{TLB Hit Rate} + (1 - \text{TLB Hit Rate}) \times \text{PageTable Hit Rate}$$

使用 Hugepage 增大了页大小, 减小了页数量, 在页数量远大于页表入口数的情况下 (这也是实际情况) 可以有效增大 TLB 命中率和页表命中率, 从而提高内存访问速度。

Sysbench

安装

在虚拟机中使用 apt 软件管理工具安装 sysbench, 以下仅展示两台虚拟机的 sysbench 版本:

```
gry@gry-ubuntu-1:~$ sysbench --version
sysbench 1.0.18

gry@gry-ubuntu-2:~/Desktop$ sysbench --version
sysbench 1.0.18
```

测试指令

```
sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256m --memory-hugetlb=on run
```

上述指令即本作业使用 sysbench 进行内存的指令的一般形式。绿色的参数是实验中要控制的变量:

--test=memory 表明内存测试

--memory-total-size=500g 控制读写的数据总量为 500g

--threads=128 控制线程数量为 128

这两个参数的设定地“比较大”（在最大内存限制下，与 sysbench 推荐的测试参数相比）是出于两个目的：1.减小偶然误差 2.将差异放大到可信程度

`--memory-access-mode=rnd` 设置内存读写方式为随机读写（rnd: random）。
设置随机读写可以体现 hugetlb 的优势。顺序读写（seq）在按照顺序访问内存，TLB miss 仅出现在访问页头位置时。而随机读写（rnd）每次读写内存的位置是随机的，相邻内存访问可能出现在不同页中。换言之，随机读写方式增多了访问不同页的次数，更能利用“Hugepage 通过增大页大小来减小页数量从而减少了 TLB miss”的优势。

`--memory-block-size=256m` 设置测试内存性能所用的内存大小为 256m。
设为 256m 是因为，256m 在总内存大小限制下允许设置的最大值。memory-block-size 设置地越大，测试所涉及的页的数量就越多，更能体现出 hugepage 的优势。

`--memory-hugetlb=on | off` 设置是/否使用 hugepage。这是测试的内生变量。

分组实验

为了测试主机是否使用 Hugepage、虚拟机是否使用 Hugepage 与主机使用 2M、1G Hugepage，本次作业设计了 6 组实验：

- 1. 主机 2M Hugepage，虚拟机 2M Hugepage
- 2. 主机 2M Hugepage，虚拟机不使用 Hugepage
- 3. 主机 1G Hugepage，虚拟机 2M Hugepage
- 4. 主机 1G Hugepage，虚拟机不使用 Hugepage
- 5. 主机不使用 Hugepage，虚拟机 2M Hugepage
- 6. 主机不使用 Hugepage，虚拟机不使用 Hugepage

每组实验测量 5 次取平均值。其中虚拟机主机 Hugetlb 大于 2G，虚拟机分配 2G 内存；进入虚拟机后先分配 hugetlb=1G 再进行实验。实验结果如下所示：

总 时 间 (s)	1	2	3	4	5	均值	样 本 标 准 差
Host no vm 2M	45.1529	82.8566 (离 群值)	49.7090	44.4999	45.3155	46.16933	2.38596
Host no vm no	76.2189	78.7225	76.0335	73.7059	78.2518	76.58652	1.79305
Host 1G vm no	78.0668	74.7009	74.5731	74.2965	75.5286	75.43318	1.37935
Host 1G vm 2M	43.7381	50.0157	47.3348	45.1681	43.50	45.95134	2.44761
Host 2M vm no	76.2944	75.5145	74.6936	78.0469	76.7134	76.25256	1.13215
Host 2M vm 2M	45.9621	45.0900	45.5786	43.7243	44.2557	44.92214	0.92461

结果分析

一、虚拟机是否启用 Hugepage

性能（1/时间）	开启 Hugepage	不开启 Hugepage	百分比提升
Host_no	1/46.16933	1/76.58652	40%
Host_1G	1/45.95134	1/75.43318	41%
Host_2M	1/44.92214	1/76.25256	42%

虚拟机是否开启 hugepage 对测试结果影响较大（41%）左右。

Hugepage 对性能提升的原理在“Hugepage 原理”一节详细介绍，为了方便在这里再重复一遍：

$$\text{Page Hit Rate} = \text{TLB Hit Rate} + (1 - \text{TLB Hit Rate}) \times \text{PageTable Hit Rate}$$

使用 Hugepage 增大了页大小，减小了页数量，在页数量远大于页表入口数的情况下（这也是实际情况）可以有效增大 TLB 命中率和页表命中率，从而提高内存访问速度。

二、主机是否开启 Hugepage/使用不同大小 Hugepage

时间	Host_1G	Host_2G	Host_no	1G 百分比提升	2M 百分比提升
VM_no	75.43318	76.25256	76.58652	1.5%	3%
VM_2M	45.95134	44.92214	46.16933	0.5%	2.2%

主机是否开启 Hugepage 对虚拟机内部读写性能几乎没有影响。

虚拟机开启 Hugepage 对性能影响大、主机开启 Hugepage 影响较小的原因：

实验所用的区域仅仅只有给虚拟机分配的 2G 内存中的 256M，实验数据也只能反映对这 256M 空间的提升。产生差异的原因在于：

1. 虚拟机内存需要经历“虚拟机→主机”的内存映射，虚拟机中在一个页中的内存区域在主机上不一定也属于同一个页

2. 虚拟机中是否开启 Hugepage 直接影响测试用的内存区域，而主机开启 Hugepage 表现为对虚拟机 2G 内存的整体的影响。在这 2G 内存中占据主导地位的是并不是测试使用的 256M 区域。

原始数据

Host 不开启, VM 开启

```
root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=on run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.10 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 262144KiB
  total size: 512000MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 2.83 per second)

32768.00 MiB transferred (725.69 MiB/sec)

General statistics:
  total time:          45.1529s
  total number of events: 128

Latency (ms):
  min:                44091.07
  avg:                 44610.59
  max:                 45125.35
  95th percentile:    45200.79
  sum:                 5710155.53

Threads fairness:
  events (avg/stddev):    1.0000/0.00
  execution time (avg/stddev): 44.6106/0.23
```

```
root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=on run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.10 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 262144KiB
  total size: 512000MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.54 per second)

32768.00 MiB transferred (395.47 MiB/sec)

General statistics:
  total time:          82.8560s
  total number of events: 128

Latency (ms):
  min:                81060.43
  avg:                 82034.38
  max:                 82840.46
  95th percentile:    82031.09
  sum:                 10506400.27

Threads fairness:
  events (avg/stddev):    1.0000/0.00
  execution time (avg/stddev): 82.0344/0.39
```

```
root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=on run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.10 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 262144KiB
  total size: 512000MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 2.57 per second)

32768.00 MiB transferred (659.18 MiB/sec)

General statistics:
  total time:          49.7090s
  total number of events: 128

Latency (ms):
  min:                48328.14
  avg:                 49085.06
  max:                 49622.42
  95th percentile:    49546.09
  sum:                 6282887.46

Threads fairness:
  events (avg/stddev):    1.0000/0.00
  execution time (avg/stddev): 49.0851/0.30
```

```
root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=on run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.10 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 262144KiB
  total size: 512000MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 128 (   2.88 per second)

32768.00 MiB transferred (736.34 MiB/sec)

General statistics:
  total time:                   44.4999s
  total number of events:       128

Latency (ms):
  min:                         43253.66
  avg:                         43916.63
  max:                         44451.17
  95th percentile:            44472.74
  sum:                         5621328.21

Threads fairness:
  events (avg/stddev):        1.0000/0.00
  execution time (avg/stddev): 43.9166/0.25
```

```
root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=on run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.10 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 262144KiB
  total size: 512000MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 128 (   2.82 per second)

32768.00 MiB transferred (723.07 MiB/sec)

General statistics:
  total time:                   45.3155s
  total number of events:       128

Latency (ms):
  min:                         43907.67
  avg:                         44707.09
  max:                         45282.45
  95th percentile:            45280.79
  sum:                         5722597.50

Threads fairness:
  events (avg/stddev):        1.0000/0.00
  execution time (avg/stddev): 44.7071/0.26
```

Host 不开启 VM 不开启

```
root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=off run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.10 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 262144KiB
  total size: 512000MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 128 (   1.68 per second)

32768.00 MiB transferred (429.91 MiB/sec)

General statistics:
  total time:                   76.2189s
  total number of events:       128

Latency (ms):
  min:                         74822.17
  avg:                         75629.32
  max:                         76182.64
  95th percentile:            76336.47
  sum:                         9680552.63

Threads fairness:
  events (avg/stddev):        1.0000/0.00
  execution time (avg/stddev): 75.0293/0.27
```



```

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=off run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with the following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.63 per second)

32768.00 MiB transferred (416.24 MiB/sec)

General statistics:
total time: 78.7225s
total number of events: 128

Latency (ms):
min: 76883.81
avg: 77964.28
max: 78670.87
95th percentile: 79129.46
sum: 9979428.43

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 77.9643/0.35

```

```

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=off run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with the following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.68 per second)

32768.00 MiB transferred (430.96 MiB/sec)

General statistics:
total time: 76.0335s
total number of events: 128

Latency (ms):
min: 74567.02
avg: 75490.67
max: 75903.13
95th percentile: 76330.47
sum: 9662805.88

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 75.4907/0.26

```

```

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=off run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with the following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.74 per second)

32768.00 MiB transferred (444.57 MiB/sec)

General statistics:
total time: 73.7059s
total number of events: 128

Latency (ms):
min: 72463.00
avg: 73140.34
max: 73011.50
95th percentile: 73630.49
sum: 9361903.70

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 73.1403/0.24

```

```

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256m --memory-hugetlb=off run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.64 per second)
32768.00 MiB transferred (418.74 MiB/sec)

General statistics:
total time: 78.2518s
total number of events: 128

Latency (ms):
min: 76015.88
avg: 77548.84
max: 78153.59
95th percentile: 77217.37
sum: 9926251.48

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 77.5488/0.34

```

Host 2M VM 开启

```

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256m --memory-hugetlb=on run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 2.78 per second)
32768.00 MiB transferred (712.91 MiB/sec)

General statistics:
total time: 45.9621s
total number of events: 128

Latency (ms):
min: 44611.61
avg: 45454.40
max: 45889.87
95th percentile: 46103.52
sum: 5818174.40

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 45.4545/0.26

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256m --memory-hugetlb=on run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 2.84 per second)
32768.00 MiB transferred (726.70 MiB/sec)

General statistics:
total time: 45.0900s
total number of events: 128

Latency (ms):
min: 43579.78
avg: 44477.55
max: 45013.47
95th percentile: 45280.79
sum: 5693126.13

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 44.4775/0.27

```

```

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=on run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 262144KiB
  total size: 512000MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 2.81 per second)
32768.00 MiB transferred (718.91 MiB/sec)

General statistics:
  total time:          45.5786s
  total number of events: 128

Latency (ms):
  min:                44039.81
  avg:                 44898.68
  max:                 45517.61
  95th percentile:    45280.79
  sum:                 5747030.94

Threads fairness:
  events (avg/stddev):    1.0000/0.00
  execution time (avg/stddev): 44.8987/0.29

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=on run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 262144KiB
  total size: 512000MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 2.93 per second)
32768.00 MiB transferred (749.39 MiB/sec)

General statistics:
  total time:          43.7243s
  total number of events: 128

Latency (ms):
  min:                43542.25
  avg:                 43172.94
  max:                 43684.95
  95th percentile:    43679.10
  sum:                 5526520.36

Threads fairness:
  events (avg/stddev):    1.0000/0.00
  execution time (avg/stddev): 43.1759/0.20

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=on run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 262144KiB
  total size: 512000MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 2.89 per second)
32768.00 MiB transferred (740.40 MiB/sec)

General statistics:
  total time:          44.2557s
  total number of events: 128

Latency (ms):
  min:                43099.01
  avg:                 43682.58
  max:                 44208.02
  95th percentile:    44472.74
  sum:                 5591370.32

Threads fairness:
  events (avg/stddev):    1.0000/0.00
  execution time (avg/stddev): 43.6826/0.24

```

Host 2M VM 不开启

```

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=off run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.10 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.68 per second)
32768.00 MiB transferred (429.49 MiB/sec)

General statistics:
total time: 76.2944s
total number of events: 128

Latency (ms):
min: 75202.42
avg: 75755.56
max: 76245.04
95th percentile: 76330.47
sum: 9596712.29

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 75.7556/0.23

```

```

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=off run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.10 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.69 per second)
32768.00 MiB transferred (433.92 MiB/sec)

General statistics:
total time: 75.5145s
total number of events: 128

Latency (ms):
min: 74202.86
avg: 74979.11
max: 75494.44
95th percentile: 74968.33
sum: 9597526.39

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 74.9791/0.28

```

```

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=off run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.10 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.71 per second)
32768.00 MiB transferred (438.69 MiB/sec)

General statistics:
total time: 74.6926s
total number of events: 128

Latency (ms):
min: 73357.97
avg: 74158.69
max: 74640.90
95th percentile: 74968.33
sum: 9492312.10

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 74.1587/0.24

```

```

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=off run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.64 per second)
32768.00 MiB transferred (419.84 MiB/sec)

General statistics:
total time: 78.0469s
total number of events: 128

Latency (ms):
min: 76283.45
avg: 77426.44
max: 78003.97
95th percentile: 77717.37
sum: 9918584.93

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 77.4264/0.29

```

```

root@gry-ubuntu-2:/home/gry/Desktop# sysbench --test=memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=off run
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.67 per second)
32768.00 MiB transferred (427.14 MiB/sec)

General statistics:
total time: 76.7134s
total number of events: 128

Latency (ms):
min: 75148.30
avg: 76090.89
max: 76665.23
95th percentile: 76330.47
sum: 9739634.25

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 76.0909/0.30

```

Host 1G VM 开启

```

root@gry-ubuntu-1:/home/gry/Desktop# sysbench memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256n --memory-hugetlb=on run
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 2.93 per second)
32768.00 MiB transferred (749.16 MiB/sec)

General statistics:
total time: 43.7381s
total number of events: 128

Latency (ms):
min: 42577.70
avg: 43210.28
max: 43710.04
95th percentile: 43679.10
sum: 5531684.03

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 43.2163/0.21

```

```

root@gry-ubuntu-1:/home/gry/Desktop# sysbench memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256m --memory-hugetlb=on run
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 262144KiB
  total size: 512000MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 2.56 per second)

32768.00 MiB transferred (655.12 MiB/sec)

General statistics:
total time: 50.0157s
total number of events: 128

Latency (ms):
min: 47646.62
avg: 49253.15
max: 50093.64
95th percentile: 49546.69
sum: 6304403.71

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 49.2532/0.43

```

```

root@gry-ubuntu-1:/home/gry/Desktop# sysbench memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256m --memory-hugetlb=on run
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 262144KiB
  total size: 512000MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 2.70 per second)

32768.00 MiB transferred (692.23 MiB/sec)

General statistics:
total time: 47.3348s
total number of events: 128

Latency (ms):
min: 45879.58
avg: 46741.78
max: 47303.85
95th percentile: 46941.21
sum: 5982948.23

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 46.7418/0.29

```

```

root@gry-ubuntu-1:/home/gry/Desktop# sysbench memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256m --memory-hugetlb=on run
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
  block size: 262144KiB
  total size: 512000MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 2.83 per second)

32768.00 MiB transferred (725.43 MiB/sec)

General statistics:
total time: 45.1681s
total number of events: 128

Latency (ms):
min: 43920.10
avg: 44569.00
max: 45101.15
95th percentile: 45280.79
sum: 5704831.43

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 44.5690/0.25

```

```

root@gry-ubuntu-1:/home/gry/Desktop# sysbench memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256m --memory-hugetlb=on run
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 2.94 per second)

32768.00 MiB transferred (753.11 MiB/sec)

General statistics:
total time: 43.5078s
total number of events: 128

Latency (ms):
min: 42210.90
avg: 42952.71
max: 43444.20
95th percentile: 43679.10
sum: 5497946.69

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 42.9527/0.25

```

Host 1G VM 不开启

```

root@gry-ubuntu-1:/home/gry/Desktop# sysbench memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256m --memory-hugetlb=off run
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.64 per second)

32768.00 MiB transferred (419.73 MiB/sec)

General statistics:
total time: 76.0668s
total number of events: 128

Latency (ms):
min: 76447.55
avg: 77417.82
max: 78017.33
95th percentile: 77717.37
sum: 9909481.19

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 77.4178/0.34

```

```

root@gry-ubuntu-1:/home/gry/Desktop# sysbench memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=256m --memory-hugetlb=off run
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.71 per second)

32768.00 MiB transferred (438.64 MiB/sec)

General statistics:
total time: 74.7009s
total number of events: 128

Latency (ms):
min: 73287.02
avg: 74153.67
max: 74631.60
95th percentile: 74968.33
sum: 9491669.31

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 74.1537/0.25

```



```

root@gry-ubuntu-1:/home/gry/Desktop# sysbench memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=250m --memory-hugetlb=off run
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.72 per second)

32768.00 MiB transferred (439.39 MiB/sec)

General statistics:
total time: 74.5731s
total number of events: 128

Latency (ms):
min: 73246.18
avg: 74032.98
max: 74555.22
95th percentile: 74968.33
sum: 9476221.92

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 74.0330/0.26

```

```

root@gry-ubuntu-1:/home/gry/Desktop# sysbench memory --memory-total-size=500g --threads=128 --memory-access-mode=rnd --memory-block-size=250m --memory-hugetlb=off run
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 128
Initializing random number generator from current time

Running memory speed test with the following options:
block size: 262144KiB
total size: 512000MiB
operation: write
scope: global

Initializing worker threads...

Threads started!

Total operations: 128 ( 1.72 per second)

32768.00 MiB transferred (441.03 MiB/sec)

General statistics:
total time: 74.2965s
total number of events: 128

Latency (ms):
min: 72697.98
avg: 73684.69
max: 74227.60
95th percentile: 73638.49
sum: 9421488.68

Threads fairness:
events (avg/stddev): 1.0000/0.00
execution time (avg/stddev): 73.6847/0.33

```