Linux Performance Tuning and Stabilization Tips

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- Synchronous I/O, Filesystem, and I/O scheduler
- Useful commands and tools
  - iostat, mpstat, oprofile, SystemTap, gdb

Random Access Memory

- The most important H/W component for RDBMS
- RAM access speed is much faster than HDD/SSD
  - RAM: -60ns
    - 100,000 queries per second is not impossible
  - HDD: -5ms
  - SSD: 100-500us
- 16-64GB RAM is now pretty common

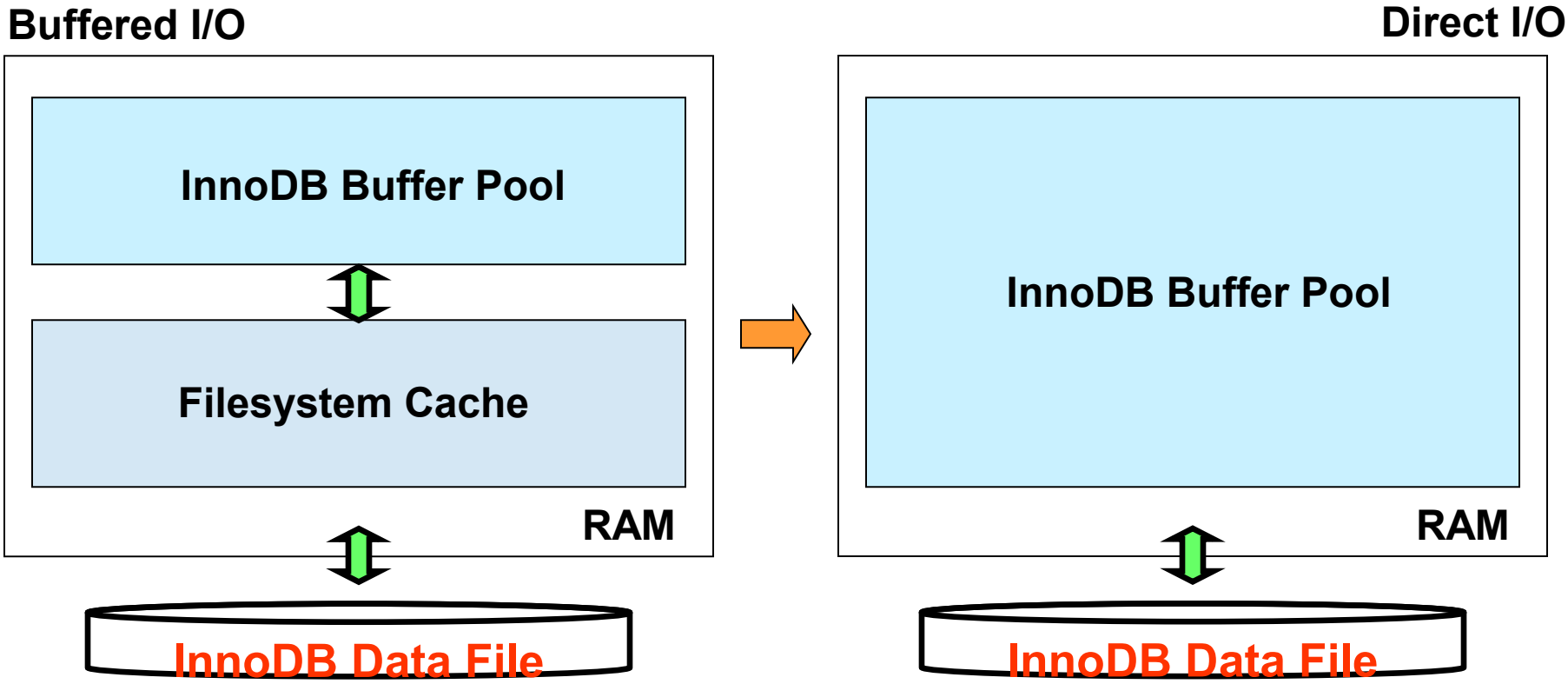
- *hot application data* should be cached in memory
- Minimizing hot application data size is important
  - Use compact data types (SMALLINT instead of VARCHAR/BIGINT, TIMESTAMP instead of DATETIME, etc)
  - Do not create unnecessary indexes
  - Delete records or move to archived tables, to keep hot tables smaller

Cache hot application data in memory

DBT-2 (W200)	Transactions per Minute	%user	%iowait
Buffer pool 1G	1125.44	2%	30%
Buffer pool 2G	1863.19	3%	28%
Buffer pool 5G	4385.18	5.5%	33%
Buffer pool 30G (All data in cache)	36784.76	36%	8%

- DBT-2 benchmark (write intensive)
- 20-25GB hot data (200 warehouses, running 1 hour)
- Nehalem 2.93GHz x 8 cores, MySQL 5.5.2, 4 RAID1+0 HDDs
- RAM size affects everything. Not only for SELECT, but also for INSERT/UPDATE/DELETE
  - INSERT: Random reads/writes happen when inserting into indexes in random order
  - UPDATE/DELETE: Random reads/writes happen when modifying records

Use Direct I/O



- Direct I/O is important to fully utilize Memory
- innodb_flush_method=O_DIRECT
- Alignment: File i/o unit must be a factor of 512 bytes
  - Can't use O_DIRECT for InnoDB Log File, Binary Log File, MyISAM, PostgreSQL data files, etc

Do not allocate too much memory

```
user$ top
Mem:  32967008k total, 32808696k used,   158312k free,    10240k buffers
Swap: 35650896k total,  4749460k used, 30901436k free,   819840k cached
  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
 5231 mysql     25   0 35.0g  30g  324 S  0.0 71.8   7:46.50 mysqld
```

- What happens if no free memory space is available?
  - Reducing filesystem cache to allocate memory space
  - Swapping process(es) to allocate memory space
- Swap is bad
  - Process spaces are written to disk (swap out)
  - Disk reads happen when accessing on-disk process spaces (swap in)
  - Massive random disk reads and writes will happen

What if setting swap size to zero?

- By setting swap size to zero, swap doesn't happen anymore. But..
  - Very dangerous
- When neither RAM nor swap space is available, OOM killer is invoked. OOM Killer may kill any process to allocate memory space
- The most memory-consuming process (mysqld) will be killed at first
  - It's abort shutdown. Crash recovery takes place on restart
  - Priority is determined by ORDER BY /proc/<PID>/oom_score DESC
  - Normally mysqld has the highest score
    - Depending on VMsize, CPU time, running time, etc
- It often takes very long time (minutes to hours) for OOM Killer to kill processes
  - We can't do anything until enough memory space is available

Do not set swap=zero

```
top - 01:01:29 up  5:53,  3 users,  load average: 0.66, 0.17, 0.06
Tasks: 170 total,   3 running, 167 sleeping,   0 stopped,   0 zombie
Cpu(s):  0.0%us, 24.9%sy,  0.0%ni,75.0%id,0.2%wa,0.0%hi,  0.0%si,0.0%st
Mem:  32967008k total, 32815800k used,   151208k free,     8448k buffers
Swap:        0k total,        0k used,        0k free,   376880k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
26988 mysql     25   0   30g  30g 1452 R 98.5 97.7   0:42.18 mysqld
```

- If no memory space is available, OOM killer will be invoked
- Some CPU cores consume 100% system resources
  - 24.9% (average) = 1 / 4 core use 100% cpu resource in this case
  - Terminal freezed (SSH connections can't be established)
- Swap is bad, but OOM killer is much worse than swap

What if stopping OOM Killer?

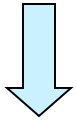
- If /proc/<PID>/oom_adj is set to -17, OOM Killer won't kill the process
  - Setting -17 to sshd is a good practice so that we can continue remote login
  - # echo -17 > /proc/<pid of sshd>/oom_adj
- But don't set -17 to mysqld
  - If over-memory-consuming process is not killed, Linux can't have any available memory space
  - We can't do anything for a long long time.. -> Long downtime

Swap space management

- Swap space is needed to stabilize systems
  - But we don't want mysqld swapped out
- What consumes memory?
  - RDBMS
    - Mainly process space is used (innodb_buffer_pool, key_buffer, sort_buffer, etc)
    - Sometimes filesystem cache is used (MyISAM files, etc)
  - Administration (backup, etc)
    - Mainly filesystem cache is used
- We want to keep mysqld in RAM, rather than allocating large filesystem cache

Be careful about backup operations

```
Mem:  32967008k total, 28947472k used,  4019536k free,   152520k buffers
Swap: 35650896k total,        0k used, 35650896k free,   197824k cached
PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
 5231 mysql     25   0 27.0g  27g  288 S  0.0 92.6   7:40.88 mysqld
```



Copying 8GB datafile

```
Mem:  32967008k total, 32808696k used,   158312k free,    10240k buffers
Swap: 35650896k total,  4749460k used, 30901436k free,  8819840k cached
 PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
 5231 mysql     25   0 27.0g  22g  324 S  0.0 71.8   7:46.50 mysqld
```

- Copying large files often causes swap

vm.swappiness = 0

```
Mem:  32967008k total, 28947472k used,  4019536k free,   152520k buffers
Swap: 35650896k total,        0k used, 35650896k free,   197824k cached
PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
 5231 mysql     25   0 27.0g  27g  288 S  0.0 91.3   7:55.88 mysqld
```

Copying 8GB of datafile

```
Mem:  32967008k total, 32783668k used,   183340k free,     3940k buffers
Swap: 35650896k total,      216k used, 35650680k free,  4117432k cached
PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
 5231 mysql     25   0 27.0g  27g  288 S  0.0 80.6   8:01.44 mysqld
```

- Set vm.swappiness=0 in /etc/sysctl.conf
  - Default is 60
- When physical RAM was fully consumed, Linux kernel reduces filesystem cache with high priority (lower swappiness increases priority)
- After no file system cache is available, swapping starts
  - OOM killer won't be invoked if large enough swap space is allocated. It's safer

Memory allocator

- mysqld uses malloc()/mmap() for memory allocation
- Faster and more concurrent memory allocator such as tcmalloc can be used
  - Install Google Perftools (tcmalloc is included)
    - # yum install libunwind
    - # cd google-perftools-1.5 ; ./configure --enable-frame-pointers; make; make install
  - export LD_PRELOAD=/usr/local/lib/tcmalloc_minimal.so; mysqld_safe &
- InnoDB internally uses its own memory allocator
  - Can be changed in InnoDB Plugin
    - If Innodb_use_sys_malloc = 1(default 1), InnoDB uses OS memory allocator
    - tcmalloc can be used by setting LD_PRELOAD

Memory allocator would matter for CPU bound workloads

	Default allocator	tcmalloc_minimal	%user	up
Buffer pool 1G	1125.44	1131.04	2%	+0.50%
Buffer pool 2G	1863.19	1881.47	3%	+0.98%
Buffer pool 5G	4385.18	4460.50	5.5%	+1.2%
Buffer pool 30G	36784.76	38400.30	36%	+4.4%

- DBT-2 benchmark (write intensive)
- Nehalem 2.93GHz x 8 cores, MySQL 5.5.2
- 20-25GB hot data (200 warehouses, running 1 hour)

Be careful about per-session memory

- Do not allocate much more memory than needed (especially for per-session memory)
- Allocating 2MB takes much longer time than allocating 128KB
  - Linux malloc() internally calls brk() if size <= 512KB, else calling mmap()
- In some cases too high per-session memory allocation causes negative performance impacts
  - SELECT * FROM huge_myisam_table LIMIT 1;
  - SET read_buffer_size = 256*1024; (256KB)
    - -> 0.68 second to run 10,000 times
  - SET read_buffer_size = 2048*1024; (2MB)
    - -> 18.81 seconds to run 10,000 times
- In many cases MySQL does not allocate per-session memory than needed. But be careful about some extreme cases (like above: MyISAM+LIMIT+FullScan)

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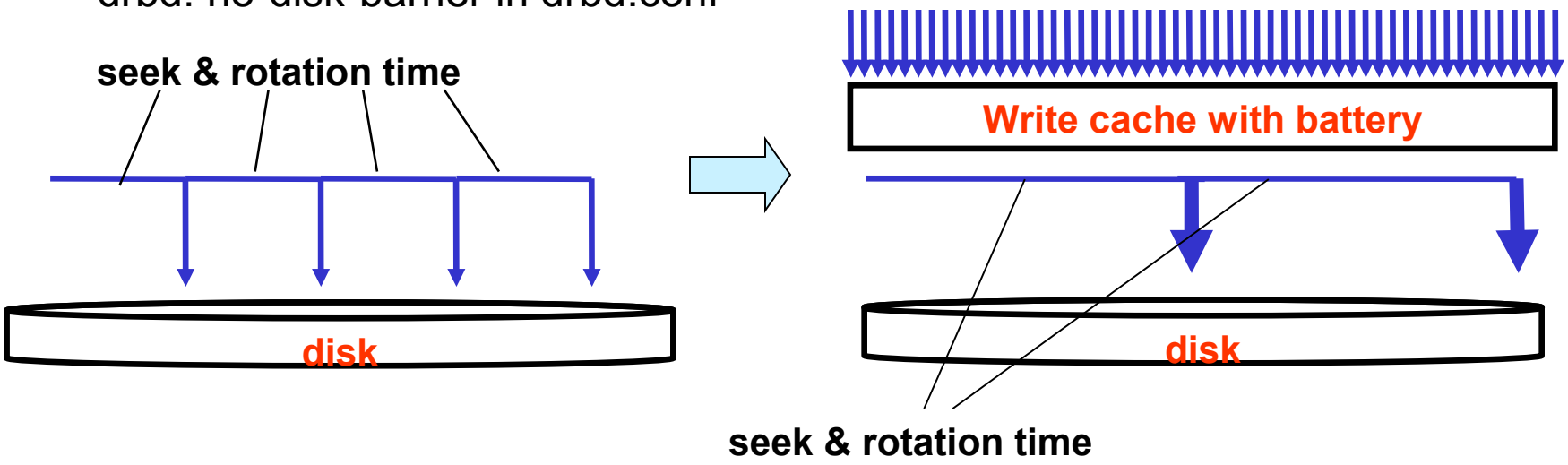
File I/O and synchronous writes

- RDBMS calls fsync() many times (per transaction commit, checkpoints, etc)
- Make sure to use Battery Backed up Write Cache (BBWC) on raid cards
  - 10,000+ fsync() per second, without BBWC less than 200 on HDD
  - Disable write cache on disks for safety reasons
- Do not set “write barrier” on filesystems (enabled by default in some cases)
  - Write-through to disks even though BBWC is enabled (very slow)
  - ext3: mount -o barrier=0
  - xfs: mount -o nobarrier
  - drbd: no-disk-barrier in drbd.conf



Overwriting or Appending?

- Some files are overwritten (fixed file size), others are appended (increasing file size)
  - Overwritten: InnoDB Logfile
  - Appended: Binary Logfile

- Appending + fsync() is much slower than overwriting + fsync()
    - Additional file space needs to be allocated & file metadata needs to be flushed per fsync()
  - 10,000+ fsync/sec for overwriting, 3,000 or less fsync/sec for appending
    - Appending speed highly depends on filesystems
    - Copy-on-write filesystems such as Solaris ZFS is fast enough for appending (7,000+)
  - Be careful when using sync-binlog=1 for binary logs
    - Consider using ZFS
    - Check “preallocating binlog” worklog: WL#4925
  - Do not extend files too frequently
    - innodb-autoextend-increment = 20 (default 8)

Quick file i/o health check

- Checking BBWC is enabled, and write barrier is disabled
  - Overwriting + fsync() test
    - Run mysqlslap insert(InnoDB, single-threaded, innodb_flush_log_at_trx_commit=1), check qps is over 1,000

```
$ mysqlslap --concurrency=1 --iterations=1 --engine=innodb \
  --auto-generate-sql --auto-generate-sql-load-type=write \
  --number-of-queries=100000
```

Buffered and asynchronous writes

- Some file i/o operations are not direct i/o, not synchronous
  - file copy, MyISAM, mysqldump, innodb_flush_log_at_trx_commit=2, etc
- Dirty pages in filesystem cache needs to be flushed to disks in the end
  - pdflush takes care of it, maximum 8 threads
- When? -> highly depending on vm.dirty_background_ratio and vm.dirty_ratio
  - Flushing dirty pages starts in background after reaching dirty_background_ratio * RAM (Default is 10%, 10% of 64GB is 6.4GB)
  - Forced flush starts after reaching dirty_ratio * RAM (Default is 40%)
- Forced, and burst dirty page flushing is problematic
  - All buffered write operations become synchronous, which hugely increase latency
- Do flush dirty pages aggressively
  - Execute sync; while doing massive write operations
  - Reduce vm.dirty_background_ratio
  - Upgrade to 2.6.32 or higher
    - pdflush threads are allocated per device. Flushing to slow devices won't block other pdflush threads

Filesystem – ext3

- By far the most widely used filesystem
- But not always the best
- Deleting large files takes long time
  - Internally has to do a lot of random disk i/o (slow on HDD)
  - In MySQL, if it takes long time to DROP table, all client threads will be blocked to open/close tables (by LOCK_open mutex)
  - Be careful when using MyISAM, InnoDB with innodb_file_per_table, PBXT, etc
- Writing to a file is serialized
  - Serialized by “i-mutex”, allocated per i-node
  - Sometimes it is faster to allocate many files instead of single huge file
  - Less optimized for faster storage (like PCI-Express SSD)
- Use “dir_index” to speed up searching files
- Use barrier=0 to disable write-through

Filesystem – xfs/ext2

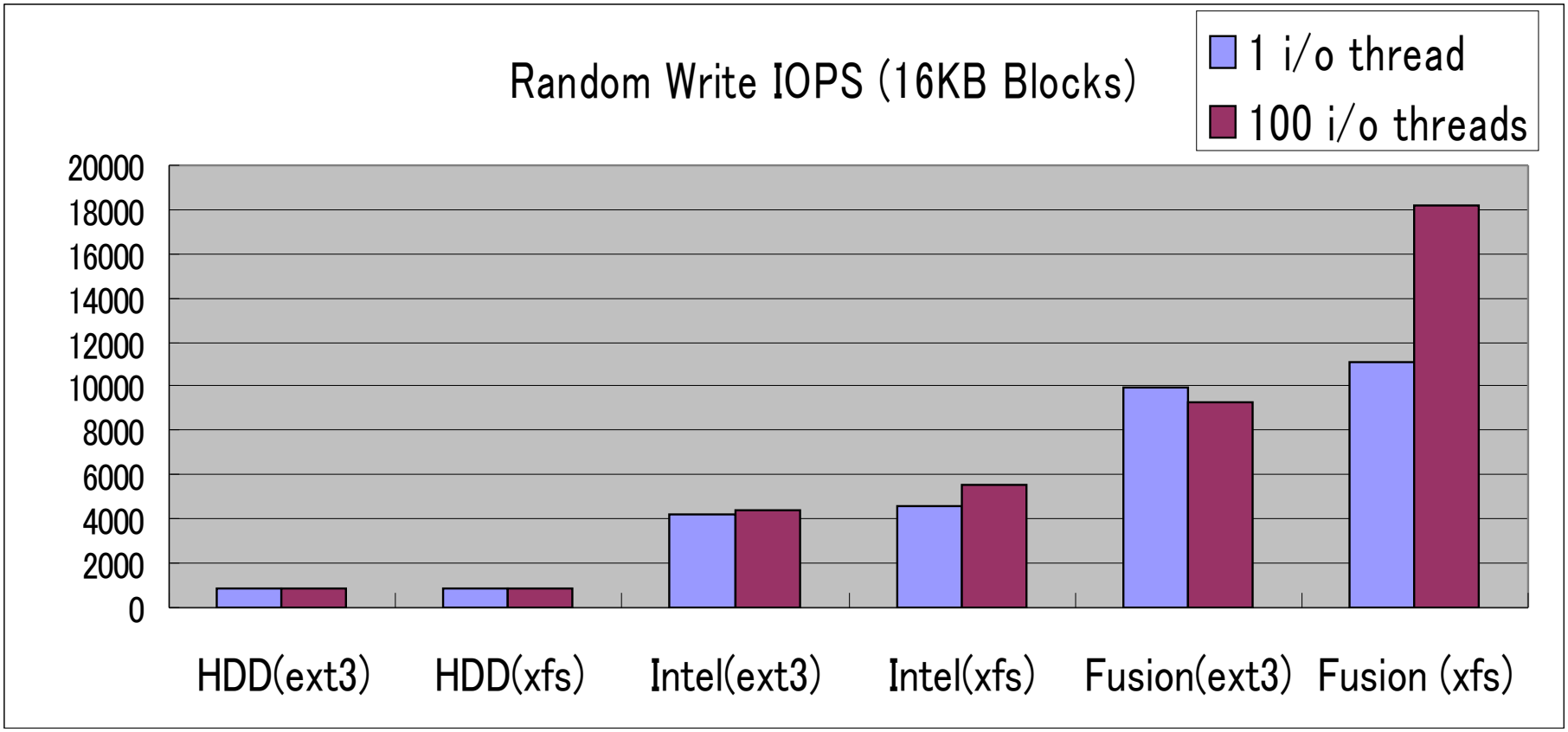
- xfs
  - Fast for dropping files
  - Concurrent writes to a file is possible when using O_DIRECT
  - Not officially supported in current RHEL (Supported in SuSE)
  - Disable write barrier by setting “nobarrier”

- ext2
  - Faster for writes because ext2 doesn’t support journaling
  - It takes very long time for fsck
  - On active-active redundancy environment (i.e. MySQL Replication),

    in some cases ext2 is used to gain performance

- Btrfs (under development)
  - Copy-on-write filesystem
  - Supporting transactions (no half-block updates)
  - Snapshot backup with no overhead

Concurrent write matters on fast storage



- Negligible on HDD (4 SAS RAID1)
- 1.8 times difference on Fusion I/O

I/O scheduler

- Note: RDBMS (especially InnoDB) also schedules I/O requests so theoretically Linux I/O scheduler is not needed

- Linux has I/O schedulers
  - to efficiently handle lots of I/O requests
  - “I/O scheduler type” and “Queue Size” matters

- Types of I/O schedulers (introduced in 2.6.10: RHEL5)
  - noop: Sorting incoming i/o requests by logical block address, that’s all
  - deadlilne: Prioritize read (sync) requests rather than write requests (async) to some extent (to avoid “write-starving-reads” problem)
  - cfq(default): Fairly scheduling i/o requests per i/o thread
  - anticipatory: Removed in 2.6.33 (bad scheduler. Don’t use it)

- Default is cfq, but noop / deadline is better in many cases
  - # echo noop > /sys/block/sdX/queue/scheduler

cfq madness

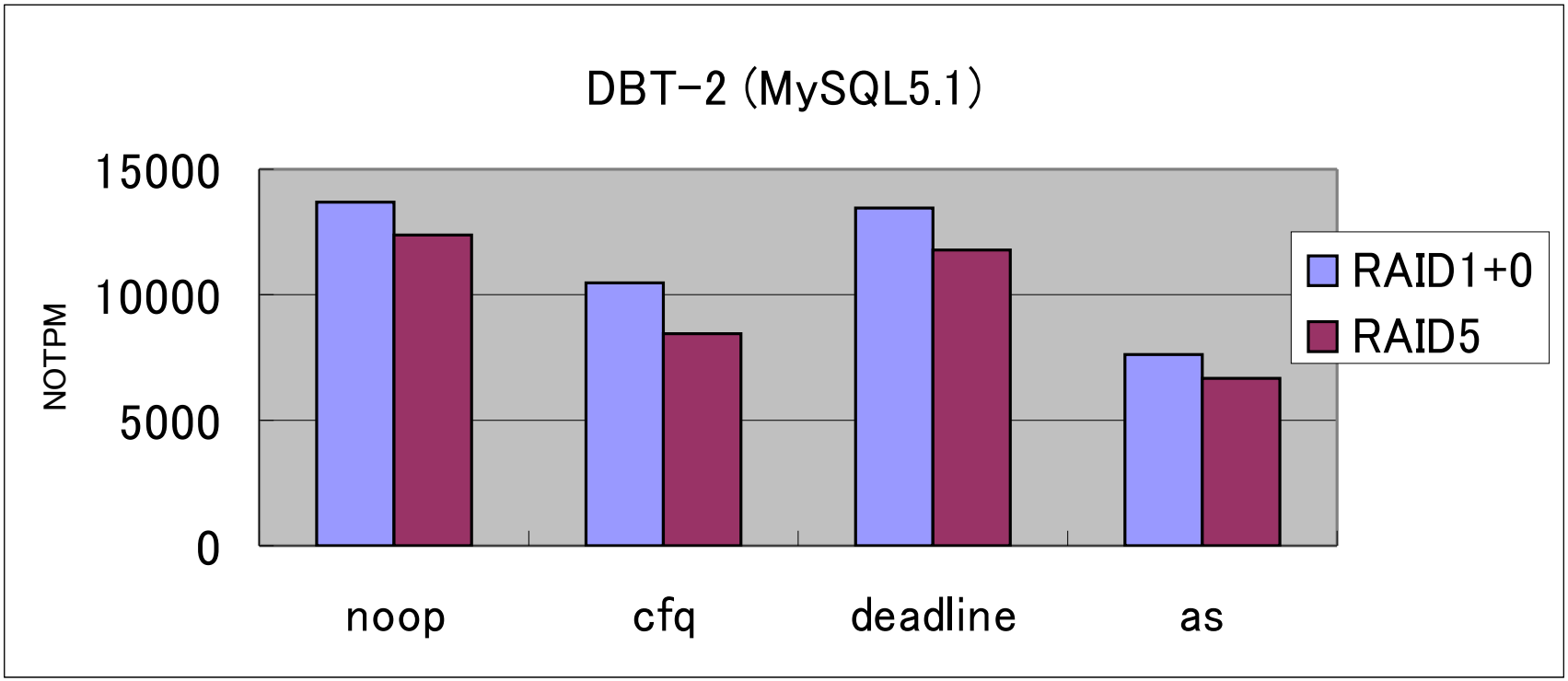
Running two benchmark programs concurrently

1. **Multi-threaded random disk reads (Simulating RDBMS reads)**
2. **Single-threaded overwriting + fsync() (Simulating redo log writes)**

Random Read i/o threads	write+fsync() running	Scheduler	reads/sec from iostat	writes/sec from iostat
1	No	noop/deadline	260	0
		cfq	260	0
100	No	noop/deadline	2100	0
		cfq	2100	0
1	Yes	noop/deadline	212	14480
		cfq	248	246
		noop/deadline	1915	12084
		cfq	2084	0

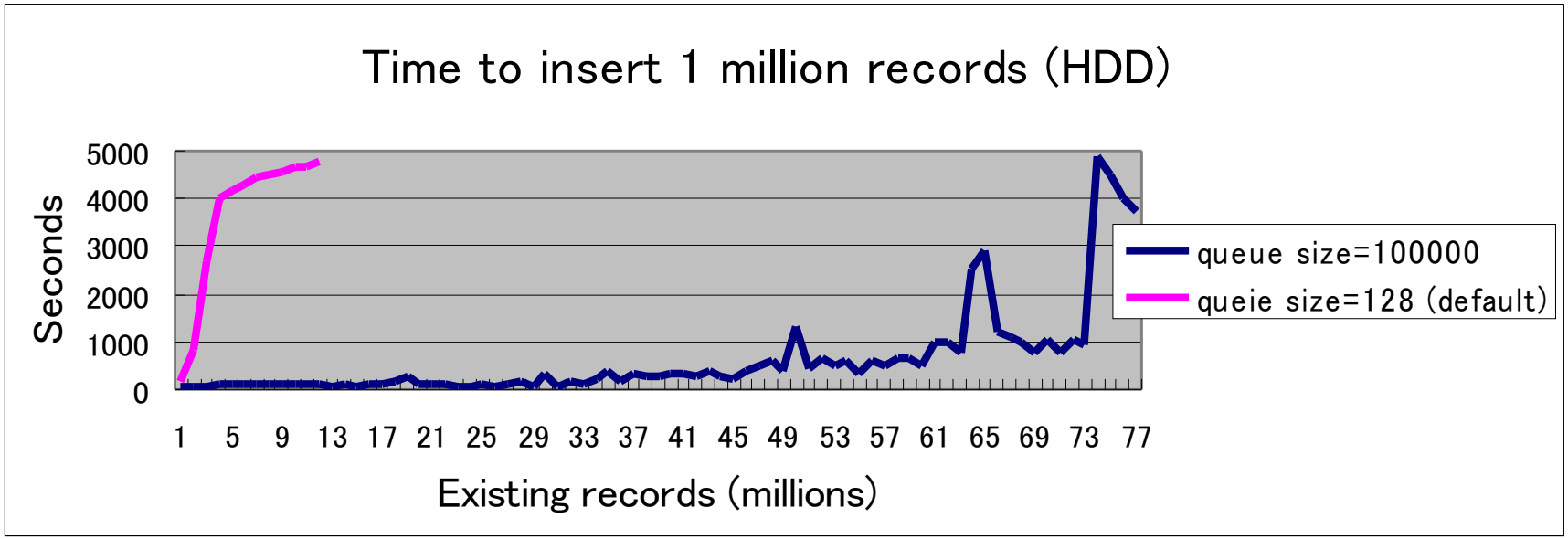
- In RDBMS, write IOPS is often very high because HDD + write cache can handle thousands of transaction commits per second (write+fsync)
- Write iops was adjusted to per-thread read iops in cfq, which reduced total iops significantly
- Verified on RHEL5.3 and SuSE 11, Sun Fire X4150, 4 HDD H/W RAID1+0

Changing I/O scheduler (InnoDB)



- Sun Fire X4150 (4 HDDs, H/W RAID controller+BBWC)
- RHEL5.3 (2.6.18-128)
- Built-in InnoDB 5.1

Changing I/O scheduler queue size (MyISAM)



- Queue size = N
  - Sorting N outstanding I/O requests to optimize disk seeks
- MyISAM does not optimize I/O requests internally
  - Highly depending on OS and storage
  - When inserting into indexes, massive random disk writes/reads happen
- Increasing I/O queue size reduces disk seek overheads
  - # echo 100000 > /sys/block/sdX/queue/nr_requests
- No impact in InnoDB
  - Many RDBMS including InnoDB internally sort I/O requests

Useful commands and tools

- iostat
- mpstat
- oprofile
- SystemTap (stap)
- gdb

iostat

- Detailed I/O statistics per device
- Very important tool because in most cases RDBMS becomes I/O bound
- iostat -x
- Check r/s, w/s, svctm, %util
  - IOPS is much more important than transfer size
- Always %util = (r/s + w/s) * svctm (hard coded in the iostat source file)

```
# iostat -xm 10
avg-cpu: %user %nice %system %iowait %steal %idle
         21.16  0.00    6.14   29.77   0.00 42.93
Device: rqm/s wrqm/s     r/s   w/s rMB/s wMB/s avgrq-sz avgqu-sz await svctm %util
   sdb   2.60 389.01  283.12 47.35  4.86  2.19    43.67      4.89 14.76  3.02 99.83
```

(283.12+47.35) * 3.02(ms)/1000 = 0.9980 = 100% util

iostat example (DBT-2)

```
# iostat -xm 10
avg-cpu: %user %nice %system %iowait %steal %idle
         21.16  0.00    6.14   29.77   0.00 42.93
Device: rqm/s wrqm/s    r/s    w/s rMB/s wMB/s avgrq-sz avgqu-sz await svctm %util
   sdb   2.60 389.01 283.12  47.35  4.86  2.19    43.67     4.89 14.76  3.02 99.83
```

(283.12+47.35) * 3.02(ms)/1000 = 0.9980 = 100% util

```
# iostat -xm 10
avg-cpu: %user %nice %system %iowait %steal %idle
         40.03  0.00   16.51   16.52   0.00 26.94
Device: rrqm/s wrqm/s    r/s    w/s rMB/s wMB/s avgrq-sz avgqu-sz await svctm %util
   sdb    6.39 368.53 543.06 490.41  6.71  3.90    21.02     3.29  3.20  0.90 92.66
```

(543.06+490.41) * 0.90(ms)/1000 = 0.9301 = 93% util

- Sometimes throughput gets higher even though %util reaches 100%
  - Write cache, Command Queuing, etc
- In both cases %util is almost 100%, but r/s and w/s are far different
- Do not trust %util too much
- Check svctm rather than %util
  - If your storage can handle 1000 IOPS, svctm should be less than 1.00 (ms) so you can send alerts if svctm is higher than 1.00 for a couple of minutes

mpstat

- Per CPU core statistics
- vmstat displays average statistics
- It's very commom that only one of CPU cores consumes 100% CPU resources
  - The rest CPU cores are idle
  - Especially applies to batch jobs
- If you check only vmstat/top/iostat/sar you will not notice single threaded bottleneck
- You can also check network bottlenecks (%irq, %soft) from mpstat
  - vmstat counts them as %idle

vmstat and mpstat

```
# vmstat 1
...
procs -----------memory---------- ---swap-- -----io---- --system-- -----cpu------
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 0  1 2096472 1645132  18648  19292    0    0  4848     0 1223  517  0  0 88 12  0
 0  1 2096472 1645132  18648  19292    0    0  4176     0 1287  623  0  0 87 12  0
 0  1 2096472 1645132  18648  19292    0    0  4320     0 1202  470  0  0 88 12  0
 0  1 2096472 1645132  18648  19292    0    0  3872     0 1289  627  0  0 87 12  0
```

```
# mpstat -P ALL 1
...
11:04:37 AM  CPU    %user   %nice    %sys %iowait    %irq   %soft  %steal  %idle   intr/s
11:04:38 AM  all    0.00    0.00    0.12   12.33    0.00    0.00    0.00   87.55 1201.98
11:04:38 AM    0    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00  990.10
11:04:38 AM    1    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00    0.00
11:04:38 AM    2    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00    0.00
11:04:38 AM    3    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00    0.00
11:04:38 AM    4    0.99    0.00    0.99   98.02    0.00    0.00    0.00    0.00  206.93
11:04:38 AM    5    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00    0.00
11:04:38 AM    6    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00    4.95
11:04:38 AM    7    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00    0.00
```

- vmstat displays average statistics. 12% * 8 (average) = 100% * 1 + 0% * 7

Oprofile

- Profiling CPU usage from running processes
- You can easily identify which functions consume CPU resources
- Supporting both user space and system space profiling
- Mainly used by database-internal developers
- If specific functions consume most of recourses, applications might be re-designed to skip calling them
- Not useful to check low-CPU activities
  - I/O bound, mutex waits, etc

- How to use
  - opcontrol --start (--no-vmlinux)
  - benchmarking
  - opcontrol --dump
  - opcontrol --shutdown
  - opreport -l /usr/local/bin/mysqld

Oprofile example

```
# opreport -l /usr/local/bin/mysqld
samples  %        symbol name
83003     8.8858  String::copy(char const*, unsigned int, charset_info_st*,
charset_info_st*, unsigned int*)
79125     8.4706  MYSQLparse(void*)
68253     7.3067  my_wc_mb_latin1
55410     5.9318  my_pthread_fastmutex_lock
34677     3.7123  my_utf8_uni
18359     1.9654  MYSQLlex(void*, void*)
12044     1.2894  _ZL15get_hash_symbolPKcjb
11425     1.2231
_ZL20make_join_statisticsP4JOINP10TABLE_LISTP4ItemP16st_dynamic_array
```

- You can see quite a lot of CPU resources were spent for character conversions (latin1 <-> utf8)
- Disabling character code conversions on application side will improve performance (20% in this case)

```
samples  %        symbol name
83107    10.6202  MYSQLparse(void*)
68680     8.7765  my_pthread_fastmutex_lock
20469     2.6157  MYSQLlex(void*, void*)
13083     1.6719  _ZL15get_hash_symbolPKcjb
12148     1.5524  JOIN::optimize()
11529     1.4733
_ZL20make_join_statisticsP4JOINP10TABLE_LISTP4ItemP16st_dynamic_array
```

SystemTap

- SystemTap provides a simple command line interface and scripting language for writing instrumentation for a live running kernel (and applications).

- Similar to DTrace
- SystemTap script runs as a Linux Kernel module
- No-need to rebuild applications to profile
  - kernel-header/devel, kernel-debuginfo packages are needed
- Supported in RHEL 5 by default (5.4 is more stable than older versions, but be careful about bug reports)

- User level functions can be profiled if a target program has DWARF debugging symbols
  - MySQL official binary has DWARF symbols, so you do not need to rebuild mysqld
  - Add -g if you build MySQL by yourselves

- You can write custom C code inside a SystemTap script, but it's limited
  - This is called "guru" mode
  - Easily causes kernel panic. Be extremely careful
  - Since it is kernel module, user-side libraries can not be used

SystemTap use-case 1 : Per-file i/o statistics

```
# filestat 10
2010-04-05 11:18:55
     iotime      r/s      w/s   rBytes/s   wBytes/s   file
      6.12s    182.4      1.6      2.85M      30.4K   /hdd/data/dbt2/stock.ibd
      2.36s     64.1      0.7      1.00M      11.2K   /hdd/data/dbt2/customer.ibd
      1.05s     25.7      6.1     411.2K     100.8K   /hdd/data/dbt2/orders.ibd
    826.6ms     15.1      0.5     241.6K       9.6K   /hdd/data/dbt2/order_line.ibd
    645.1ms     16.6      2.1     265.6K     107.2K   /hdd/data/dbt2/new_order.ibd

2010-04-05 11:19:05
     iotime      r/s      w/s   rBytes/s   wBytes/s   file
      4.76s    173.9      0.6      2.72M      12.8K   /hdd/data/dbt2/stock.ibd
      2.22s     68.1      2.3      1.06M      36.8K   /hdd/data/dbt2/customer.ibd
      1.23s     18.4      1.2     294.4K      25.6K   /hdd/data/dbt2/order_line.ibd
    919.6ms     14.3     11.0     228.8K     521.6K   /hdd/data/dbt2/new_order.ibd
...
```

- iostat provides per-device i/o statistics, iotop provides per-process i/o statistics
  - Not enough for mysqld

Sample Code

```
probe syscall.read, syscall.pread {
 if (execname() == “mysqld”) {
  readstats[pid(), fd] <<< count
  fdlist[pid(), fd] = fd
 }
}
probe timer.s($1) {
 foreach ([pid+, fd] in fdlist) {
  reads=@count(readstats[pid, fd])
  rbytes=@sum(rdbs[pid, fd])
  print  “%d %d %d\n”, fd, reads, rbytes
...
```

```
#!/bin/sh
stap  filestat.stap 10 | perl sum.pl
```

- Programming within SystemTap is possible, but difficult
  - Most of utility libraries can not be used
  - limited to 1000 statements per probe
- Typical coding style:
  - Print raw statistical information (i.e. file descriptor, iotime, reads, writes, bytes-read, bytes-written, etc) to STDOUT
  - Pipe to Perl script (or python/ruby/etc)
  - Filtering/Grouping/Sorting/Decorating etc in Perl

SystemTap use-case 2 : Userspace profiling

```
mysql> EXPLAIN SELECT user_id, post_date, title
    -> FROM diary ORDER BY rating DESC limit 100\G
*********
 select_type: SIMPLE
 table:       diary
 type:        ALL
 key:         NULL
 rows:        1163
 Extra:       Using filesort

mysql> SELECT user_id, post_date, title
    -> FROM diary ORDER BY rating DESC limit 100;
...
100 rows in set (0.73 sec)
```

```
[root #] stap sort.stp
# of returned rows sorted by old algorithm: 0
# of returned rows sorted by new algorithm: 100
```

Background: MySQL Sorting Algorithm

- MySQL has two sorting algorithms (old algorithm / new algorithm)
- Choosing either of the two, depending on column length, data types, etc..
- Currently there is no MySQL status variable to check which algorithm is used
- Sometimes performance difference is huge (especially when used with LIMIT)
- Inside MySQL, rr_from_pointers() is called by old algorithm, rr_unpack_from_buffer() by new algorithm

Old algorithm

1) Load into sort buffer

rating	RowID
4.71	1
3.32	2
4.10	3
4.50	4

2) Sort

rating	RowID
4.71	1
4.50	4
4.10	3
3.32	3

3) Fetch the rest columns

user_id	post_date	rating	title
100	2010-03-29	4.71	UEFA CL: Inter vs Chelsea
2	2010-03-30	3.32	Denmark vs Japan, 3-0
3	2010-03-31	4.10	MySQL Administration
10	2010-04-01	4.50	Linux tuning

New algorithm

1) Load all columns into sort buffer

user_id	post_date	rating	title
100	2009-03-29	4.71	UEFA CL: Inter vs Chelsea
2	2009-03-30	3.32	Denmark vs Japan, 3-0
3	2009-03-31	4.10	MySQL Administration
10	2009-04-01	4.50	Linux tuning

2) Sort

SystemTap Script 2

```
global oldsort=0;
global newsort=0;

probe process("/usr/local/bin/mysqld").function("*rr_from_pointers*").return
{
  oldsort++;
}

probe
process("/usr/local/bin/mysqld").function("*rr_unpack_from_buffer*").return
{
  newsort++;
}

probe end
{
  printf("# of returned rows sorted by old algorithm: %d \n", oldsort);
  printf("# of returned rows sorted by new algorithm: %d \n", newsort);
}
-----
[root #] stap sort.stp
# of returned rows sorted by old algorithm: 0
# of returned rows sorted by new algorithm: 100
```

gdb

- Debugging tool
- gdb has a functionality to take thread stack dumps from a running process (similar to Solaris “truss”)
- Useful to identify where and why mysqld hangs up, slows down, etc
  - But you have to read MySQL source code
- Debugging symbol is required on the target program

gdb case study

```
mysql> SELECT query_time, start_time, sql_text
    -> FROM mysql.slow_log WHERE start_time
    -> BETWEEN '2010-02-05 23:00:00' AND '2010-02-05 01:00:00'

    -> ORDER BY query_time DESC LIMIT 10;
+------------+---------------------+----------+
| query_time | start_time          | sql_text |
+------------+---------------------+----------+
| 00:00:11   | 2010-02-05 23:09:55 | begin    |
| 00:00:09   | 2010-02-05 23:09:55 | Prepare  |
| 00:00:08   | 2010-02-05 23:09:55 | Prepare  |
| 00:00:08   | 2010-02-05 23:09:55 | Init DB  |
| 00:00:08   | 2010-02-05 23:09:55 | Init DB  |
| 00:00:07   | 2010-02-05 23:09:55 | Prepare  |
| 00:00:07   | 2010-02-05 23:09:55 | Init DB  |
| 00:00:07   | 2010-02-05 23:09:55 | Init DB  |
| 00:00:07   | 2010-02-05 23:09:55 | Init DB  |
| 00:00:06   | 2010-02-05 23:09:55 | Prepare  |
+------------+---------------------+----------+
10 rows in set (0.02 sec)
```

- **Suddenly all queries were not responding for 1-10 seconds**
- **Checking slow query log**
- **All queries are simple enough, it's strange to take 10 seconds**
- **CPU util (%us, %sy) were almost zero**
- **SHOW GLOBAL STATUS, SHOW FULL PROCESSLIST were not helpful**

Taking thread dumps with gdb

```
gdbtrace() {
…
  PID=`cat /var/lib/mysql/mysql.pid`
  STACKDUMP=/tmp/stackdump.$$
  echo 'thread apply all bt' >
$STACKDUMP
  echo 'detach' >> $STACKDUMP
  echo 'quit' >> $STACKDUMP
  gdb --batch --pid=$PID -x $STACKDUMP
}

while loop
do
  CONN=`netstat -an | grep 3306 | grep
ESTABLISHED | wc | awk '{print $1}'`
  if [ $CONN -gt 100 ]; then
    gdbtrace()
  done
  sleep 3
done
```

- Attaching running mysqld, then taking a thread dump
- Taking dumps every 3 seconds
- Attaching & Dumping with gdb is expensive so invoke only when exceptional scenario (i.e. conn > threshold) happens

- Check if the same LWPs are waiting at the same place

Stack Trace

```
.....
Thread 73 (Thread 0x46c1d950 (LWP 28494)):
#0  0x00007ffda5474384 in __lll_lock_wait () from /lib/libpthread.so.0
#1  0x00007ffda546fc5c in _L_lock_1054 () from /lib/libpthread.so.0
#2  0x00007ffda546fb30 in pthread_mutex_lock () from
/lib/libpthread.so.0
#3  0x0000000000a0f67d in my_pthread_fastmutex_lock (mp=0xf46d30) at
thr_mutex.c:487
#4  0x000000000060cbe4 in dispatch_command (command=16018736, thd=0x80,
    packet=0x65 <Address 0x65 out of bounds>, packet_length=4294967295)
    at sql_parse.cc:969
#5  0x000000000060cb56 in do_command (thd=0xf46d30) at sql_parse.cc:854
#6  0x0000000000607f0c in handle_one_connection (arg=0xf46d30) at
sql_connect.cc:1127
#7  0x00007ffda546dfc7 in start_thread () from /lib/libpthread.so.0
#8  0x00007ffda46305ad in clone () from /lib/libc.so.6
#9  0x0000000000000000 in ?? ()
```

- Many threads were waiting at pthread_mutex_lock(), called from sql_parse.cc:969

Reading sql_parse.cc:969

```
953  bool dispatch_command(enum enum_server_command command, THD *thd,
954                        char* packet, uint packet_length)
955  {
956    NET *net= &thd->net;
957    bool error= 0;
958    DBUG_ENTER("dispatch_command");
959    DBUG_PRINT("info",("packet: '%*.s'; command: %d", packet_length,
packet, command));
960
961    thd->command=command;
962    /*
963      Commands which always take a long time are logged into
964      the slow log only if opt_log_slow_admin_statements is set.
965    */
966    thd->enable_slow_log= TRUE;
967    thd->lex->sql_command= SQLCOM_END; /* to avoid confusing VIEW
detectors */
968    thd->set_time();
969    VOID(pthread_mutex_lock(&LOCK_thread_count));
```

Who locked LOCK_thread_count for seconds?

```
Thread 1 (Thread 0x7ffda58936e0 (LWP 15380)):
#0  0x00007ffda4630571 in clone () from /lib/libc.so.6
#1  0x00007ffda546d396 in do_clone () from /lib/libpthread.so.0
#2  0x00007ffda546db48 in pthread_create@@GLIBC_2.2.5 () from
/lib/libpthread.so.0
#3  0x0000000000600a66 in create_thread_to_handle_connection (thd=0x3d0f00)
    at mysqld.cc:4811
#4  0x00000000005ff65a in handle_connections_sockets (arg=0x3d0f00) at
mysqld.cc:5134
#5  0x00000000005fe6fd in main (argc=4001536, argv=0x4578c260) at
mysqld.cc:4471
#0  0x00007ffda4630571 in clone () from /lib/libc.so.6
```

- gdb stack dumps were taken every 3 seconds
- In all cases, Thread 1 (LWP 15380) was stopped at the same point
- clone() (called by pthread_create()) seemed to take a long time

Reading mysqld.cc:4811

```
4795 void create_thread_to_handle_connection(THD *thd)
4796 {
4797   if (cached_thread_count > wake_thread)
4798   {
4799     /* Get thread from cache */
4800     thread_cache.append(thd);
4801     wake_thread++;
4802     pthread_cond_signal(&COND_thread_cache);
4803   }
4804   else
4805   {
4811     if ((error=pthread_create(&thd->real_id,&connection_attrib,
4812                               handle_one_connection,
4813                               (void*) thd)))
4839   }
4840   (void) pthread_mutex_unlock(&LOCK_thread_count);
```

- pthread_create is called under critical section (LOCK_thread_count is released after that)
- If cached_thread_count > wake_thread, pthread_create is not called
- Increasing thread_cache_size will fix the problem!

Configuration Summary

- Install at least sar, mpstat, iostat (sysstat package)
  - Oprofile, gdb and SystemTap(stap) are recommended
- Allocate swap space (approx half of RAM size)
- Set vm.swappiness = 0 and use O_DIRECT
- Set /sys/block/sdX/queue/scheduler = deadline or noop
- Filesystem Tuning
  - relatime (noatime)
  - ext3: tune2fs –O dir_index -c –l –i 0
  - xfs: nobarrier
  - Make sure write cache with battery is enabled
- Others
  - Make sure to allocate separate database partitions (/var/lib/mysql, /tmp) from root partition (/)
    - When database size becomes full, it should not affect Linux kernels
  - /etc/security/limits.conf
    - soft nofile 8192
    - hard nofile 8192
  - Restart linux if kernel panic happens
    - kernel.panic_on_oops = 1
    - kernel.panic = 1

Enjoy the conference!

- The slides will be published at Slideshare very soon
- My talks on Wed/Thu
  - More Mastering the Art of Indexing
    - April 14th (Wed), 14:00-15:00, Ballroom A
  - SSD Deployment Strategies for MySQL
    - April 15th (Thu), 14:00-14:45, Ballroom E
- Contact:
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