MySQL Performance Tuning

A practical guide

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Introduction

- Who we are?
- What we want?

Table of Contents

- Find the problem
- MySQL architecture
- Database settings
- Detect and eliminate slow queries
- Table tuning
- Application tuning
- Alternatives
- Prevention
- Dirty tricks and other stuff
- Now it's up to you...

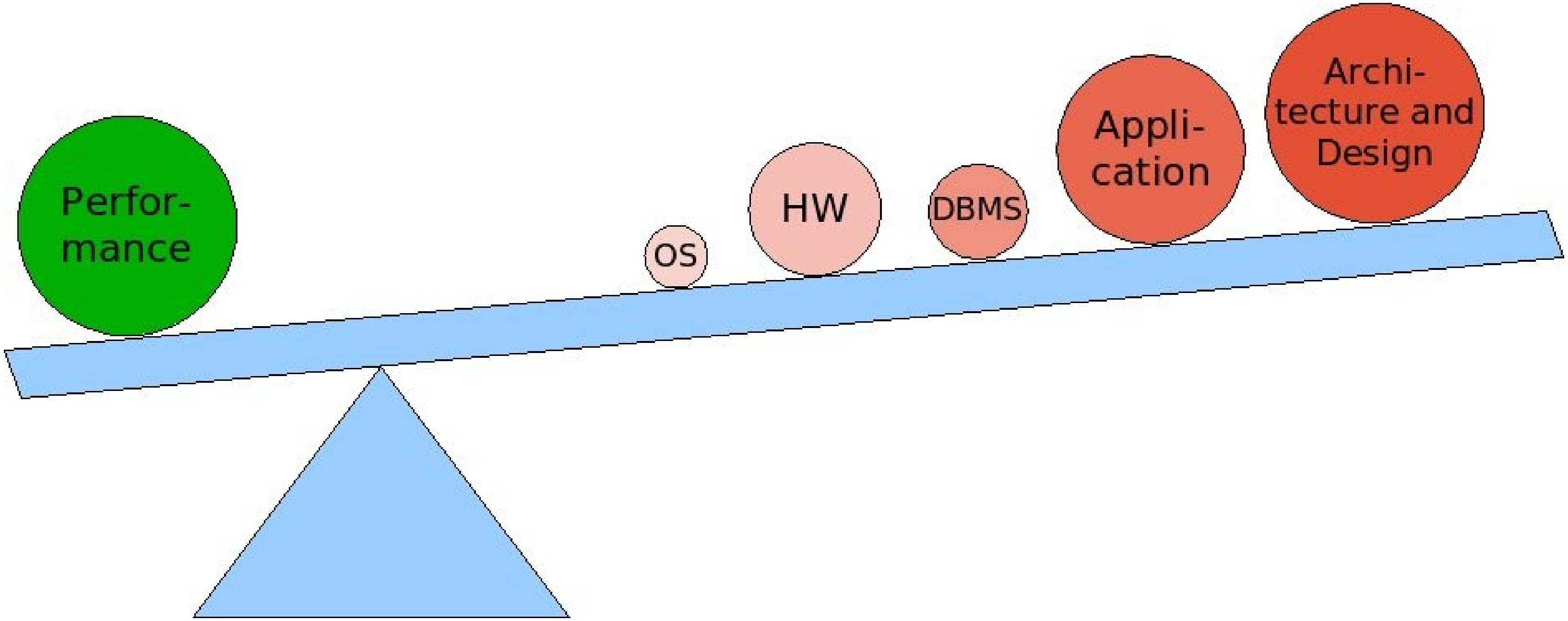
DBA: We have a problem!

- What does performance mean to you?

- How does it look like?
  - DB is (suddenly!?) slow.
  - No historical data (or not the one we need).
  - “Screw something on the DB!”
  - We are short before going life and much too slow!!!

- We have a problem. And what now?

Efficiency of tuning measurements



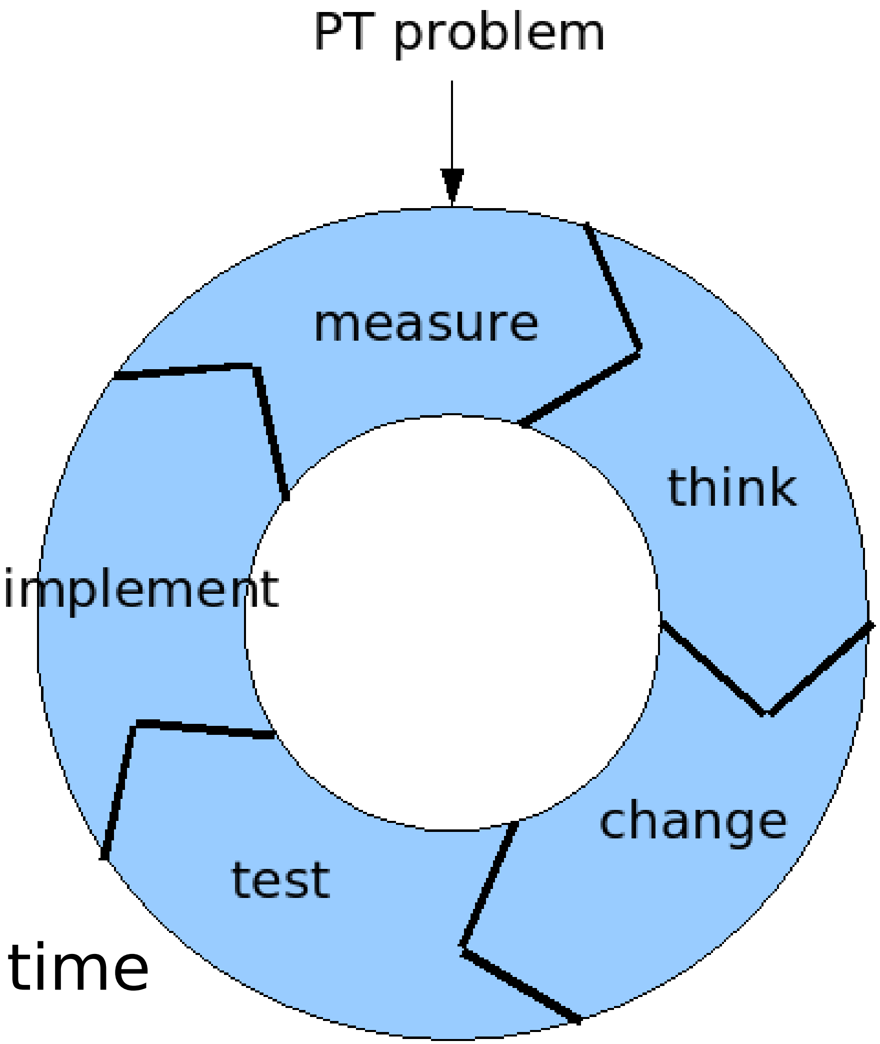
- Application/Architecture/Design
  - ➳ No way! For what ever reason :-(
- So on the DBA side: Memory, DB settings, I/O, Indexes, etc.

Find the problem / the bottleneck

- No history data!?! :-(
- Best if:
  - you can simulate it
  - it happens predictable and/or periodically
- Your friends are:
  - vmstat / dstat
  - iostat
  - top
  - any graphical history of values

Tuning means ...

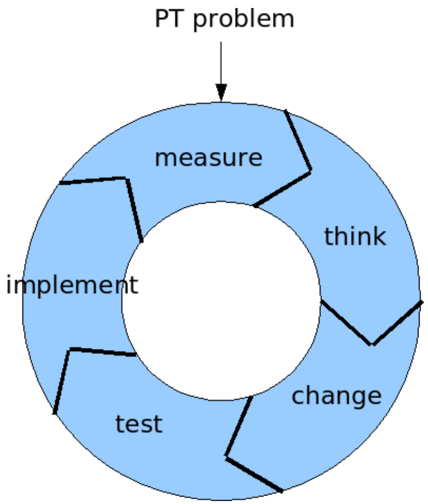
- The tuning life cycle:



- Only one change at a time

Measure

- Find the bottleneck / limiting resource:
  - – I/O
  - – Memory
  - – CPU
  - – Network bandwidth
- But how?



Measure I/O

- vmstat

```
# vmstat 1
procs ---swap-- -----io---- ----cpu----
 r  b   si   so    bi    bo us sy id wa
 0  0    3    3    94   143 21 21 56  2
 0  0    0    0     0     4  9 37 54  0
```

- iostat (--> sysstat package)

```
# iostat -x 1
avg-cpu:  %user   %nice %system %iowait  %steal   %idle
           5.88    0.00   34.31    2.94    0.00   56.86

Device:      r/s   w/s  rkB/s  wkB/s  await  svctm  %util
hda         0.00  0.00   0.00   0.00   0.00   0.00   0.00
hdc         0.00  2.94   0.00  23.53  14.67  12.00   3.53
```

Measure memory

- ps

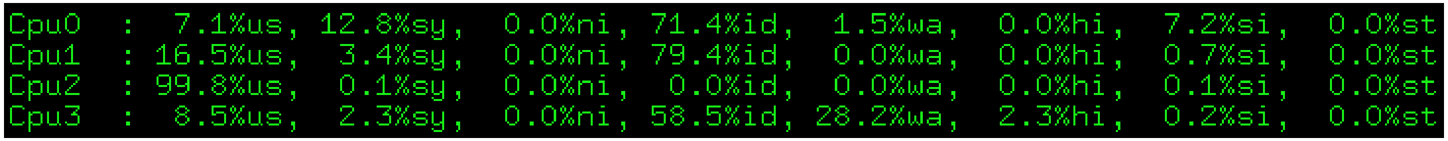
```
# ps -eo user,pid,%cpu,%mem,vsz,rsz,comm --sort -vsz | \
 egrep 'mysql|COMMAND'
USER        PID %CPU %MEM    VSZ   RSZ COMMAND
mysql      1361  0.0  1.5 108368 16444 mysqld
mysql      1210  0.0  0.1   4536  1956 bash
mysql      1289  0.0  0.1   4060  1444 safe_mysqld
mysql      1204  0.0  0.1   4048  1404 su
```

- free / top:

```
#free
             total    used     free  shared buffers  cached
Mem:       1036016  983864    52152       0   35484  547432
-/+ buffers/cache:  400948   635068
swap:      4202112   96148  4105964
```

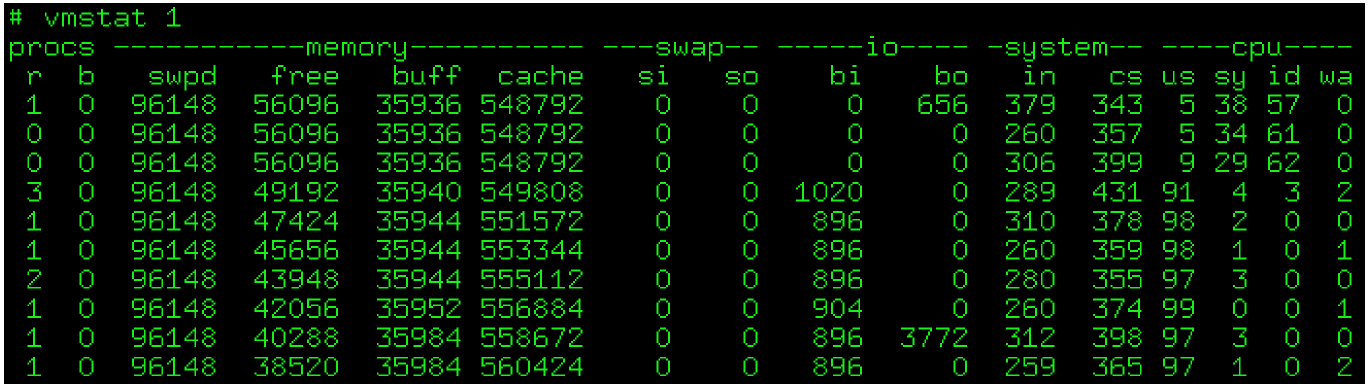
Measure CPU

- top



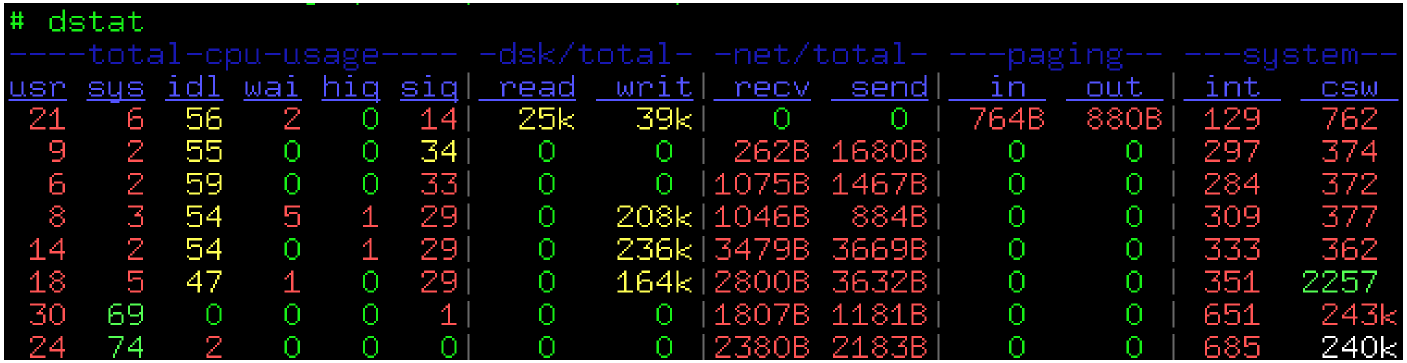
```
Cpu0  :  7.1%us, 12.8%sy,  0.0%ni, 71.4%id,  1.5%wa,  0.0%hi,  7.2%si,  0.0%st
Cpu1  : 16.5%us,  3.4%sy,  0.0%ni, 79.4%id,  0.0%wa,  0.0%hi,  0.7%si,  0.0%st
Cpu2  : 99.8%us,  0.1%sy,  0.0%ni,  0.0%id,  0.0%wa,  0.0%hi,  0.1%si,  0.0%st
Cpu3  :  8.5%us,  2.3%sy,  0.0%ni, 58.5%id, 28.2%wa,  2.3%hi,  0.2%si,  0.0%st
```

- vmstat



```
# vmstat 1
procs -----------memory---------- ---swap-- -----io---- -system-- ----cpu----
 r  b   swpd   free   buff  cache   si   so    bi    bo   in    cs us sy id wa
 1  0  96148  56096  35936 548792    0    0     0   656  379   343  5 38 57  0
 0  0  96148  56096  35936 548792    0    0     0     0  260   357  5 34 61  0
 0  0  96148  56096  35936 548792    0    0     0     0  306   399  9 29 62  0
 3  0  96148  49192  35940 549808    0    0  1020     0  289   431 91  4  3  2
 1  0  96148  47424  35944 551572    0    0   896     0  310   378 98  2  0  0
 1  0  96148  45656  35944 553344    0    0   896     0  260   359 98  1  0  1
 2  0  96148  43948  35944 555112    0    0   896     0  280   355 97  3  0  0
 1  0  96148  42056  35952 556884    0    0   904     0  260   374 99  0  0  1
 1  0  96148  40288  35984 558672    0    0   896  3772  312   398 97  3  0  0
 1  0  96148  38520  35984 560424    0    0   896     0  259   365 97  1  0  2
```

- dstat



```
# dstat
----total-cpu-usage---- -dsk/total- -net/total- ---paging-- ---system--
usr sys idl wai hiq siq| read  writ| recv  send|  in   out | int   csw
 21   6  56   2   0  14|  25k   39k|   0     0 | 764B  880B| 129   762
  9   2  55   0   0  34|   0     0 | 262B 1680B|   0     0 | 297   374
  6   2  59   0   0  33|   0     0 |1075B 1467B|   0     0 | 284   372
  8   3  54   5   1  29|   0   208k|1046B  884B|   0     0 | 309   377
 14   2  54   0   1  29|   0   236k|3479B 3669B|   0     0 | 333   362
 18   5  47   1   0  29|   0   164k|2800B 3632B|   0     0 | 351  2257
 30  69   0   0   0   1|   0     0 |1807B 1181B|   0     0 | 651   243k
 24  74   2   0   0   0|   0     0 |2380B 2183B|   0     0 | 685   240k
```

Measure network bandwidth

- dstat

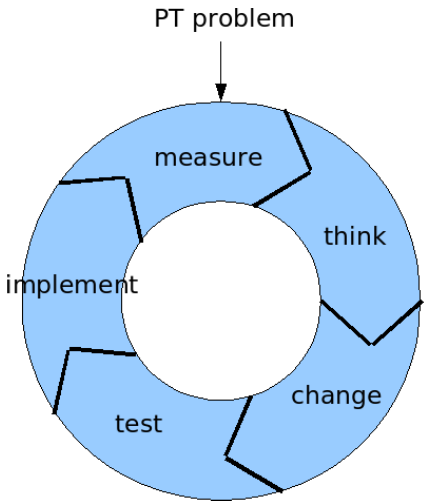
```
# dstat
----total-cpu-usage---- -dsk/total- -net/total-
usr sys idl wai hiq siq| read  writ| recv  send
 21   5  56   2   0  15|  25k   39k|   0     0
 13   3  84   0   0   0|   0     0 | 994B  437B
  8   4  88   0   0   0|   0     0 | 632B  484B
```

- ifconfig

```
# watch -n 1 -d "/sbin/ifconfig | egrep 'Link|bytes'"
eth0      Link encap:Ethernet  HWaddr 00:30:1B:2D:67:B4
          RX bytes:1751779749 (1670.6 Mb)
          TX bytes:191340381 (182.4 Mb)
```

Think

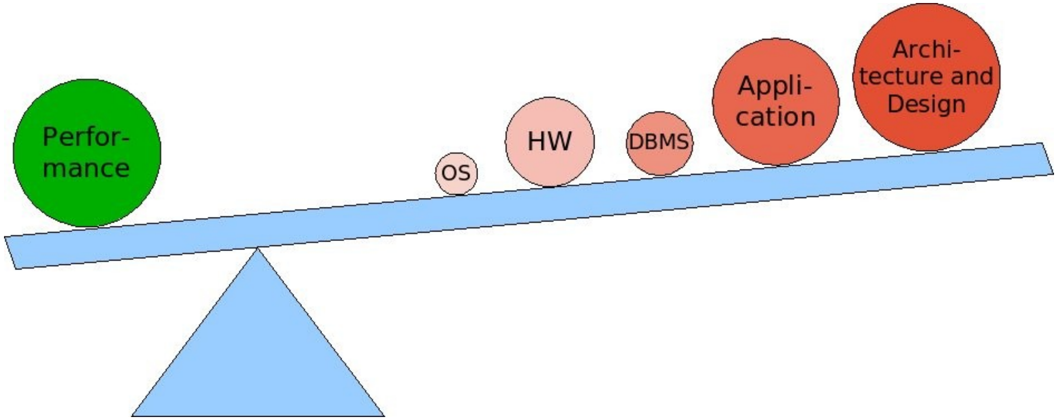
- I/O
  - Who does it?
  - Is it read or write?
  - Is it random I/O or sequential I/O?
- Memory
  - Easy to find!
  - DB sizing
  - Is it somebody else?
- CPU
  - Easy to find!
  - Who is “burning” CPU?
- Network bandwidth
  - Who does it?
  - Sniff traffic?

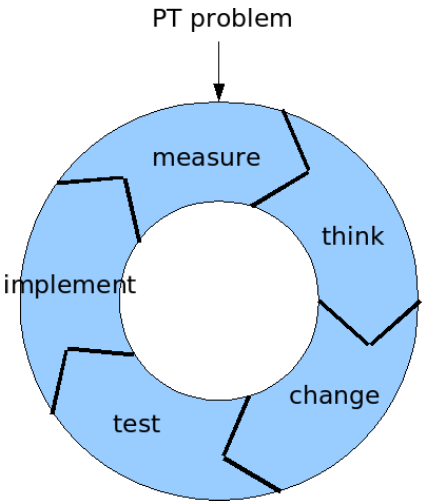


Change

- What could be changed?

- Hardware -> I/O system (RAID5), RAM, CPU, NW
- O/S -> do not touch (kernel upgrade)
- DB -> my.cnf
- Application -> Queries!!!





Change Hardware

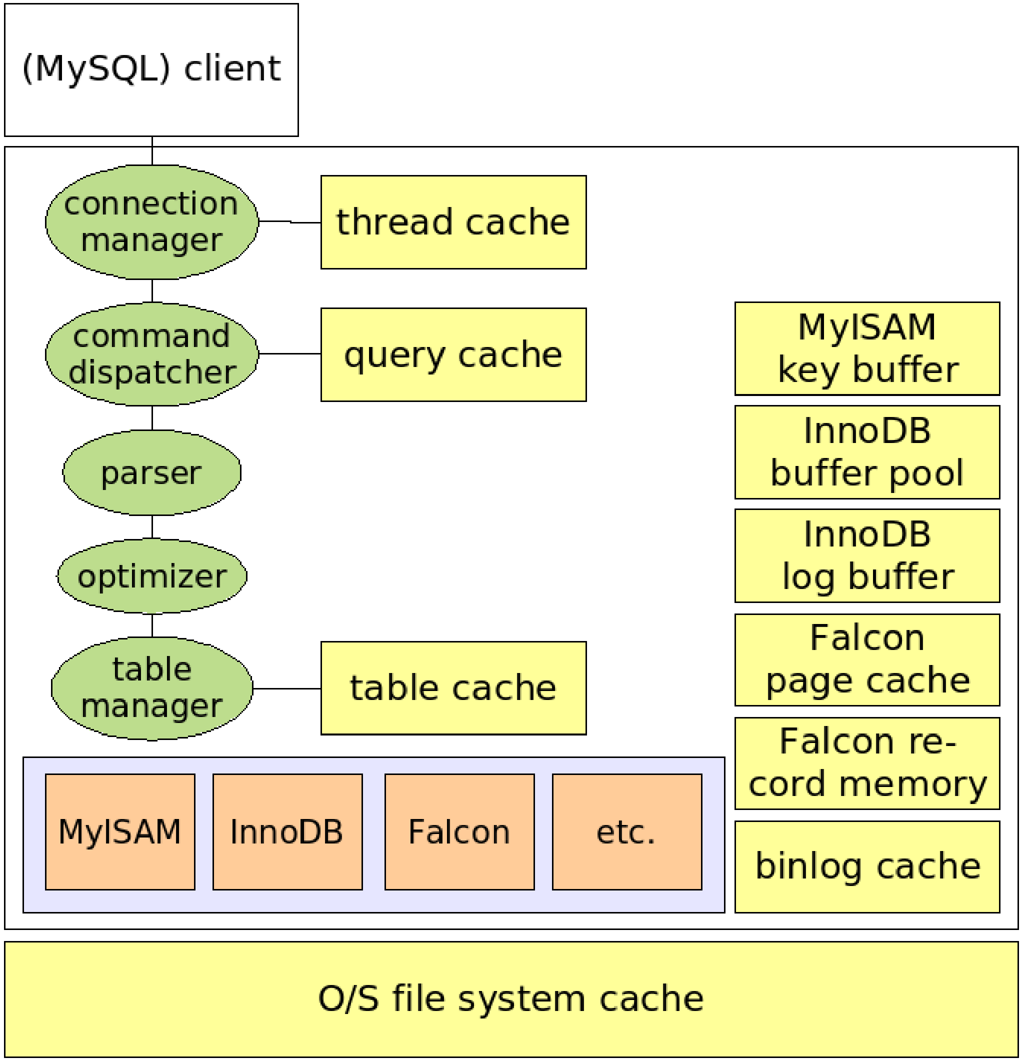
- More RAM helps more!!!
- Faster CPU if it is the bottleneck (not more!)
- More expensive I/O system:
  - RAID5 is bad for databases!!!
  - RAID10 is good.
  - Many spindles
  - Battery buffered I/O system cache???
- 1 Gbit Network?
- Forget about virtualization (VMware etc.)!!!

Change O/S

- Use mainstream O/S -> for MySQL this means SLES/RHEL!
- Use 64-bit architecture (> 4 GB RAM)
- Use recent kernel (>= 2.6.12)
- Use mainstream file system -> ext3 and xfs
- Take what you are most familiar with!

--> But on O/S you cannot change much. They are already optimal! :-)

Change MySQL: Architecture



Change MySQL: Performance Features

- The magic of caching: “Do as little work as possible: Be lazy!!!”
- Performance features:
  - Thread cache
  - Query cache
  - Prepared statements
  - Stored Procedures (see “the SP trap!”)
  - delayed INSERT (MyISAM only)

Change MySQL: database settings

- “The big 3!”
  - key_buffer_size
  - innodb_buffer_pool_size
  - innodb_log_file_size

- Some others: query_cache_size, thread_cache_size

- My approach:
  - use defaults (or templates)
  - add: “the big 3” + 2 (see above)
  - do NOT change except it was proved and measured that is useful!

Change MySQL

- Where to change?
  - my.cnf (Caution: many possible places!!!)

- Where to measure?
  - `SHOW /*!50000 GLOBAL */ STATUS;`

- Where to cheat?
  - http://dev.mysql.com/doc/refman/5.0/en/index.html
  - 5.2.3. System Variables
  - 5.2.5. Status Variables

The big 3

- MyISAM

```
key_buffer_size                 = 25-33% of RAM

Key_blocks_unused               --> actual value
Key_blocks_used                 --> high water mark
Key_read_requests / Key_reads --> >= 99% ideally
```

- InnoDB

```
innodb_buffer_pool_size             = 80% of RAM

Innodb_buffer_pool_pages_free
Innodb_buffer_pool_read_requests /
Innodb_buffer_pool_reads            --> >= 99% ideally
```

The big 3

- InnoDB

```
innodb_log_file_size          = 32 - 128 Mbyte

Innodb_os_log_pending_fsyncs  --> ???
                              --> hiccups!
```

Query cache & thread cache

- Query cache

```
  query_cache_size        = 32 - 128 Mbyte (caution: 512!)

  Qcache_total_blocks
  Qcache_free_blocks
  Qcache_free_memory      --> Fragmentation
  Qcache_hits
  Qcache_inserts          --> Hit ratio, ideally >> 2 : 1
  Qcache_lowmem_prunes    --> too small or too fragmented
```

- Thread cache

```
  thread_cache_size        = 8 - 128

  Threads_cached
  Threads_created          --> should not grow much over time
```

Some more...

- That's it! :-)
- Avoid any kind of I/O: logging!

```
sync_binlog       --> 0 !!!
#log              --> Not on production!!!
#log_bin          --> Where we do NOT need it!!!
log_slow_queries  --> is OK, we do not have such :-)
```

- Try to avoid sync writing:

```
innodb_flush_log_at_trx_commit = 2
```

  - Simulates MyISAM behaviour for InnoDB. But caution!

Some more...

- Table cache

```
table_cache      = 64 - 2048

Open_tables      --> <= table_cache
Opened_tables    --> should change moderately
```

- Other InnoDB settings:

```
innodb_additional_mem_pool_size
```

  - Do NOT change this! > 20 Mbyte is non sense!

```
innodb_flush_method
```

  - Sometimes O_DIRECT or O_DSYNC can help. But test before!

Change Application!

- Transaction log and binlog cache:

```
Binlog_cache_disk_use  --> increase binlog_cache_size
Innodb_log_waits       --> increase innodb_log_buffer_size
```

  - ➔ Too big transactions???

- Temporary results:

```
max_heap_table_size      = 16 - 256 Mbyte
tmp_table_size           = 32 - 512 Mbyte

Created_tmp_disk_tables  --> changes often
```

  - ➔ Too big temporary results?

Change Application!

- Sort buffer:

```
sort_buffer_size    = 2 - 16 Mbyte
Sort_merge_passes   --> sort buffer too small
```

  - ➔ Too big sorts???

- Application or Network problems:

```
Aborted_clients
Aborted_connects
```

- Network traffic:

```
Bytes_received
Bytes_sent
```

Change Application!

- Locking:

```
Table_locks_immediate
Table_locks_waited
```

  - Too high concurrency or too slow queries! -> Optimize queries or try InnoDB.

```
Innodb_row_lock_current_waits
Innodb_row_lock_time
Innodb_row_lock_time_avg
Innodb_row_lock_time_max
Innodb_row_lock_waits
```

  - InnoDB locking! Optimize queries or think about changing the application.

Change Application!

- Missing Indexes:

```
Select_full_join
Select_range_check  --> should both be zero!!!
```

  - ➔ Missing Index!

- Full-Table-Scan:

```
Select_scan
Handler_read_rnd_next
Sort_scan
```

  - ➔ Find the queries! :-)

Find the slow queries!

- Quick:

```
SHOW [FULL] PROCESSLIST;
```

- Proper: Enable the slow query log!

```
# my.cnf

log_slow_queries              = slow_query.log
long_query_time               = 1
log_queries_not_using_indexes = 1
```

➔ And now??? Thousands of queries!!!

Find the slow queries!

- Profile the slow query log:

```
# mysqldumpslow -s t slow-query.log > slow_query.profile
```

- That's how the profile looks like:

```
Count: 4498  Time=212.72s (956824s)  Lock=0.04s (198s)  Rows=0.0 (0)
  create table TMP.SS_temp2_36 select l.initlot,s.lot,s.wafer,s.x,s.y,

Count: 810  Time=121.74s (98610s)  Lock=0.30s (245s)  Rows=0.0 (0)
  insert into TOD.row_descr select l.initlot,w.lot,w.wafer,'S' dataset,'S'

Count: 477  Time=149.99s (71547s)  Lock=0.01s (4s)  Rows=2.7 (1284)
  SELECT l.lot,count(h.MFG_STEP_NAME) cnt FROM DB1.lot_7000 l left join

Count: 92  Time=573.43s (52756s)  Lock=0.00s (0s)  Rows=325.6 (29958)
  SELECT ps.X, ps.Y, SUM(N*ps.PARVALUE)/COUNT(ps.PARVALUE) PARMEAN FROM
```

  ➔ Start working now! EXPLAIN ...

MySQL EXPLAIN

- Generate an execution plan:

```
EXPLAIN
SELECT i.number, l.answer
  FROM poll_item i
  JOIN poll_item_l l ON (l.poll_id = i.poll_id
                     AND l.number = i.number)
WHERE i.poll_id = '4'
  AND l.language_id = '2'
ORDER BY i.number ASC;
```

```
+----+--------+-----+--------+----------+---------+-------+-----------+------+--------------------------+
| id | select | tab | type   | pos_keys | key     | k_len | ref       | rows | Extra                    |
+----+--------+-----+--------+----------+---------+-------+-----------+------+--------------------------+
|  1 | SIMPLE | i   | ref    | PRIMARY  | PRIMARY | 2     | const     |    5 | Using where; Using index |
|  1 | SIMPLE | l   | eq_ref | PRIMARY  | PRIMARY | 5     | const,... |    1 | Using where              |
+----+--------+-----+--------+----------+---------+-------+-----------+------+--------------------------+
```

- Rewrite DML into SELECT.
- Be cautious with Subqueries! They are executed!

MySQL visual explain

- http://mysqltoolkit.sourceforge.net/

```
./mysql-visual-explain test.exp

JOIN
+- Filter with WHERE
|  +- Bookmark lookup
|     +- Table
|     |  table          l
|     |  possible_keys  PRIMARY
|     +- Unique index lookup
|        key            l->PRIMARY
|        possible_keys  PRIMARY
|        key_len        5
|        ref            const,topodb.i.number,const
|        rows           1
+- Filter with WHERE
   +- Index lookup
      key            i->PRIMARY
      possible_keys  PRIMARY
      key_len        2
      ref            const
      rows           5
```

Table tuning

- Indexing
  - See above.
  - What should be indexed and how?
- Data type tuning
  - `mysqldump -all-databases --no-data`
- Table design

Table tuning – Indexing

- What should be indexed?
  - All attributes where you JOIN
  - All attributes where you filter (WHERE)
  - All attributes where you ORDER or GROUP BY
  - All attributes where you want to do an Index Scan instead of a Table scan.
  - NOT on attributes with an evenly distributed low cardinality.
- How should be indexed?
  - Indexes can only be used from left to right.
  - Keep them short.
  - Compound indexes: INDEX(a, b).
  - Prefixed indexes: INDEX(a, b(10)).
  - Do not function-cover indexed attributes

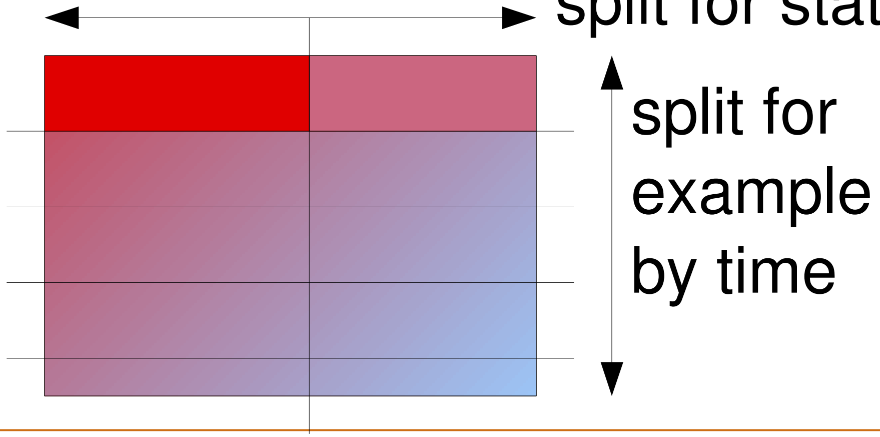
Table tuning – data type tuning

- Idea behind: Increase the data density!
- How to get: mysqldump --no-data

```
CREATE TABLE betatesters (
  user_id bigint(20) NOT NULL,
  nick varchar(255) NOT NULL,
  registerdate varchar(30) NOT NULL,
  daysregistered int(11) NOT NULL,
  value double default NULL,
  timestamp_data bigint(15) default NULL,
  ip varchar(16) default NULL
  PRIMARY KEY  (`nick`),
  UNIQUE KEY user_id (`user_id`)
  KEY (`user_id`, `nick`)
) DEFAULT CHARSET=utf8;
```

Table tuning – table design

- Normalization versus de-normalization
  - Joins are expensive --> CPU
  - Denormalized is big --> high redundancy --> RAM --> Disk --> Slow
  - ➔ Find the trade-off!
  - ➔ Bring everything in 3rd NF --> then start denormalizing if necessary.
- vertical and horizontal partitioning:



Locality of Reference

- In theory: We should not care how data are stored internally.
- In practice: It is sometimes good to know!
- Why?
- 2 examples from the last 9 months:
  - wind mills
  - vehicle tracking for parcel delivery

Example 1

- Several 100 wind mills
- 50 measured values per wind mill
- Every 5-15 minutes
- Up to 10 years
- Dozens of GB of data
- Record size up to 2k!

- Search pattern: Give me value x from wind mill #13 in this time range!

Example 2

- Several 100 vehicles
- 24 h/d
- Every 2 min position
- Status/position per vehicle, later per parcel!!!
- Dozens of GB of data
- Record size 400 bytes

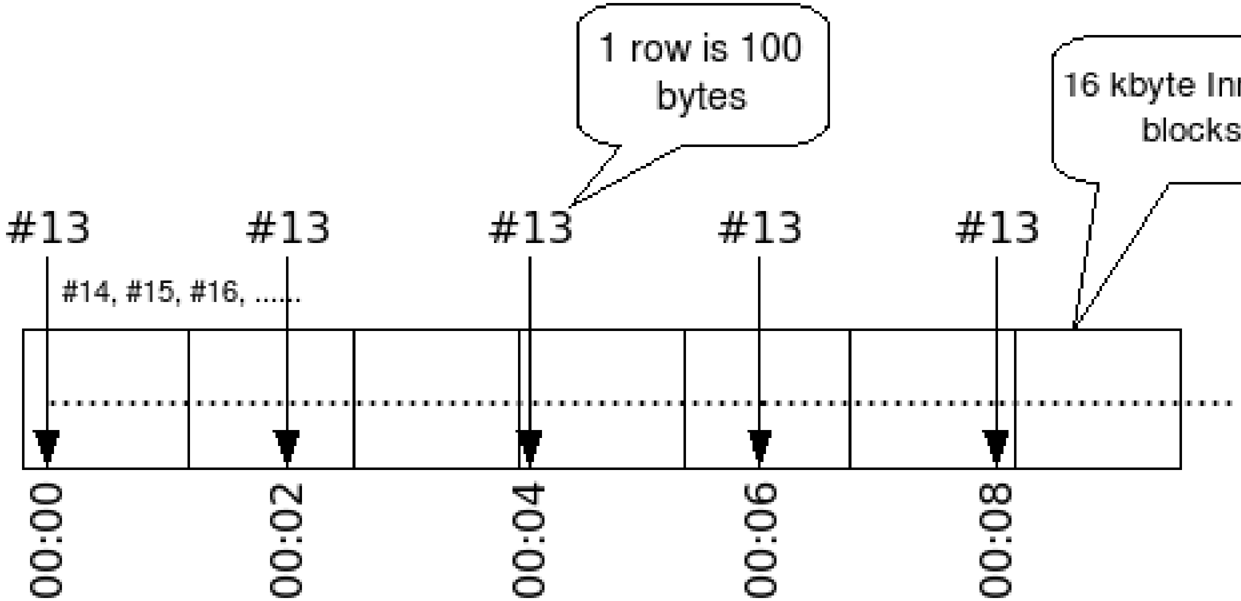
- Search pattern: Give me all positions of vehicle #13 from the last 24 hours.

Locality of Reference

- These 2 examples have one behaviour in common:
- Delivery of data is completely different than search pattern.
  - Usually data are delivered sorted by time and also (more or less) retrieved by time.
  - In this cases time has a secondary influence!
- But what happens???

Locality of Reference

- Block size is 16k/4k
- PK is AUTO_INCREMENT



- Synthetical PK are sometimes dangerous!

Locality of Reference

- What to do???

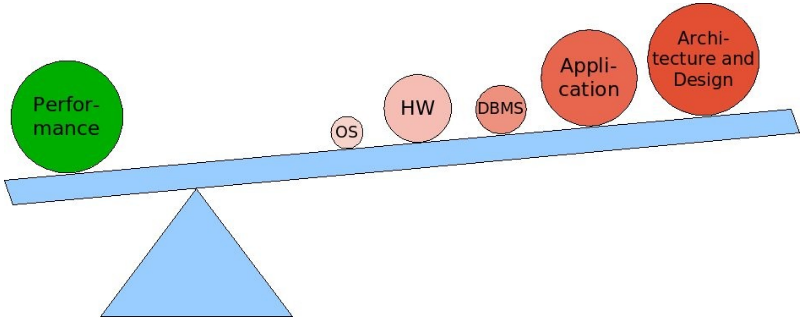
- ➔ PK on (vehicle_id, ts) for example or
- ➔ PK on (windmill_id, data, ts)

- ➔ Can be up to 100 times more efficient (not necessarily faster)

- What about MyISAM?
- What about Falcon? (Mail from Ann can be provided).

Change Application

- Where are we now?

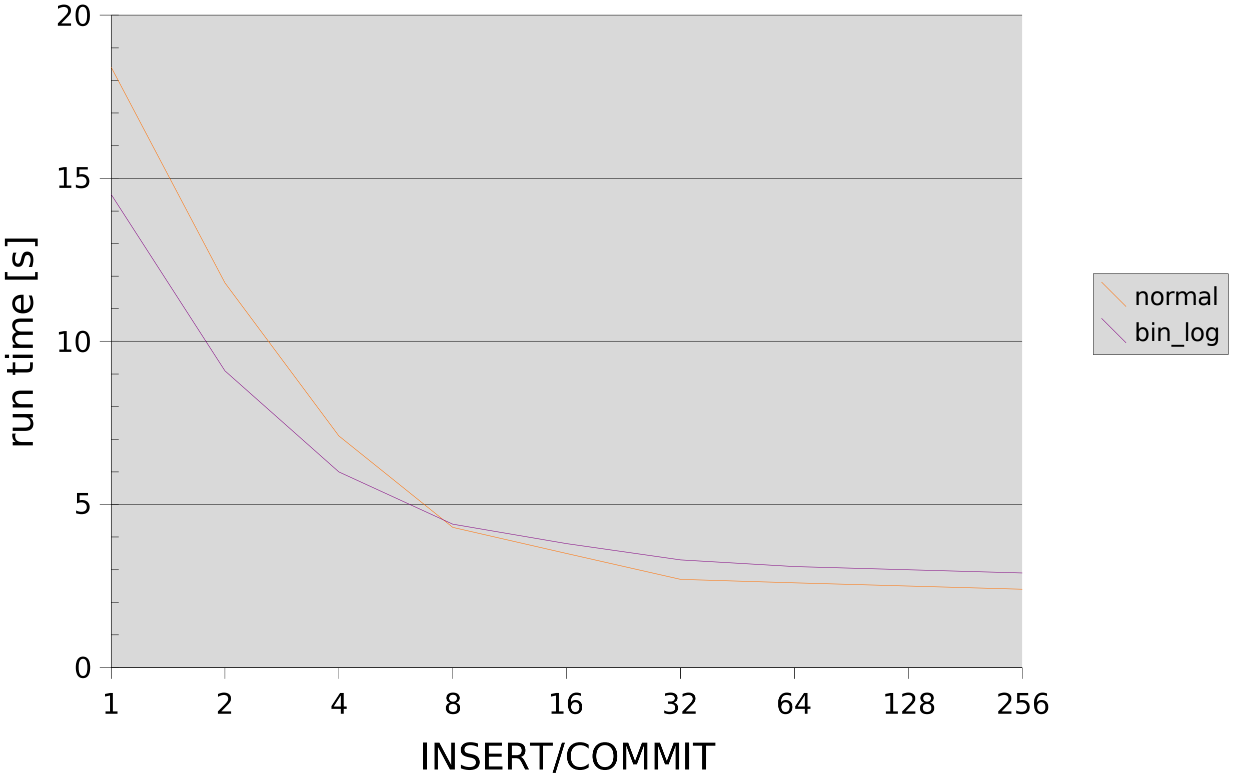


- What else can we do?
  - Avoid – reduce – optimize
- Do not!
  - Put more intelligence into your application!
- Reduce!
  - Do only once. Cache!
- Do it better!
  - Tune the statement, tune the code, tune the logic!

Change Application

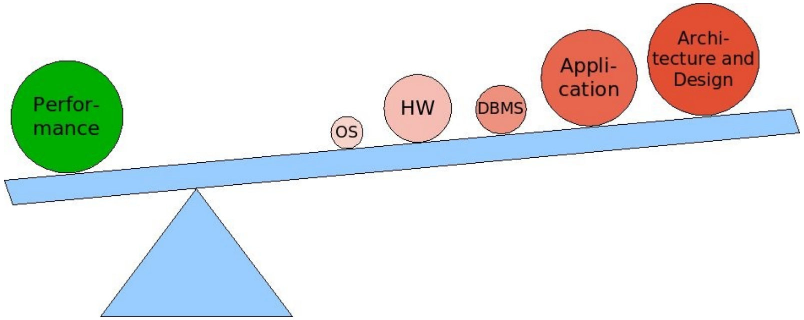
- Clean up first, before you invest into new hardware or even a redesign.
  - New hardware brings maybe a factor of 2x
  - Clean up can bring factors up to 10x
  - Sometimes new hardware is cheaper :-(
- Read issues are a caching problem.
  - ➔ Try to cache!
- Write issues are a batching problem.
  - ➔ Try to batch!

commit_demo.pl



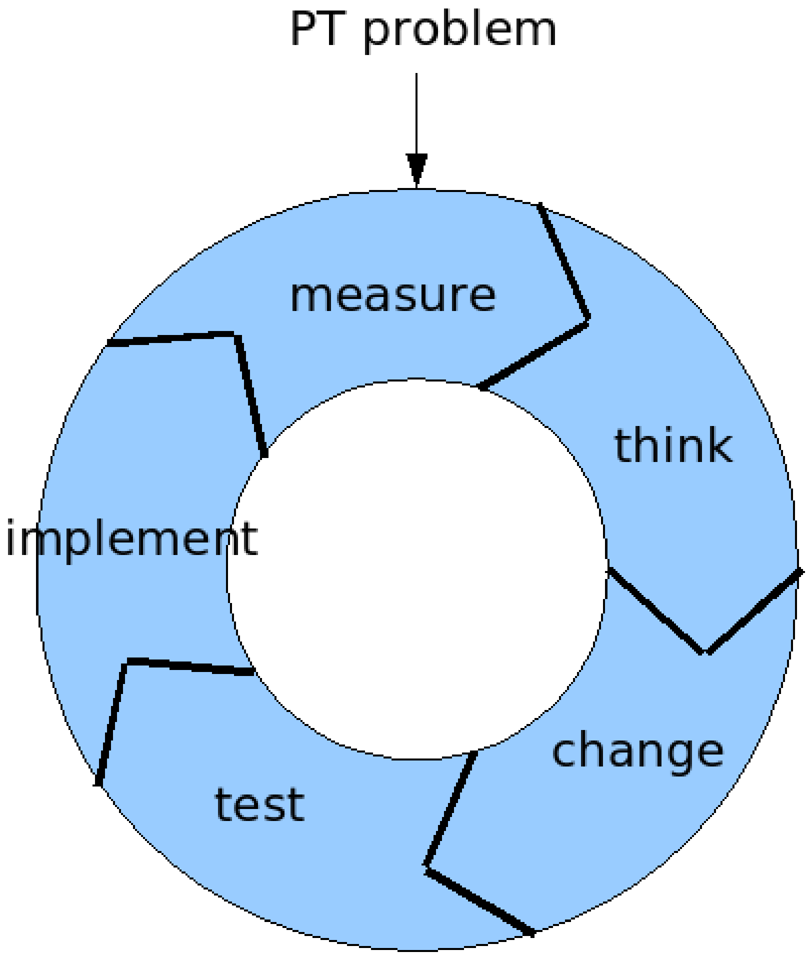
Alternatives when exhausted

- See this afternoon! :-)
- Change architecture.
  - Scale-Out?
- Tricks like Materialized Views?
- Application partitioning



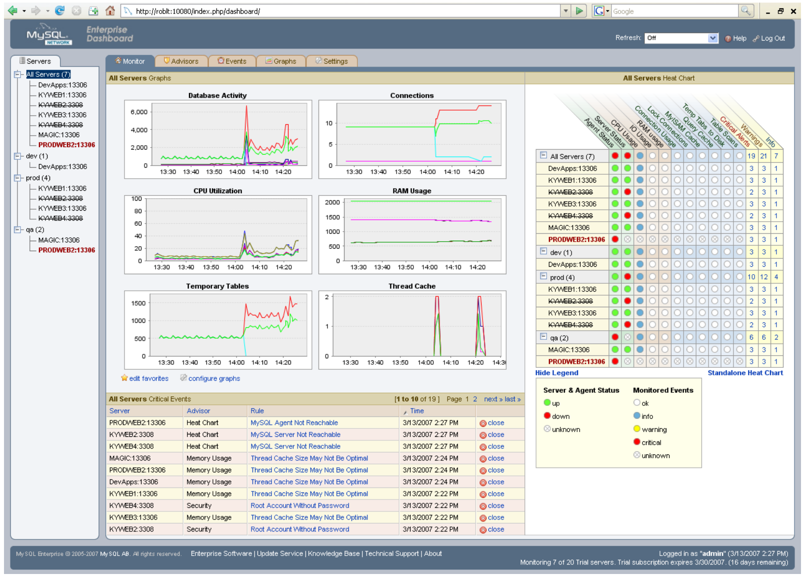
Prevention

- What can we do to prevent Performance problems?
  - Do load testing.
  - Do benchmarking.
  - Collect historical data and make predictions.
- An then: Measure and monitor…



Measure

- top, vmstat, iostat, dstat, mstat, free, ...
- mytop, innotop, mtop
- Nagios, MySQL AR, MySQL Administrator, Cacti, MRTG, RRD, Munin, Moodds, Big Sister, MySQLStat, Zabbix, Hobbit, Monit, ...



All Servers Critical Events — [1 to 10 of 19] Page 1 2 next » last »

Server	Advisor	Rule	Time	
PRODWEB2:13306	Heat Chart	MySQL Agent Not Reachable	3/13/2007 2:27 PM	close
KYWEB2:3308	Heat Chart	MySQL Server Not Reachable	3/13/2007 2:27 PM	close
KYWEB4:3308	Heat Chart	MySQL Server Not Reachable	3/13/2007 2:27 PM	close
MAGIC:13306	Memory Usage	Thread Cache Size May Not Be Optimal	3/13/2007 2:24 PM	close
PRODWEB2:13306	Memory Usage	Thread Cache Size May Not Be Optimal	3/13/2007 2:24 PM	close
DevApps:13306	Memory Usage	Thread Cache Size May Not Be Optimal	3/13/2007 2:24 PM	close
KYWEB1:13306	Memory Usage	Thread Cache Size May Not Be Optimal	3/13/2007 2:22 PM	close
KYWEB4:3308	Security	Root Account Without Password	3/13/2007 2:22 PM	close
KYWEB3:13306	Memory Usage	Thread Cache Size May Not Be Optimal	3/13/2007 2:22 PM	close
KYWEB2:3308	Security	Root Account Without Password	3/13/2007 2:22 PM	close

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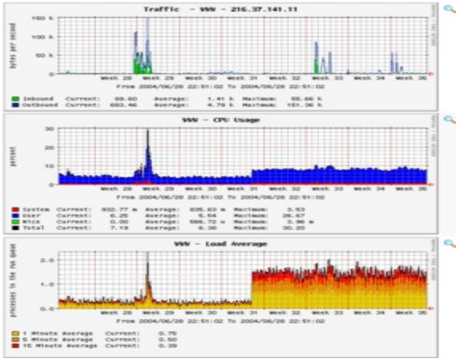
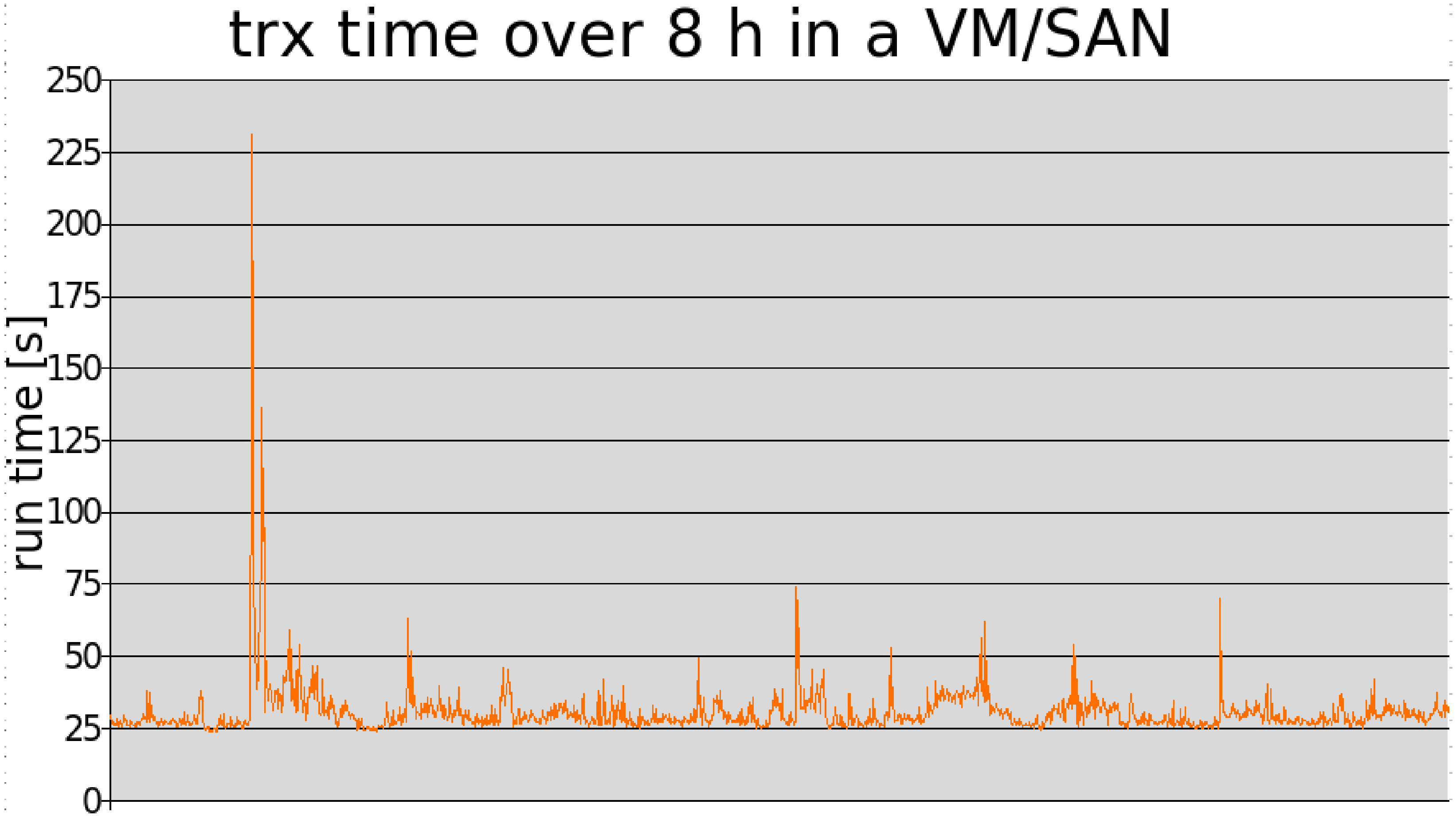
Logged in as "admin" (3/13/2007 2:27 PM)
Monitoring 7 of 20 Trial servers. Trial subscription expires 3/30/2007. (16 days remaining)



http://www.shinguz.ch/MySQL/mysql_monitoring.html

Virtualization VM /SAN



RAM disks (I)

- ORDER BY, GROUP BY, DISTINCT --> temp tables
  - bigger than:
  - BLOB/TEXT

```
tmp_table_size      = 32M
max_heap_table_size = 16M
```

- Will be written into:

```
tmpdir               =  /tmp/
```

- Can be seen in:

```
Created_tmp_disk_tables   0
Created_tmp_tables       20
```

RAM disk (II)

- Both counters are increased!

- Solutions?
  - Change your statement/requirements
  - Optimize your Query
  - Reduce size of result set
  - Avoid BLOB/TEXT

- And if you cannot?

--> Use a RAM disk!

RAM disk (III)

- RAM disk is a disk in RAM :-) --> So you need much RAM (8 Gbyte on 32-bit systems?)!
- Can use your SWAP (we do not want that)!
- More info: /usr/src/linux/Documentation/filesystems

```
# cat /proc/filesystems
# mount tmpfs -t tmpfs /mnt -o size=100m
# mount
```

- Bug in 5.0.4x!!! :-(

Now it's up to you...

- Output of: SHOW /*!50000 GLOBAL */ STATUS;
- Output of: SHOW GLOBAL VARIABLES;
- Slow query log.
- Slow queries
- Execution plans (EXPLAIN SELECT ...)
- Output of "vmstat 1" during peak time.