



MySQL Performance: Demystified Tuning & Best Practices

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Are you Dimitri?.. ;-)

- Yes, it's me :-)
- Hello from Paris! ;-)
- Passionated by Systems and Databases Performance
- Previous 15 years @Sun Benchmark Center
- Started working on MySQL Performance since v3.23
- But during all that time just for “fun” only ;-)
- Since 2011 “officially” @MySQL Performance full time now
- <http://dimitrik.free.fr/blog> / [@dimitrik_fr](https://twitter.com/dimitrik_fr)



Agenda

- Focus on Single MySQL Server Instance Performance
- with a mix of and in any order :
 - Overview of MySQL Performance
 - Performance improvements up to MySQL 5.7 & Dev
 - What can be Tuned / and what should be Avoided
 - Pending Issues and Workarounds..
- Q & A
 - (and sorry in advance for many “smiles” in the slides ;-))

Why MySQL Performance ?...

Why MySQL Performance ?..

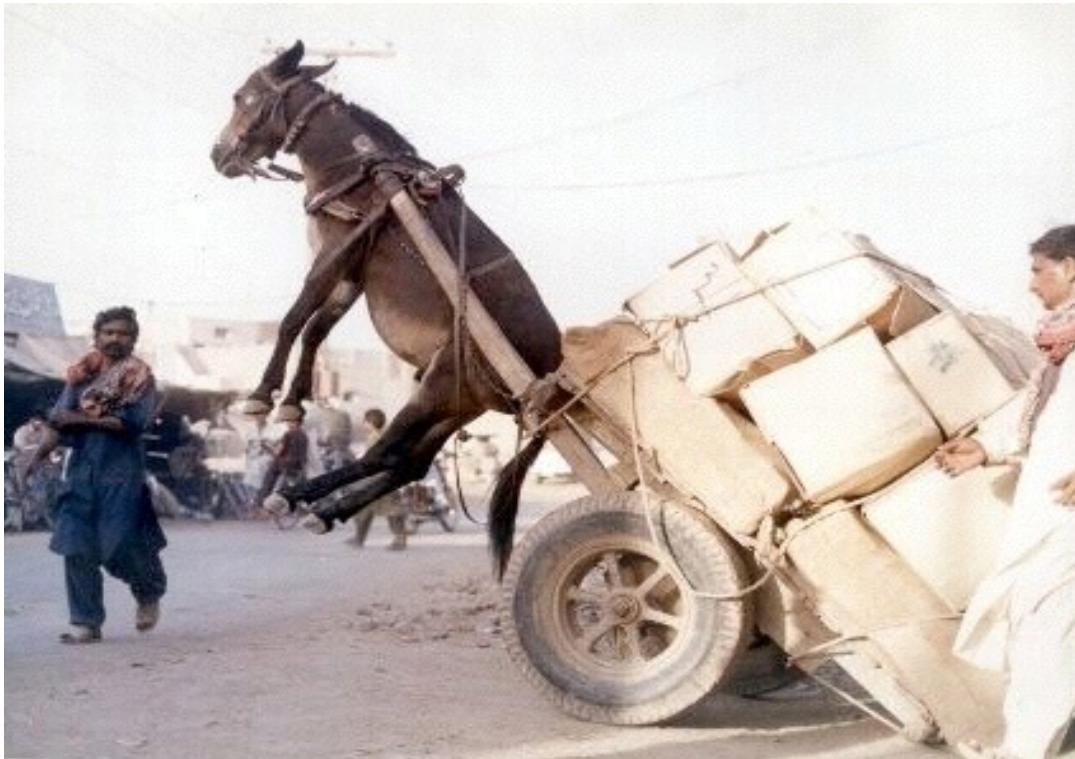
- Any solution may look “good enough”...



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Why MySQL Performance ?..

- Until it did not reach its limit..



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Why MySQL Performance ?..

- And even improved solution may not resist to increasing load..



www.freeuniverse4all.com

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Why MySQL Performance ?..

- And reach a similar limit..



<http://fishki.net>

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Why MySQL Performance ?..

- Analyzing your workload performance and testing your limits may help you to understand ahead the resistance of your solution to incoming potential problems ;-)



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Why MySQL Performance ?..

- However :
 - Even a very powerful solution but leaved in wrong hands may still be easily broken!... :-)



www.mikud.net

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The Main MySQL Performance
Best Practice #1 is... ???..

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USE YOUR BRAIN !!!... ;-)

The Main MySQL Performance Best Practice #1 is... ???..

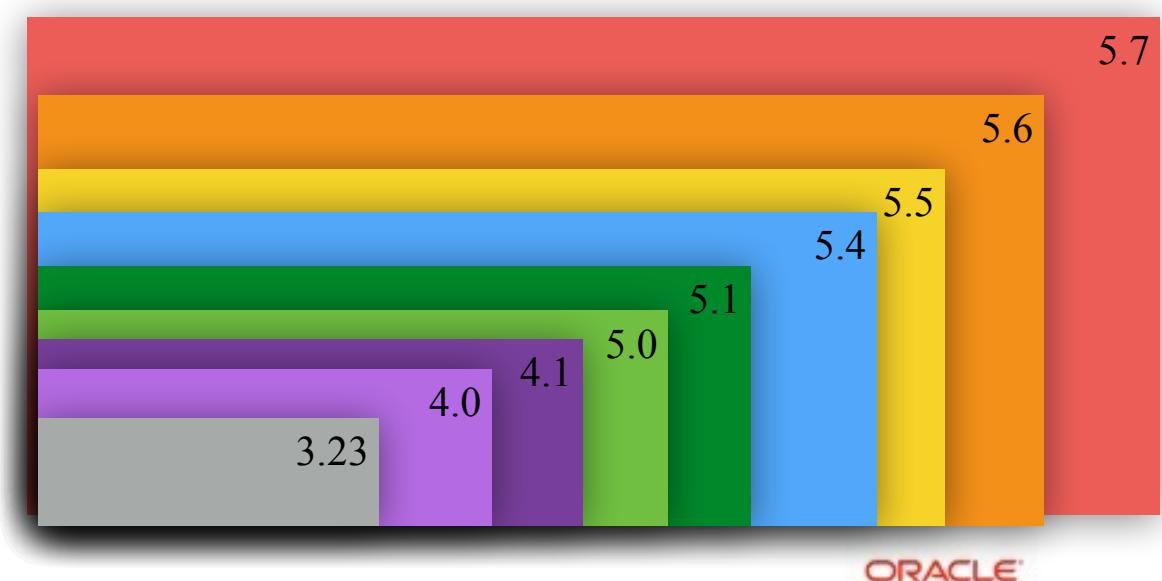
USE YOUR BRAIN !!!... ;-)



MySQL Performance Evolution

- From version-to-version :

- 3.23 => 4.0 => 4.1 => 5.0 => 5.1 => 5.4 => 5.5 => 5.6 => 5.7 ...
- More features => longer code path.. (just google: “What is new in MySQL 5.7”)
- MySQL/InnoDB code is very sensible to CPU cache(s)..
- Going slower :
 - single-user..
 - low-load..
 - small-HW..
- Going faster :
 - where scalability was improved
 - higher-load..
 - newer/bigger-HW..



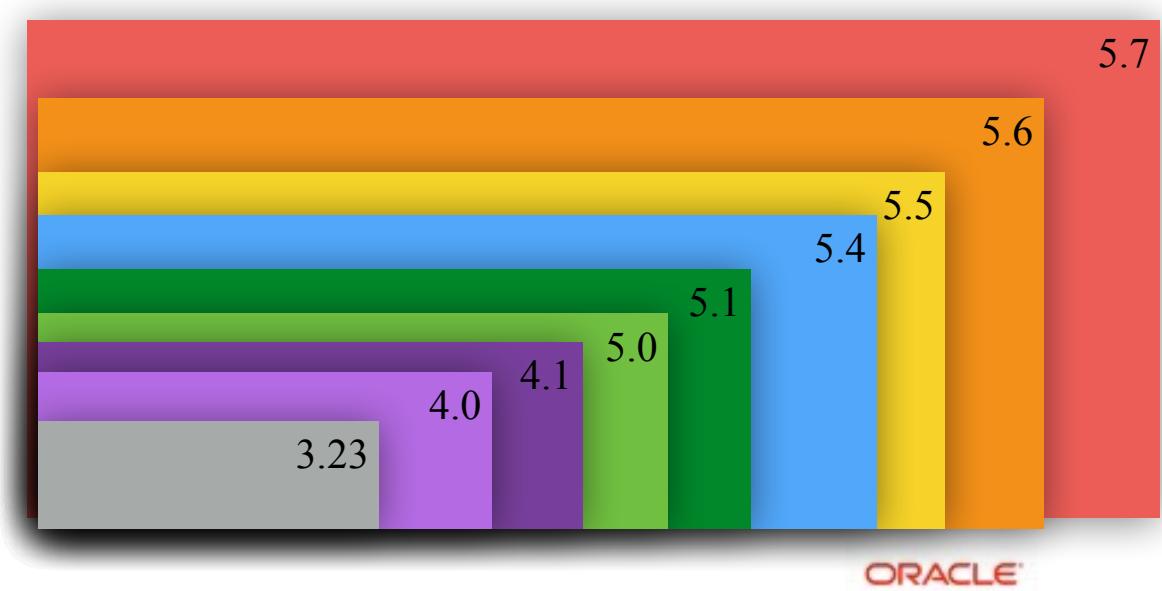
MySQL Performance Evolution

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- MySQL/InnoDB code is very sensible to CPU cache(s)..

- Less featured MySQL ?

- Drizzle !
- do you know Drizzle ?
- do you use Drizzle ?
- do you run your production on ?



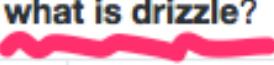
MySQL Performance Evolution

- From version-to-version :

- 3.23 =
- More f
- MySQL

- Less fe
- Drizzl
- do you
- do you
- do you

Henrik Ingo @h_ingo · Sep 17
Cool: In the DB Engines Rank, #Drizzle is exactly 4 times as popular as #TokuMX.
It's also slightly more popular than #Percona Server.

markcallaghan @markcallaghan · Sep 17
@h_ingo what is drizzle? 

FAVORITE 1

5:04 AM - 17 Sep 2014 · Details

Hide conversation

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5.7

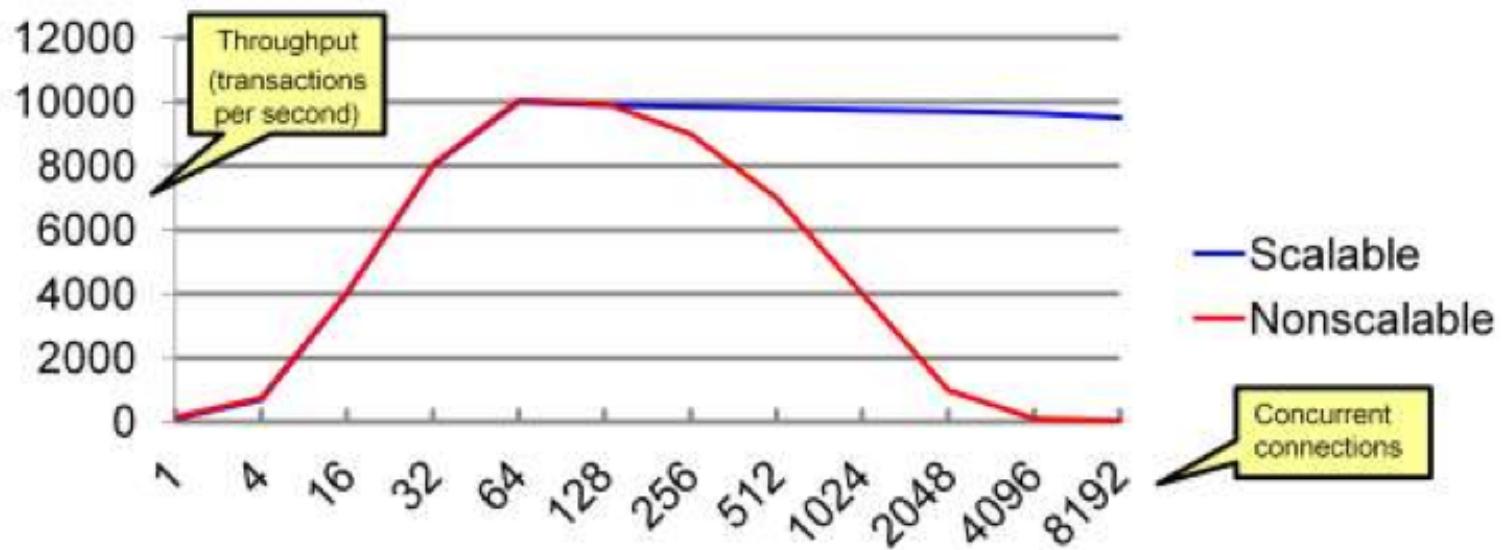
5.6

Why Scalability ?..

- CPU Speed : no more "free lunches" ;-)
 - will x2 times faster CPU increase your performance by x2 ?..
- CPU cores : more and more over year-to-year..
 - Intel 2CPU : 8cores-HT
 - Intel 2CPU : 12cores-HT
 - Intel 2CPU : 16cores-HT
 - Intel 2CPU : 20cores-HT
 - Intel 2CPU : 36cores-HT (2015)
 - Intel 2CPU : 44cores-HT (Mar.2016)
 - ...
 - 2016: 4cores ==> “commodity HW” for a SmartWatch ;-)
- Scalability In Few Words :
 - your software is able to deliver a **higher** throughput if more HW resources are available..
 - (then, scaling it well or not is another story ;-))

A B-shit Slide...

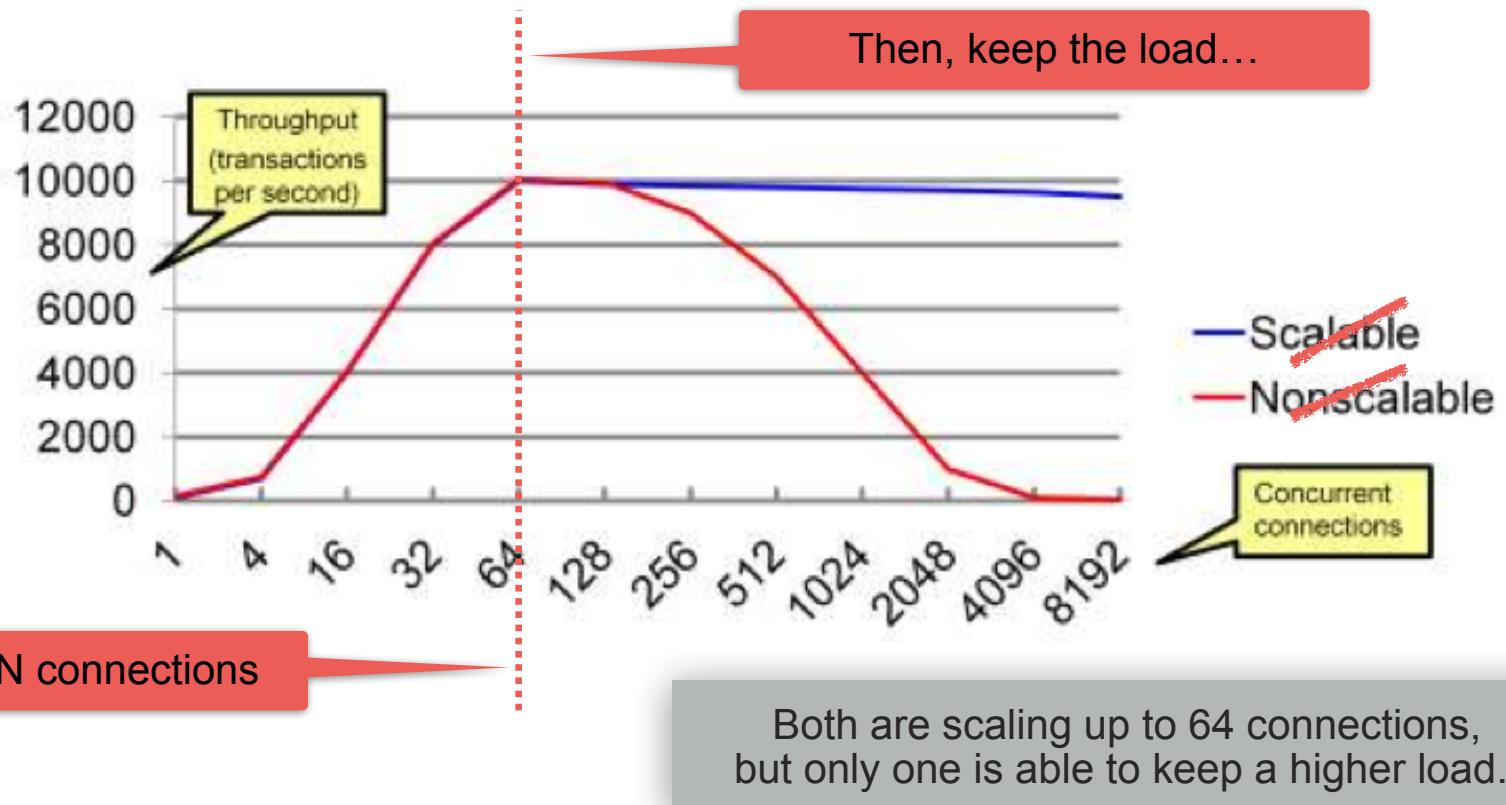
- Odd interpretation of Scalability...



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A B-shit Slide... (2)

- Odd interpretation of Scalability...



MySQL on High Load

- Once you've reached your Max TPS on your system :
 - try to understand first what is limiting you? (I/O, CPU, Network, MySQL internals?)
 - the next goal then: to avoid a TPS “regression” on a higher load
- How to keep your Max TPS on a higher load too?
 - the dumb rule : avoid to have a load higher than you're able to keep ! ;-)
 - seriously :
 - usually all you need is to find a way to do not let your workload concurrency out-pass the levels you're reaching on the TPS Max, that's all..
 - InnoDB thread concurrency helps here (yet more improved in MySQL 5.7)
 - InnoDB spin wait delay tuning helps to lower impact of mutexes / rw-locks waits
 - ThreadPool / ProxySQL / etc..
- **NOTE : there is no “magic” for response time :**
 - if your Max TPS you're reaching on N users
 - and able to keep the same Max TPS on N x2 users (or x3, x4, etc.)
 - your response time may only grow! (and be x2 times bigger (or x3, or x4, etc.))

Thread Pool in old MySQL 5.7 @Heavy OLTP_RW



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Starting point : “Tuning” HW / OS / FS related choices

- Linux :
 - LD_PRELOAD MT-oriented malloc: **jemalloc**, tcmalloc, etc.
 - right IO scheduler (not cfq)
 - right FS/ mount options/ AIO/ O_DIRECT/ etc..
 - nobarriers,noatime,nodirtime,...
- Solaris :
 - LD_PRELOAD MT-oriented malloc: mtmalloc, **umem**
 - UFS/forcedirectio
 - ZFS
- why not shared storage / ZFS Appliance / etc..
- the main rule : **TEST before deploy !!!**
 - know your HW / OS / FS limits !!!

Test Before! - Only a real test gives you a real answer...

- Avoid to tweak on production systems ;-)
 - Rather try to reproduce your load on a similar, but dedicated to test server
 - Collect test cases for all the most critical parts..
- Want to simulate your production workload?..
 - Then just simulate it! (many SW available, not always OSS/free)
 - Hard to simulate? - adapt some generic tests
- Want to know capacity limits of a given platform?
 - Still try to focus on the test which are most significant for you!
- Want just to validate config settings impacts?
 - Focus on tests which are potentially depending on these settings
- Well, just **keep thinking** about what you're doing ;-)

“Generic” Test Workloads @MySQL

- Sysbench
 - OLTP, RO/RW, N-tables, lots test workload load options, deadlocks
- DBT2 / TPCC-like
 - OLTP, RW, very complex, growing db, no options, deadlocks
 - In fact using mostly only 2 tables! (thanks Performance Schema ;-))
- dbSTRESS
 - OLTP, RO/RW, several tables, one most hot, configurable, no deadlocks
- iiBench
 - pure INSERT (time series) + SELECT
- LinkBench (Facebook)
 - OLTP, RW, very intensive, IO-hungry..
- DBT3
 - DWH, RO, complex heavy query, loved by Optimizer Team ;-)

Side Note on “Generic” Test Workloads @MySQL

- For MySQL Dev Team :
 - each generic workload represents several real problems to fight
 - there is no “marketing” ;-)
 - just a hard work on investigation & fixing of problems..

Test Case / Workload Scenario

- Before to jump into something complex...
 - Be sure first you're comfortable with “basic” operations!
 - Single table? Many tables?
 - Short queries? Long queries?
- Remember: any complex load in fact is just a mix of simple operations..
 - So, try to split problems..
 - Start from as simple as possible..
 - And then increase complexity progressively..
- NB : **any test case is important !!!**
 - Consider the case rather reject it with “I'm sure you're doing something wrong..” ;-))

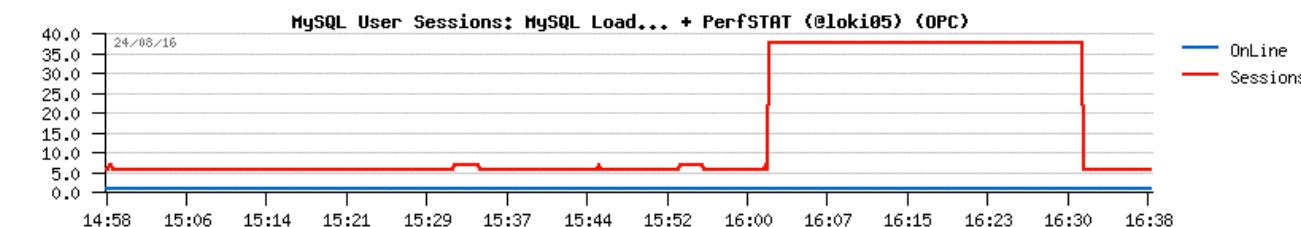
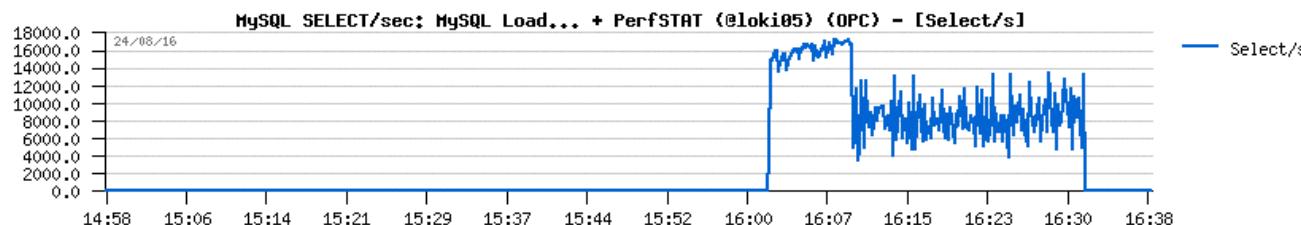
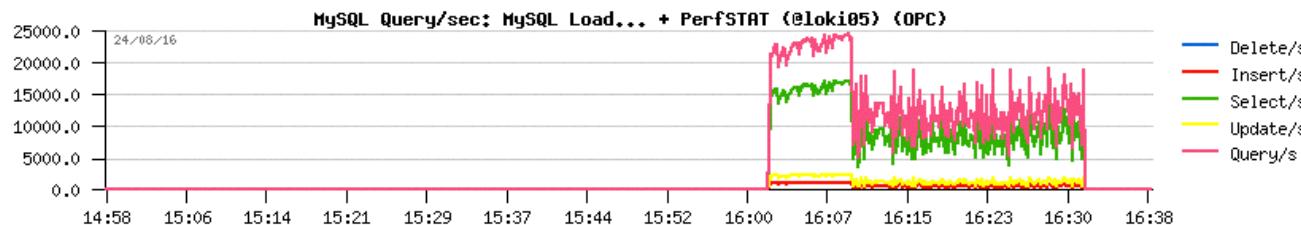


#2 - Monitoring is THE MUST !

even **don't** start to **touch** anything
without monitoring.. ;-)

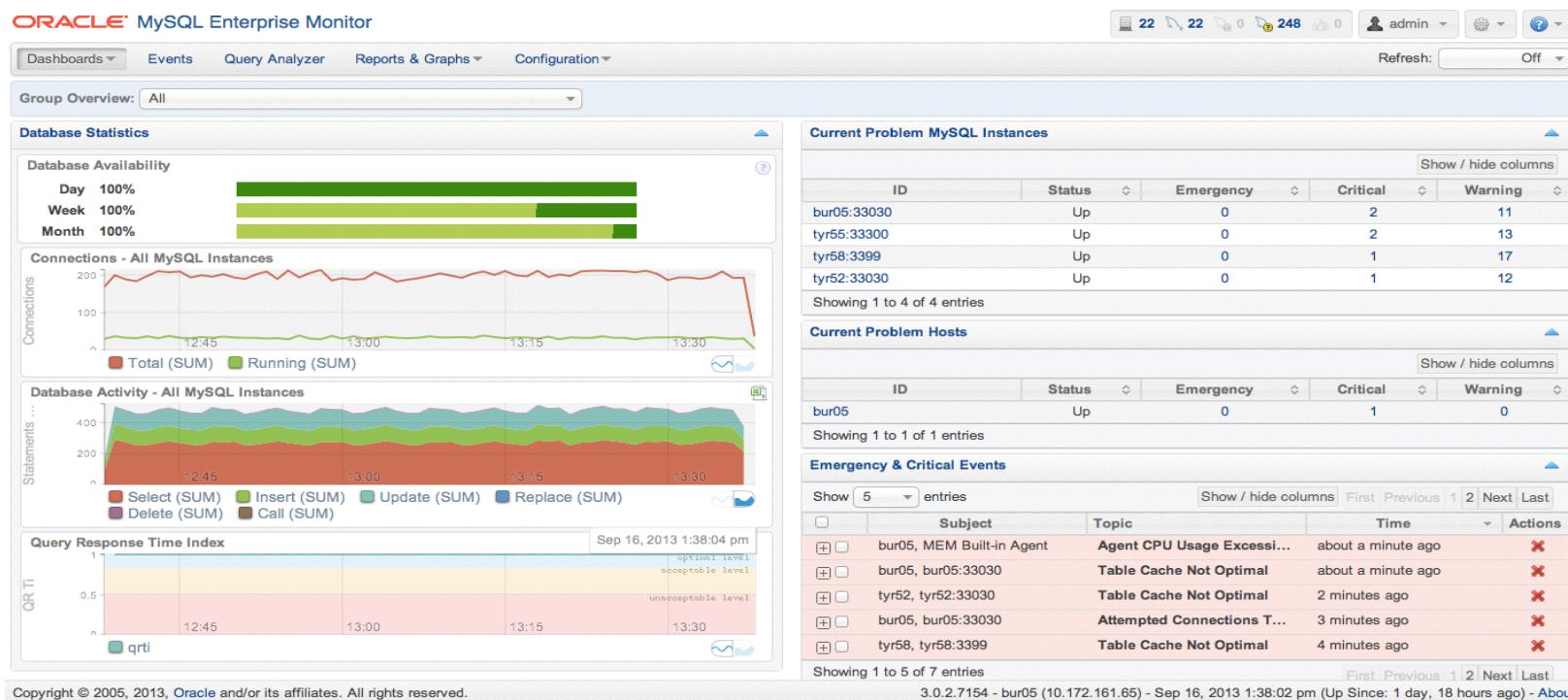
You can be surprised but what you may discover..

- MySQL Activity :



MySQL Enterprise Monitor

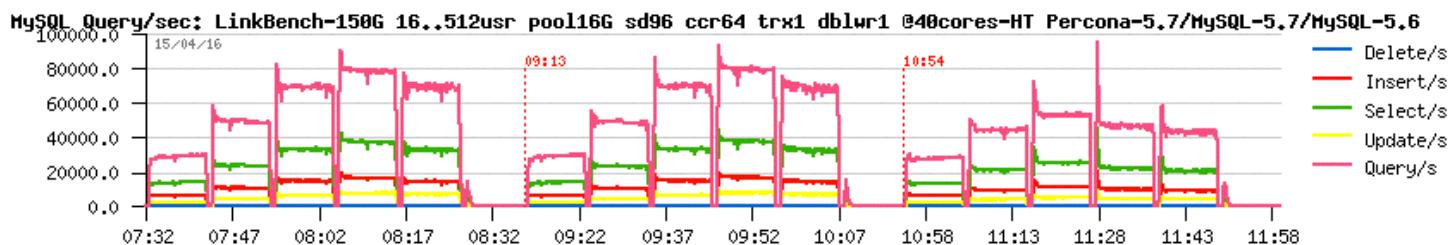
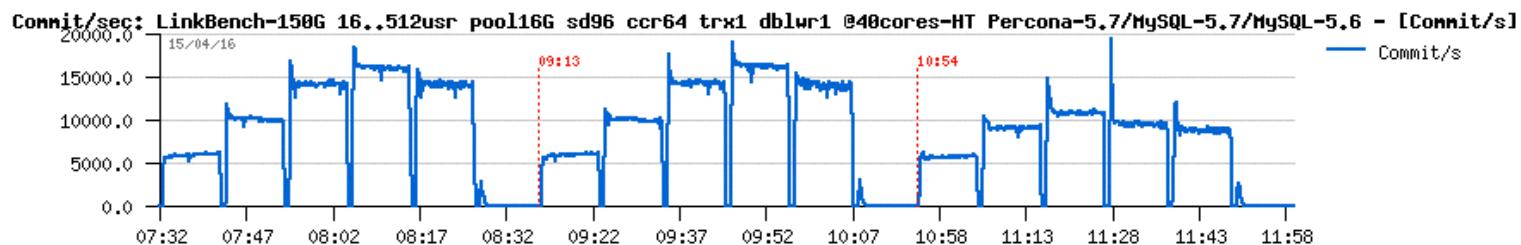
- Fantastic tool!
 - Did you already try it?.. Did you see it live?..



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Other Monitoring Tools

- Cacti, Zabbix, Nagios, Solarwinds, etc.....
- *dim_STAT*
 - well, I'm using this one, sorry ;-)
 - all graphs within presentation were made with it
 - details are on the last slides of presentation..

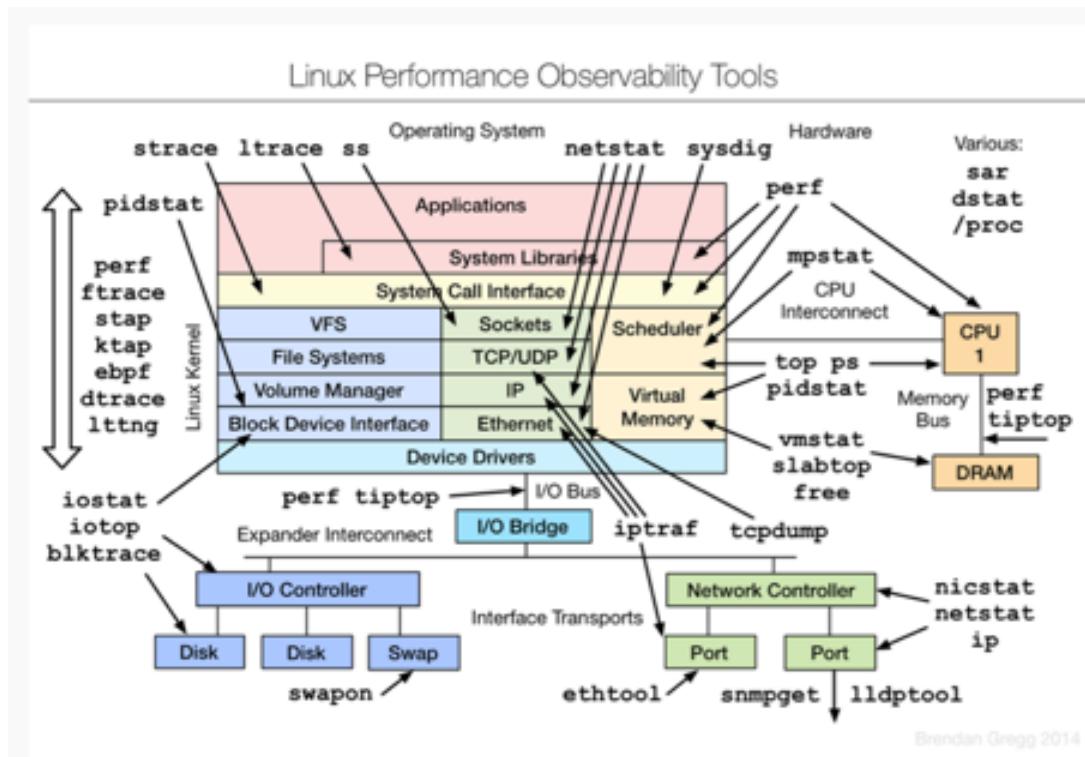


A Word about Monitoring...

- **always** validate the impact of your Monitoring on your Production ;-)
- taking 1sec measurements is fine, except :
 - if it's eating 100% CPU time on one or more CPU cores..
 - reducing your network traffic / latency..
 - eats your RAM, etc.
- avoid to be too much intrusive on MySQL/InnoDB internals..
 - you may easily create an additional overhead
 - as well you may add artificial locks on your workflow
 - for ex: run in loop "show processlist", etc..
- well, nothing is coming for free, so **think** about what you're doing !
- (#1 best practice once again ;-))

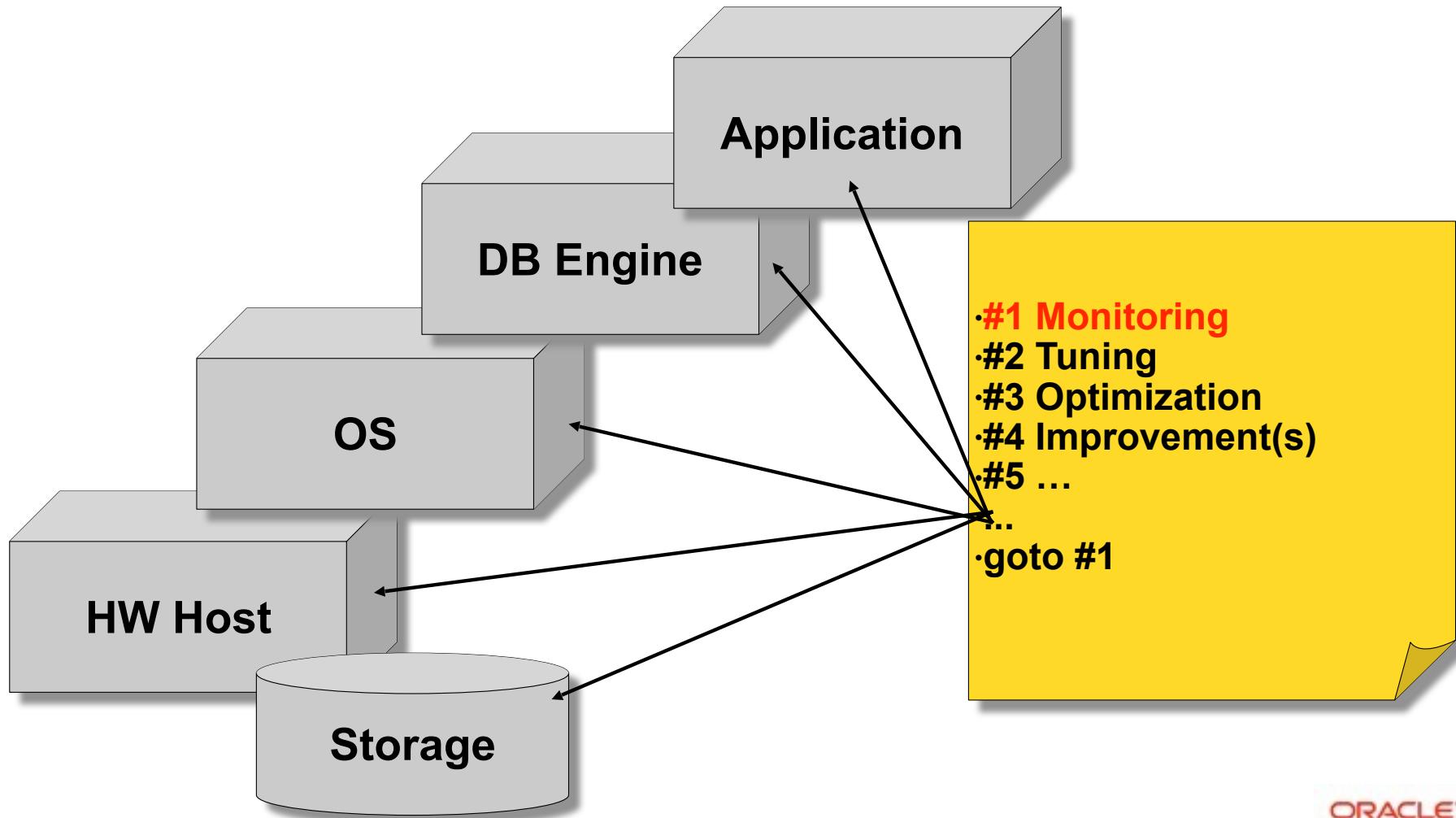
System Monitoring (Linux)

- Keep an eye on :
 - CPU Usage%
 - Run queue
 - RAM / swap
 - Top processes
 - I/O op/sec / MB/sec
 - Network traffic
 - etc..



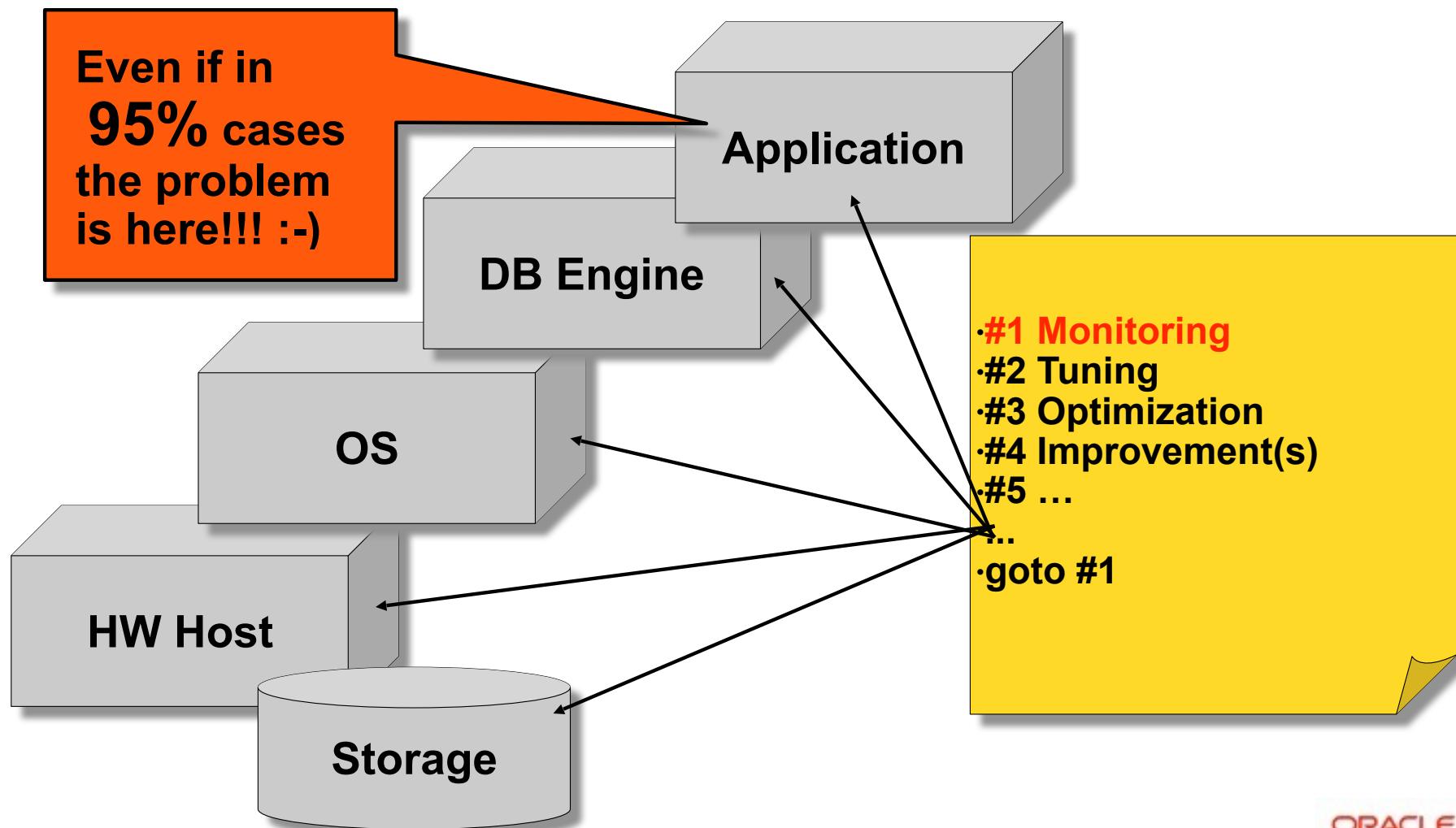
Credits image : Brendan GREGG (<http://www.brendangregg.com>)

The Infinitive Loop of Database Tuning...



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The Infinitive Loop of Database Tuning...



What to Monitor ?..

- Everything ;-)
- The main goal of Monitoring :
 - to understand what is changed once you're hitting a performance problem..
 - (all the diff between “good” -vs- “bad”)
 - otherwise all this is useless ;-))
- Then :
 - be sure the problem is coming from MySQL..
 - be sure you're not hitting any system limits !!
 - be sure you're not hitting MySQL internal limitations..

Using “perf” (Linux) — low impact profiler

- Use cases :

- # perf top -z --stdio <== live monitoring
- # perf record -a -g -f -F 99 -- sleep 20 <== record 20sec of data
- # perf report | more <== report from collected data
- # perf annotate <== jump to source code

- links :

- <https://perf.wiki.kernel.org> <== main resource
- <http://www.brendangregg.com/perf.html> <== the most fun stuff !!!
- Thanks Brendan! ;-)

Profiling example: # perf top -z --stdio

- Observations :
 - nothing special..
 - mysqld is the top running process, fine..

```
PerfTop: 312195 irqs/sec  kernel:19.2%  exact: 0.0% [4000Hz cycles], (all, 80 CPUs)

4.77% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] my_hash_sort_simple
4.42% libc-2.12.so                               [.] memcpy
2.87% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] row_search_nvcc(unsigned char*, unsigned
2.29% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] rec_get_offsets_func(unsigned char const*
1.81% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] buf_page_get_gen(page_id_t const&, page_s
1.59% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] my_strnxfm_simple
0.96% libmysqlclient_r.so.16.0.0                 [.] 0x00000000000058710
0.94% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] btr_cur_search_to_nth_level(dict_index_t*
0.89% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] page_cur_search_with_match(buf_block_t co
0.84% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] _ZL19rw_lock_s_lock_funcP9rw_lock_tmPKcm.
0.74% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] cmp_dtuple_rec_with_match_low(dtuple_t co
0.66% libc-2.12.so                               [.] __memset_sse2
0.60% [kernel]                                [k] copy_user_generic_string
```

Profiling example (2)

- Observations :

- `memcpy()` is the most hot, called by mysqld (check call-stack)
- nothing to do.. (check apps, SELECT ranges, etc..)

```
PerfTop: 286835 irqs/sec kernel:20.2% exact: 0.0% [4000Hz cycles], (all, 80 CPUs)

8.49% libc-2.12.so          [...] memcpy
4.90% mysqld-576-withPFS-03-Sep17-no OMIT-futex [...] row_search_nvcc(unsigned char*, unsigned
3.33% mysqld-576-withPFS-03-Sep17-no OMIT-futex [...] rec_get_offsets_func(unsigned char const*
1.95% mysqld-576-withPFS-03-Sep17-no OMIT-futex [...] buf_page_get_gen(page_id_t const&, page_s
1.46% libmysqlclient_r.so.16.0.0 [...] 0x0000000000005862f
1.36% [kernel]              [...] copy_user_generic_string
1.15% [kernel]              [...] native_write_msr_safe
1.02% mysqld-576-withPFS-03-Sep17-no OMIT-futex [...] btr_cur_search_to_nth_level(dict_index_t*
0.98% mysqld-576-withPFS-03-Sep17-no OMIT-futex [...] page_cur_search_with_match(buf_block_t co
0.98% mysqld-576-withPFS-03-Sep17-no OMIT-futex [...] _ZL19rw_lock_s_lock_funcP9rw_lock_tnPKcm.
0.94% mysqld-576-withPFS-03-Sep17-no OMIT-futex [...] evaluate_join_record(JOIN*, QEP_TAB*)
0.90% mysqld-576-withPFS-03-Sep17-no OMIT-futex [...] ha_innodb::general_fetch(unsigned char*
0.87% mysqld-576-withPFS-03-Sep17-no OMIT-futex [...] my_lengthsp_8bit
0.86% mysqld-576-withPFS-03-Sep17-no OMIT-futex [...] row_sel_store_mysql_field_func(unsigned c
0.83% mysqld-576-withPFS-03-Sep17-no OMIT-futex [...] row_sel_field_store_in_mysql_format_func
```

Profiling example (3)

- Observations :
 - `my_hash_sort_simple()` is the most hot (`mysqld`)
 - nothing to do.. (check apps, memory temp tables usage, query plan, etc..)

Profiling example (4)

- Observations :

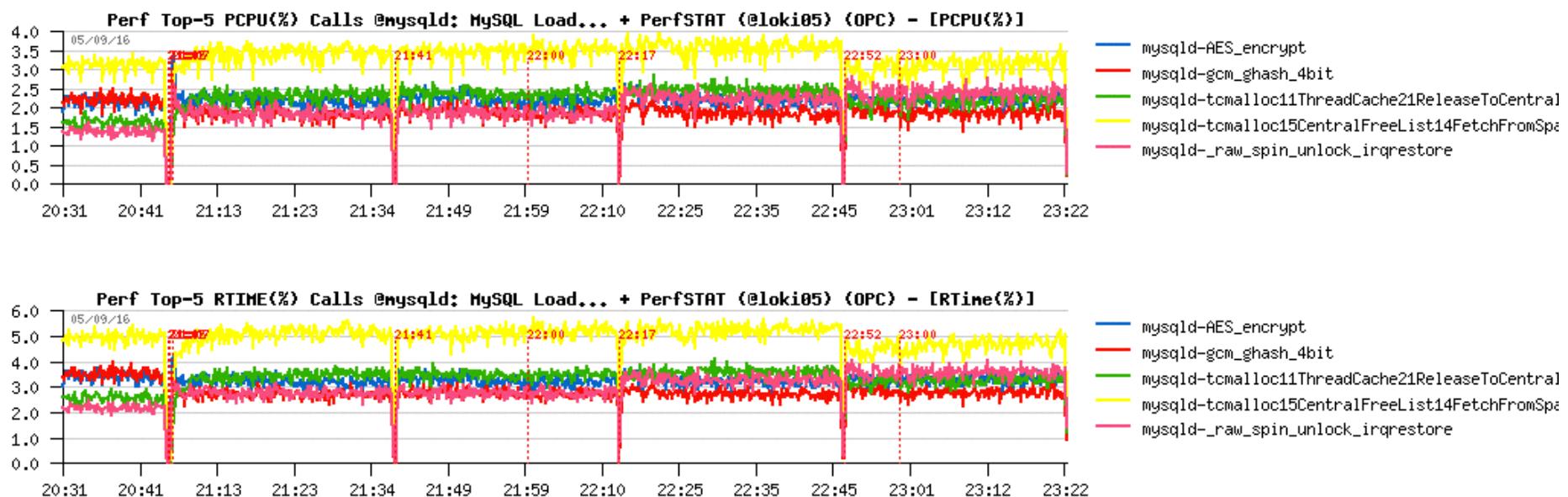
- `_spin_lock()` is the most hot (or `ut_delay`, or `rw_lock*`, or `*lock*`, etc.)
- you're hitting a lock contention! (MySQL or not)
- if MySQL : analyze PFS waits, innodb status, mutex status, etc..

```
PerfTop: 296349 irqs/sec  kernel:44.9%  exact: 0.0% [4000Hz cycles], (all, 80 CPUs)

29.04% [kernel]                                [k] _spin_lock
15.39% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] PolicyMutex<TTASMutex<NoPolicy> >::e
10.18% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] mtr_t::Command::prepare_write()
6.21% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] ut_delay(unsigned long)
1.55% [kernel]                                [k] native_write_msr_safe
1.52% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] log_write_up_to(unsigned long, bool)
0.78% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] rw_lock_x_lock_func(rw_lock_t*, unsigned
0.59% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] buf_page_get_gen(page_id_t const&, page_s
0.44% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] btr_cur_search_to_nth_level(dict_index_t*, 
0.38% [kernel]                                [k] schedule
0.35% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] lock_table(unsigned long, dict_table_t*, lo
0.34% mysqld-576-withPFS-03-Sep17-no OMIT-futex  [.] trx_undo_assign_undo(trx_t*, trx_undo_ptr_t
0.27% libjemalloc.so                           [.] free
0.27% libjemalloc.so                           [.] malloc
```

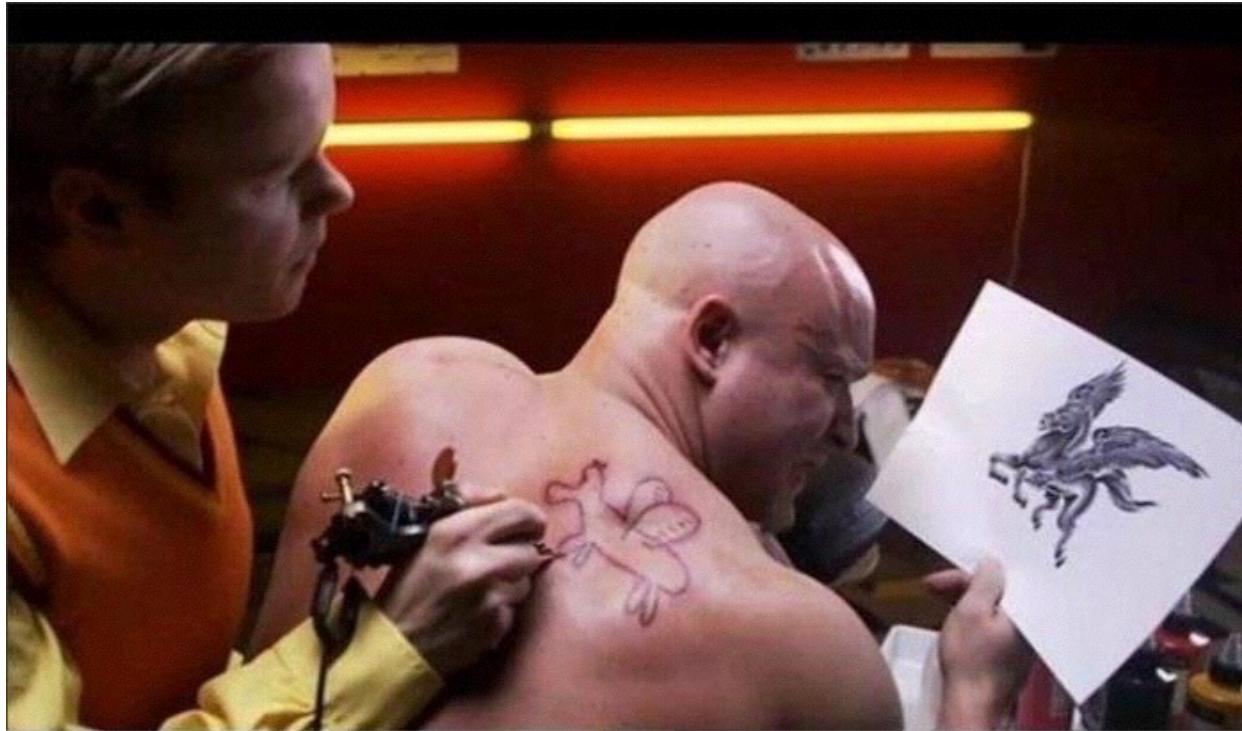
PerfSTAT example

- Observations :
 - tcmalloc is on top of CPU hot functions..
 - Action : try to use jemalloc instead
 - Result : x2 times better Max TPS (!)



Things are progressing quickly !

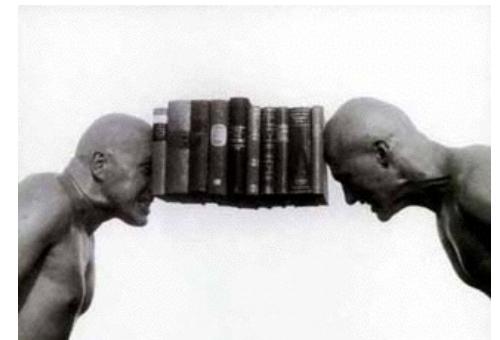
- Constantly learn and improve your skills !
- Don't delegate your production workload to googled "quick tips" ;-))



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To Really Understand Something.. (The (dim) PLAN)

- Whatever Test workload you prepared :
 - go with Read-Only scenario to begin !
 - small data volume first (20M rows at least, in-memory)
 - then a bigger dataset, but still in-mamory
 - then IO-bound test (dataset is bigger than available memory)
 - after what you can switch to Read+Write scenario
 - on begin start with “relaxed” security (trx_commit=2, no binlog, no DBLWR, etc.)
 - same as RO, small data volume first (see how well your flushing will follow)
 - then bigger volume, still in-memory (see your flushing increased, higher pages activity)
 - then IO-bound (see your TPS diff vs RO, LRU flushing, IO reads, etc.)
 - then replay all again with progressively step-by-step increased data security :
 - trx_commit = 1
 - doublewrite = 1
 - binlog & binlog sync = 100
 - binlog & binlog sync = 1
 - always monitor & observe your flushing rate & times, Purge activity / History Length, Checkpoint Age, Dirty / Free pages levels, page waits / page scans, etc..



Analyzing Workloads “by pattern” : RO -vs- RW

- Read-Only (RO) :
 - Nothing more simple when comparing DB Engines, HW configs, etc..
 - RO In-Memory : data set fit in memory / BP / cache
 - RO IO-bound : data set out-passing a given memory / BP / cache
- Read+Write (RW) :
 - I/O is **ALWAYS** present ! - storage performance matters a lot !
 - may be considered as always IO-bound ;-)
 - RW In-Memory : same as RO, data set fit in memory, but :
 - small data set => small writes
 - big dataset => big writes ;-)
 - RW IO-bound : data set out-passing a memory
 - means there will be (a lot of?) reads !
- NOTE : Random Read (RR) operation is the main IO-bound killer !!!
 - so, **GO Flash !!!**

Read-Only Performance @MySQL / InnoDB

- Depends on a workload..
 - sometimes the limit is only within your memcpy() rate ;-)
- But really started to scale only since MySQL 5.7
 - due improved TRX list management, MDL, THR_lock, etc..
 - scaling up to 96 CPU cores-HT for sure, reported on more cores too..
 - Note : remind my “scalability” notes ;-))
 - Note : code path is growing with new features! (small HW may regress)

RO related starter configuration settings

- my.conf :

```
join_buffer_size=32K .. 2M
sort_buffer_size=32K .. 2M

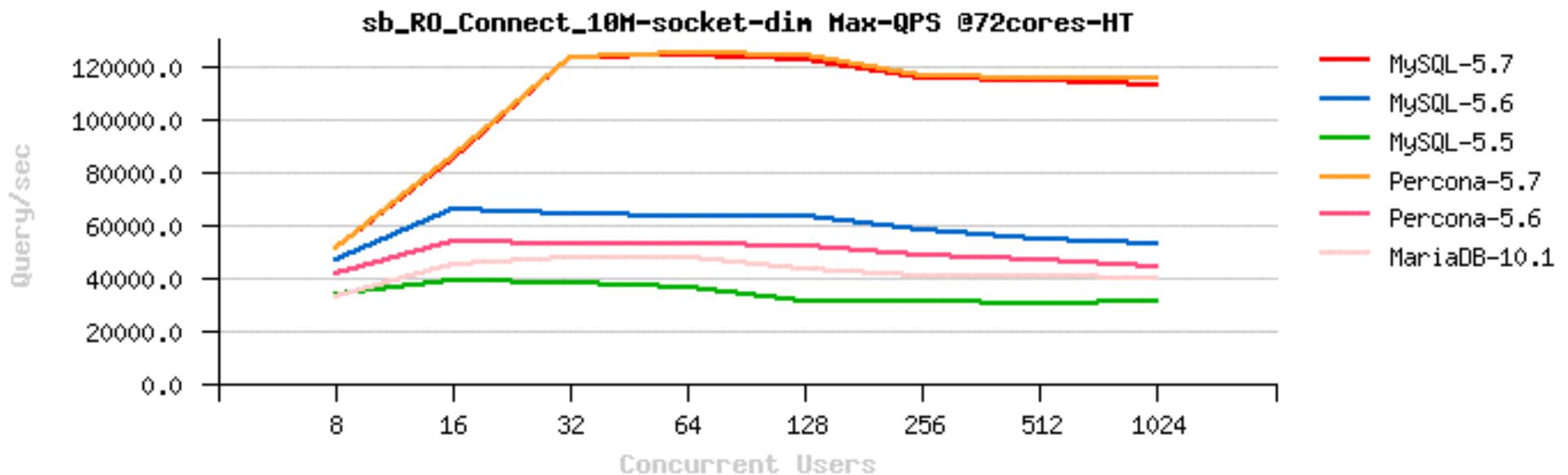
table_open_cache = 8000
table_open_cache_instances = 16
query_cache_type = 0

innodb_buffer_pool_size= 64000M (2/3 RAM ?)
innodb_buffer_pool_instances = 32
innodb_thread_concurrency = 0 / 32 / 64
innodb_spin_wait_delay= 6 / 48 / 96

innodb_stats_persistent = 1
innodb_adaptive_hash_index= 0 / 1
innodb_monitor_enable = '%'
```

Entry Ticket : RO_Connect

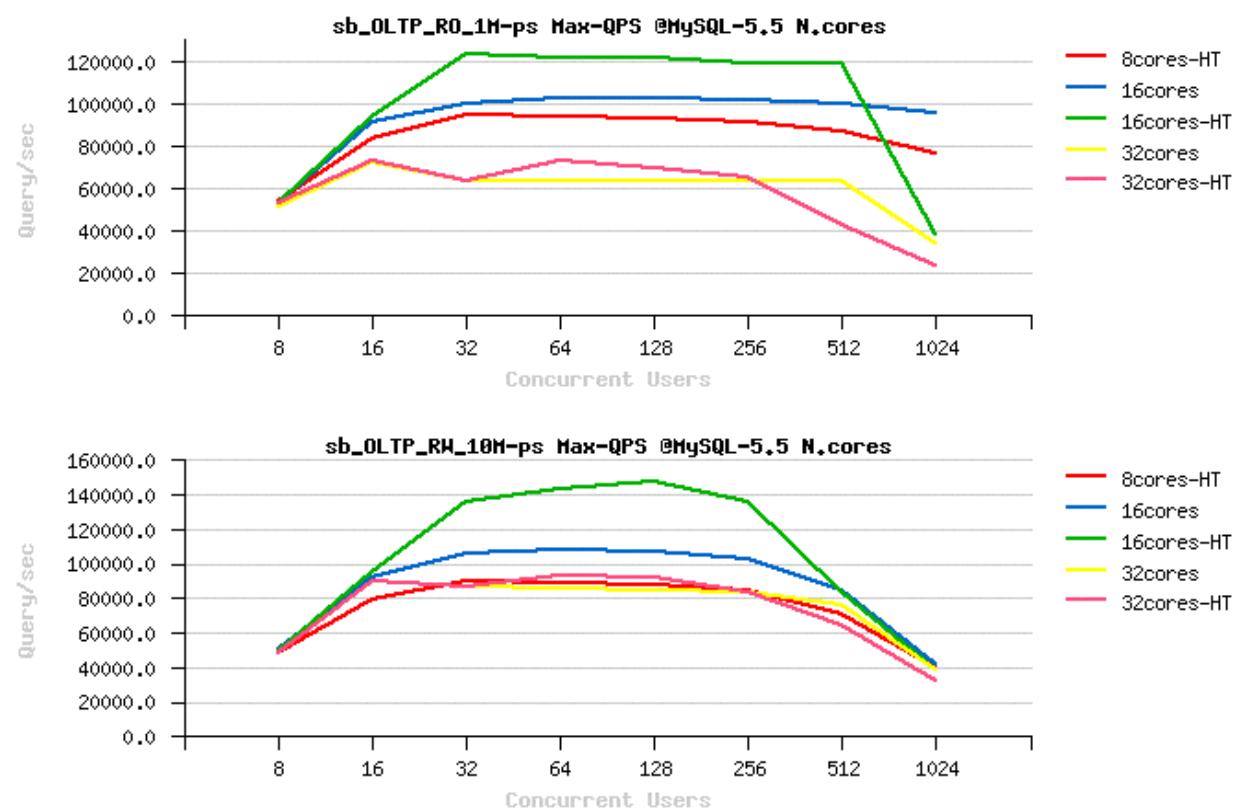
- Many web apps cannot use persistent connections
 - connect => Query(s) => disconnect



Why so much attention to RO Performance in MySQL 5.7 ?..

From where we're coming with MySQL 5.7 ?..

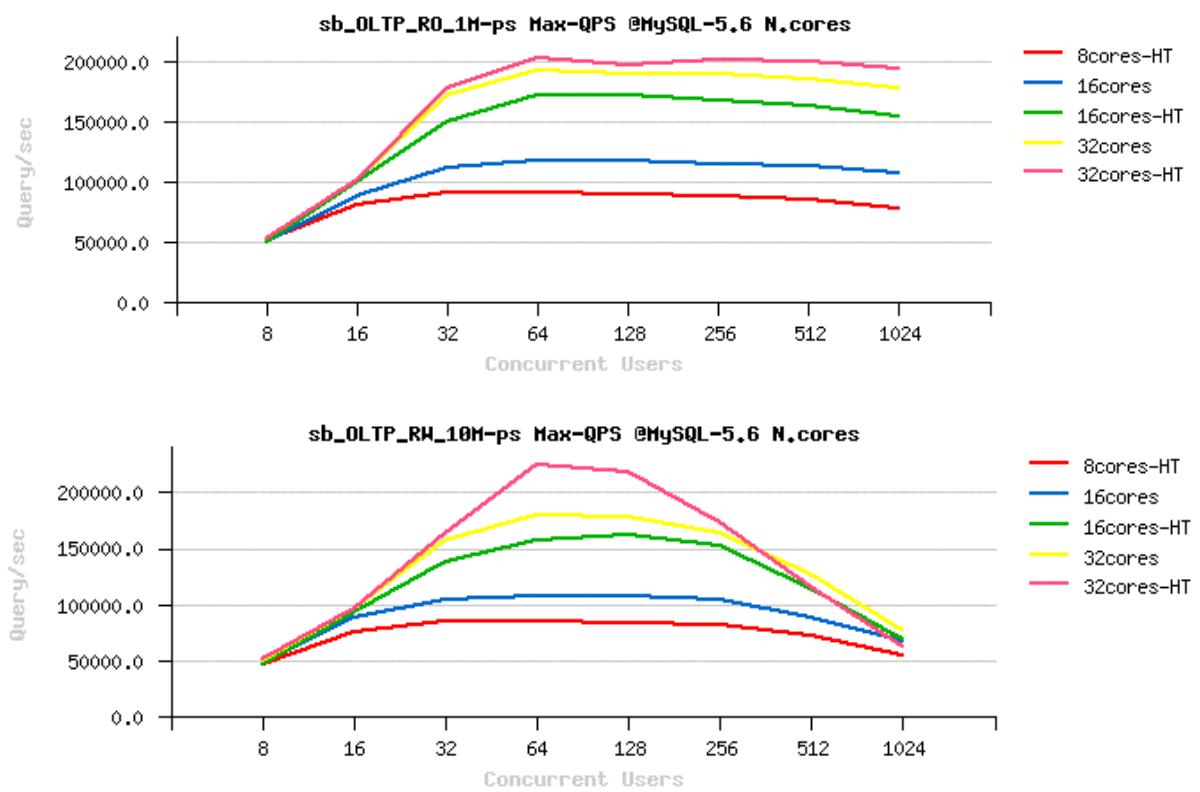
- MySQL 5.5 : RO & RW
 - QPS Max on 16cores
 - worse on 32cores
 - Note: RW out-pass RO!



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From where we're coming with MySQL 5.7 ?..

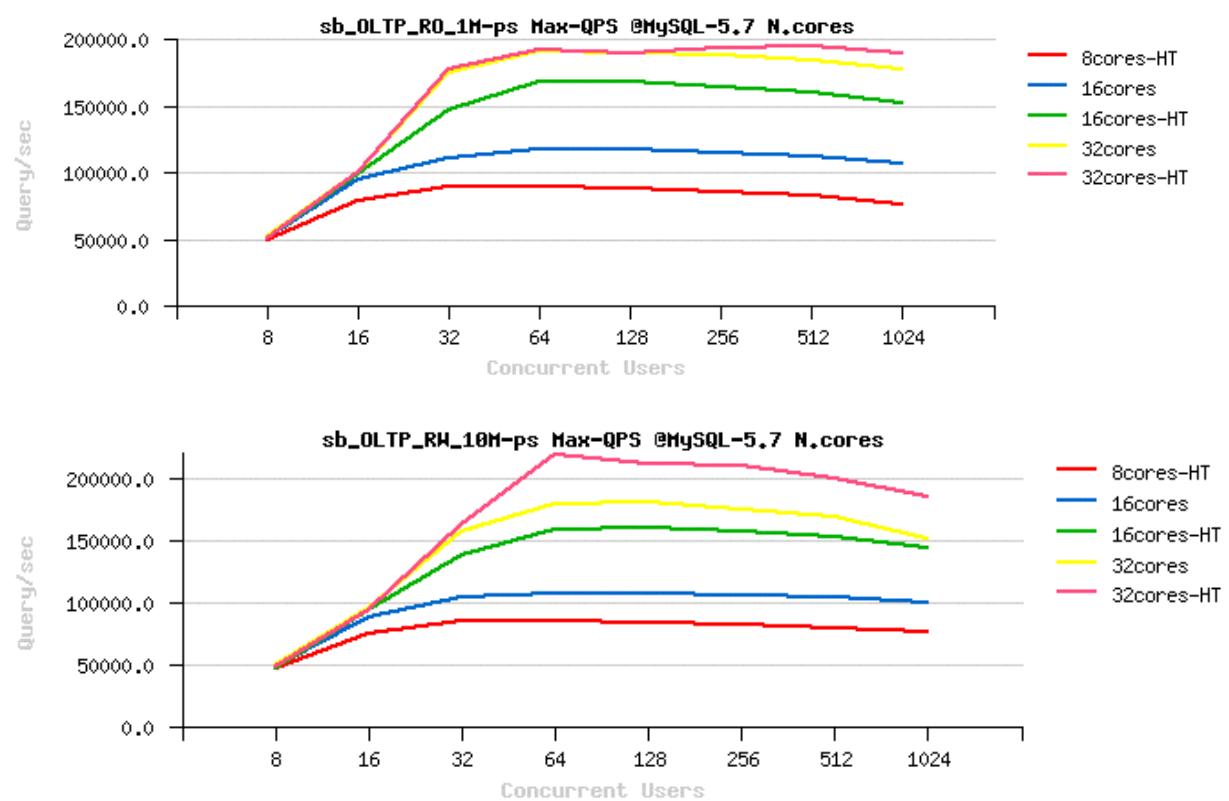
- MySQL 5.6 : RO & RW
 - not lower on 32cores!! ;-)
 - RW out-pass RO !!..??



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From where we're coming with MySQL 5.7 ?..

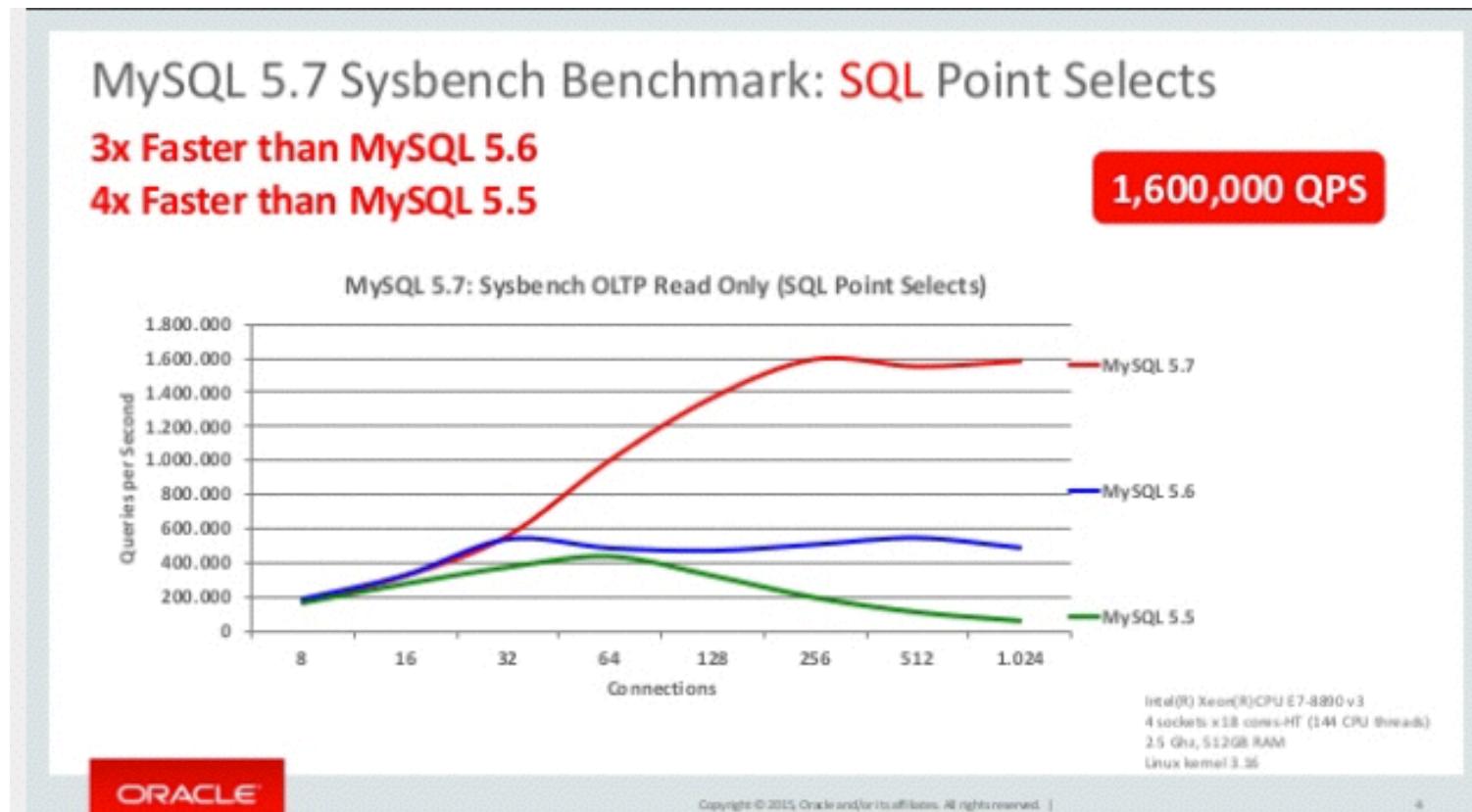
- MySQL 5.7.1 : RO & RW
 - more stable than 5.6
 - RW out-pass RO !!..



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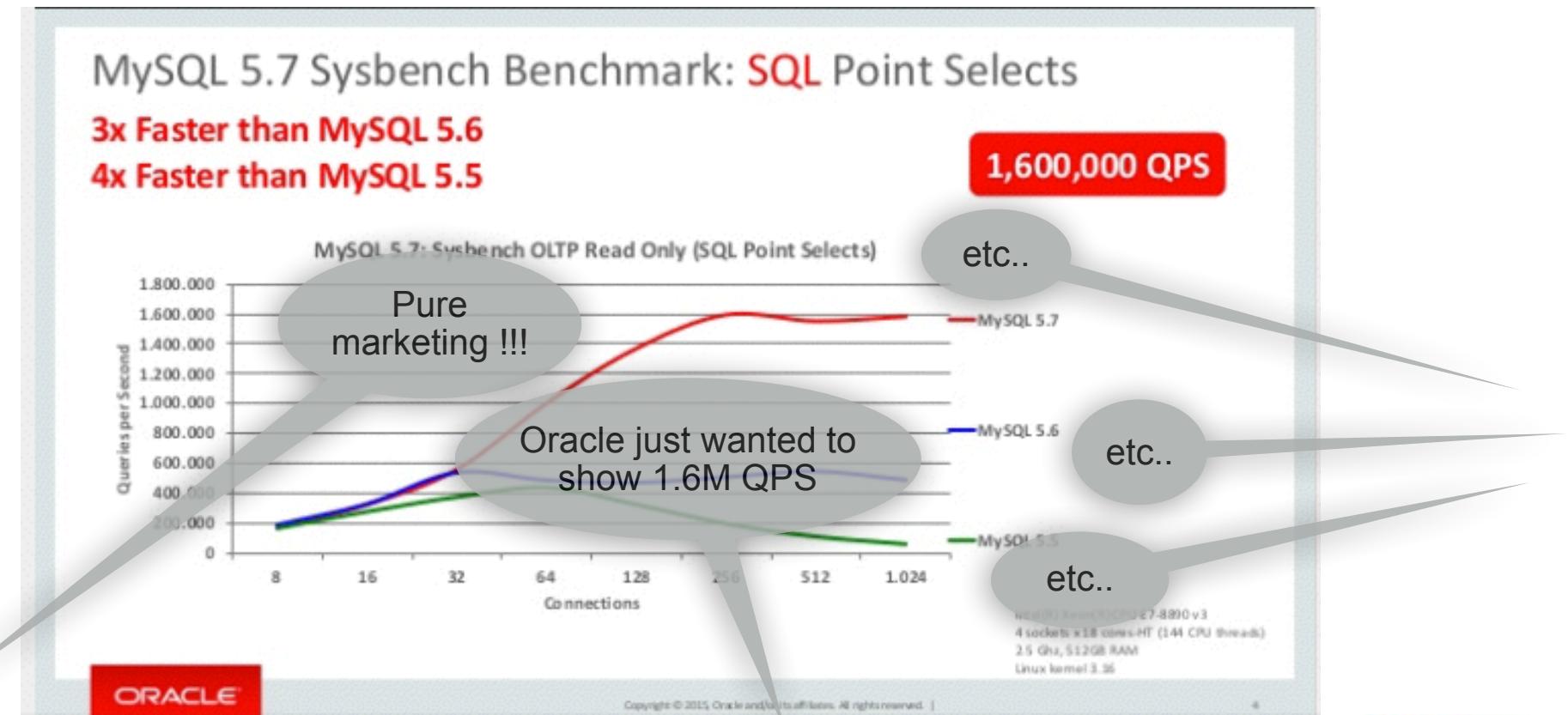
MySQL 5.7 : 1.6M QPS

- What is behind this number ?..



MySQL 5.7 : 1.6M QPS

- What is behind this number ?..



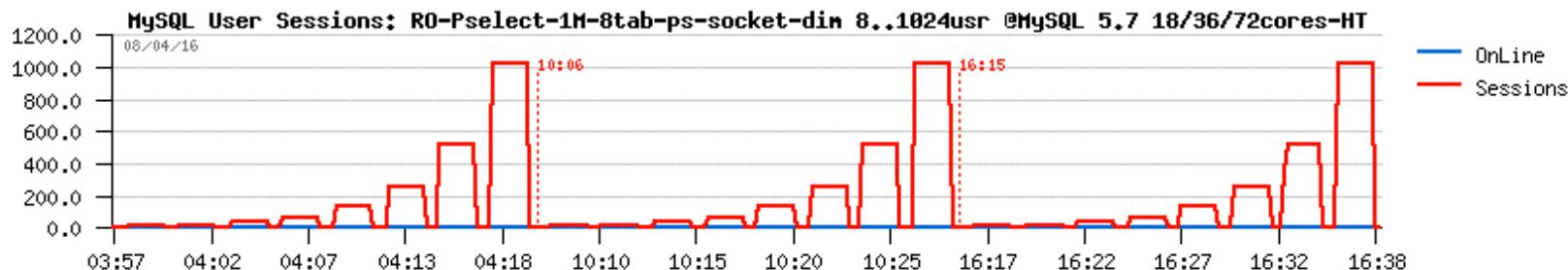
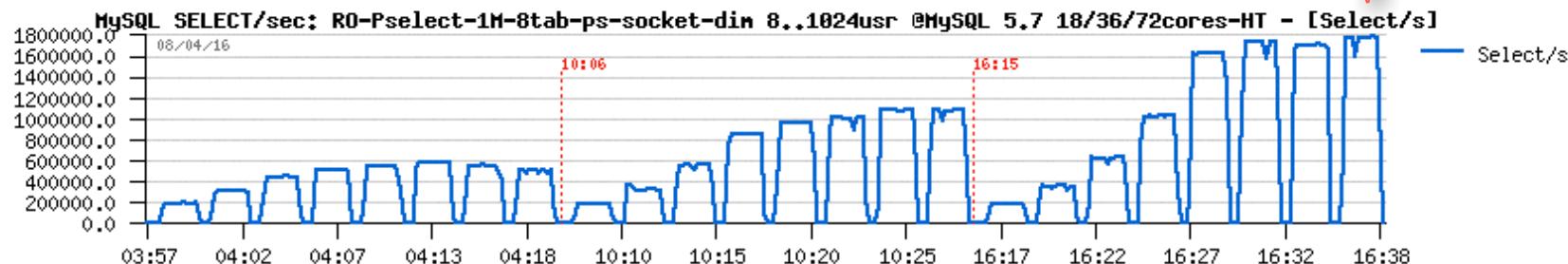
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Marketing ?..

- Why you did not hear then about **1.8M QPS** ?.. ;-))

- same 72cores-HT server, same MySQL 5.7
- we are not running after numbers ;-)
- numbers are just reflecting what is behind..

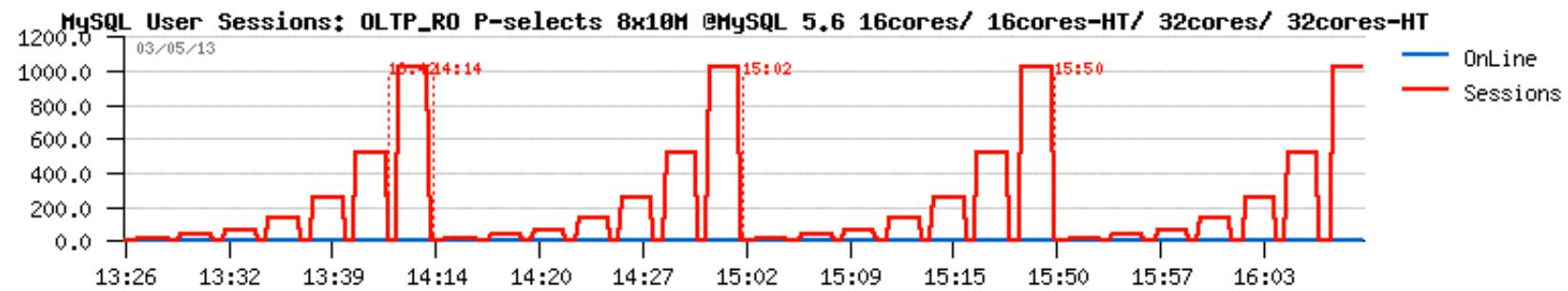
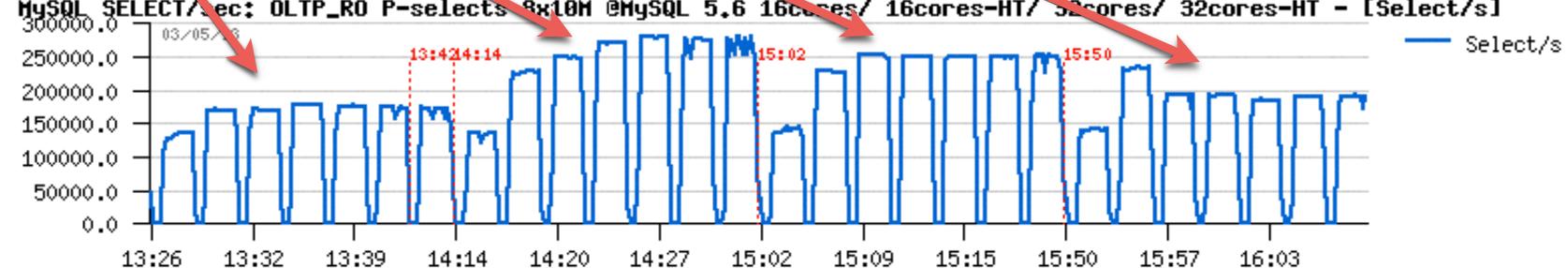
1.8M QPS



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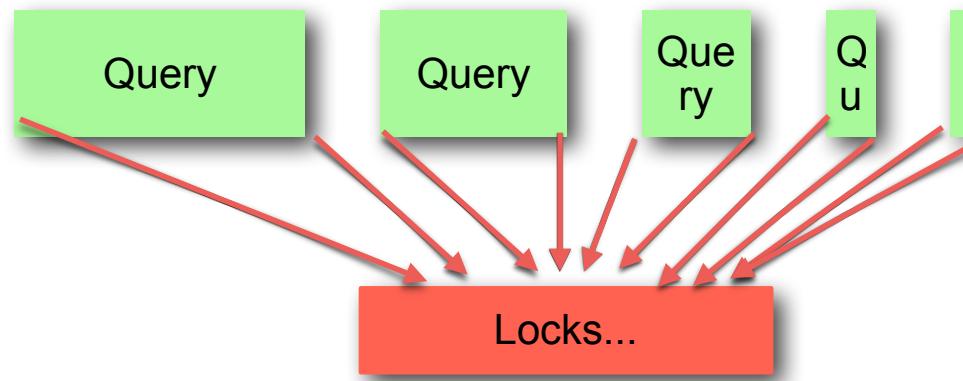
Behind the numbers...

- MySQL 5.6, RO Point-Select Performance
 - 16cores, 16cores-HT, 32cores, 32cores-HT



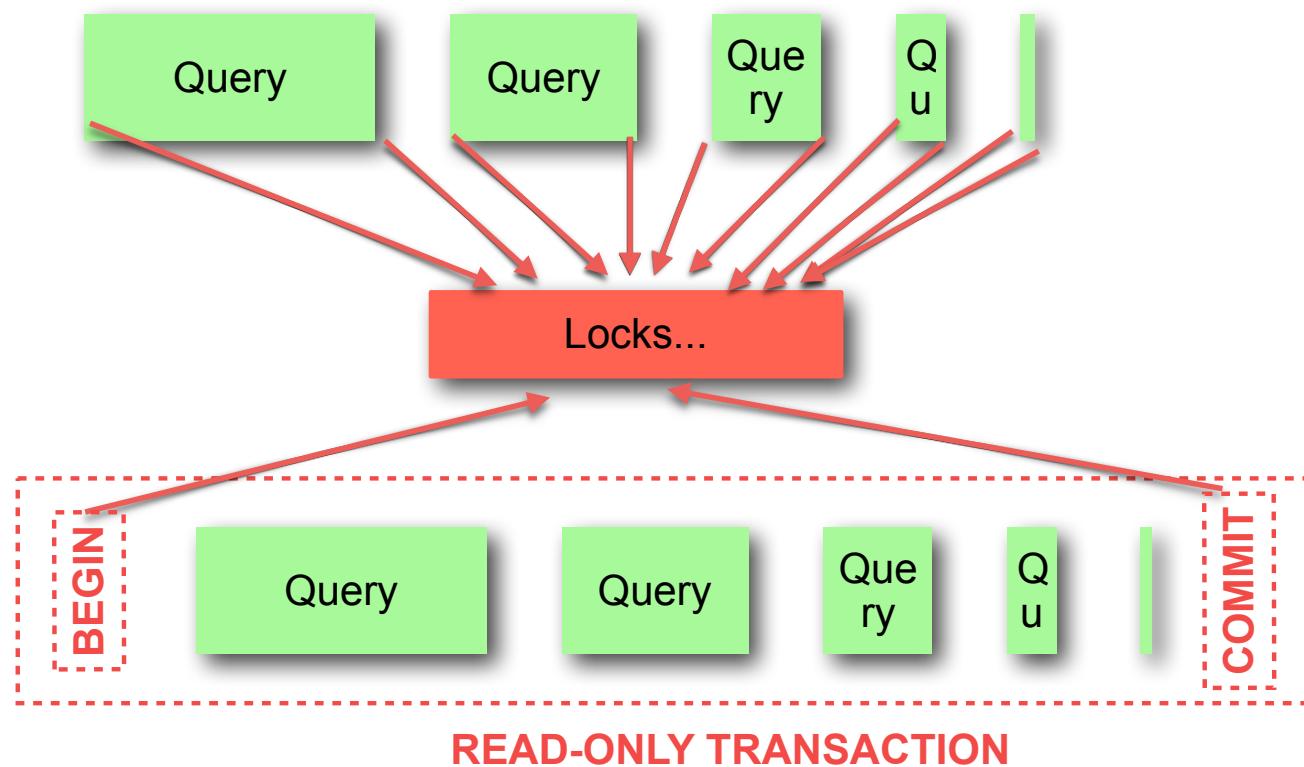
Behind the numbers...

- Why ?..



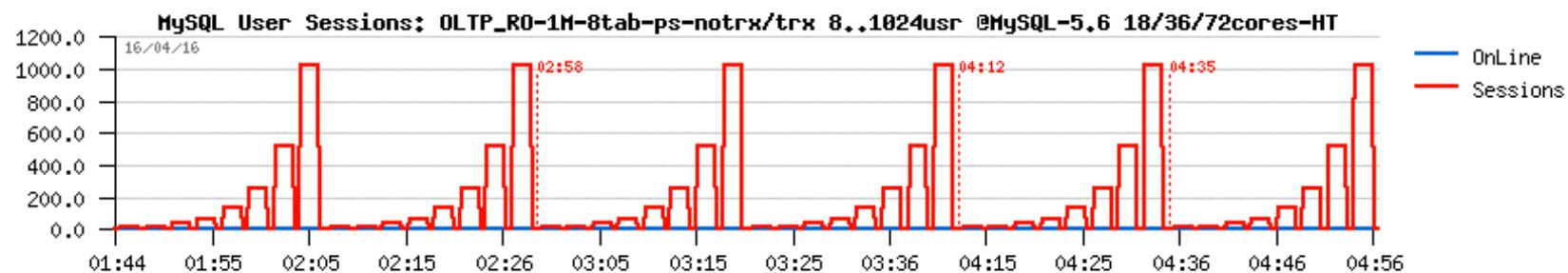
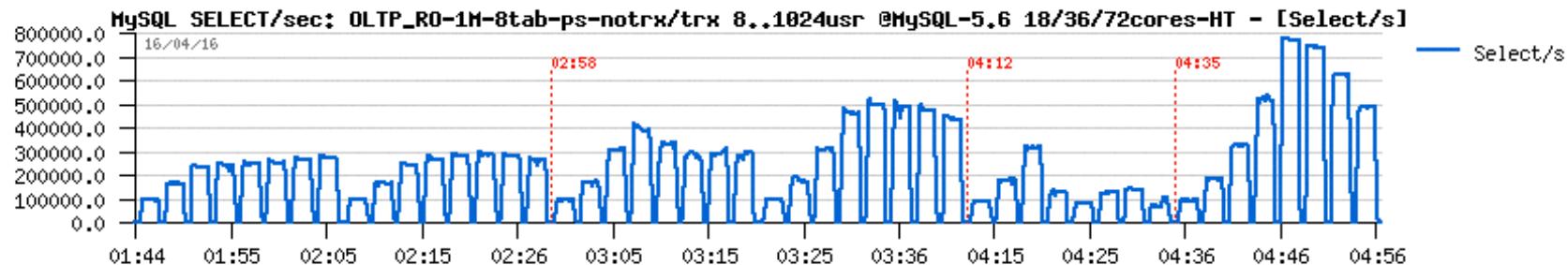
Behind the numbers...

- MySQL 5.6 : Read-Only Transactions "workaround" :



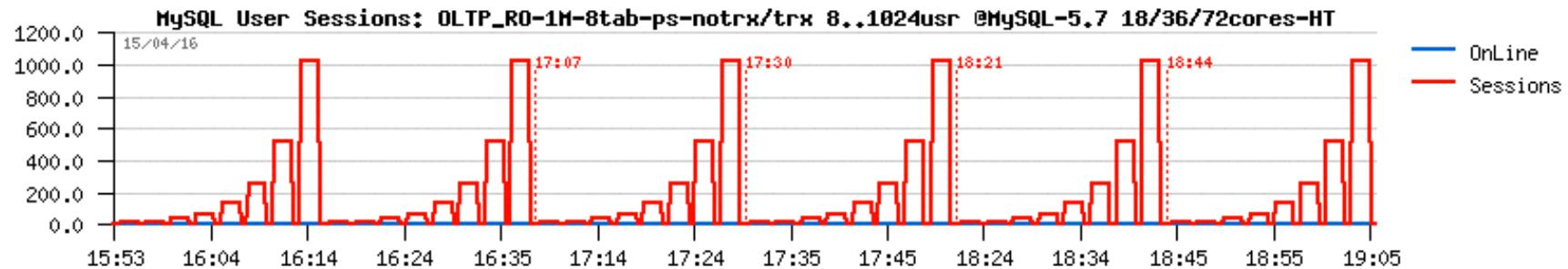
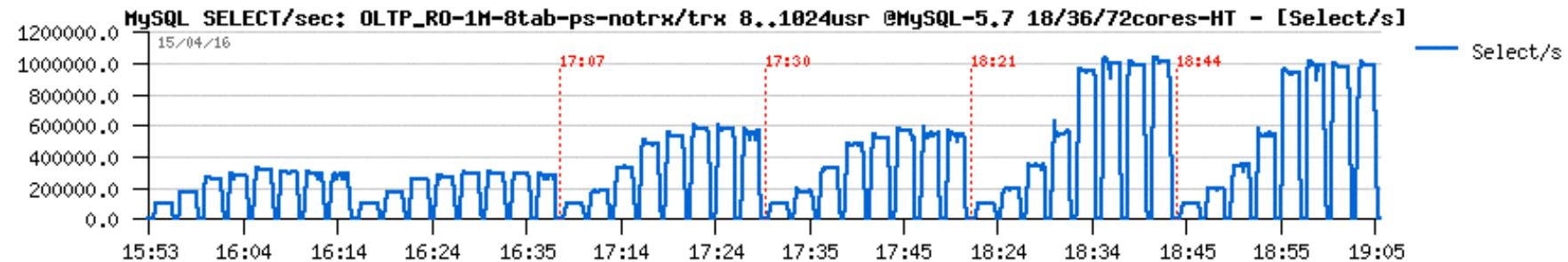
Behind the numbers...

- MySQL 5.6, OLTP_RO-1Mx8-tables, 72cores-HT
 - OLTP_RO : [x14 SELECT Queries]
 - without / with transaction enclosure, 18/36/72cores-HT



Behind the numbers...

- MySQL 5.7, OLTP_RO-1Mx8-tables, 72cores-HT
 - OLTP_RO : [x14 SELECT Queries]
 - without / with transaction enclosure, 18/36/72cores-HT



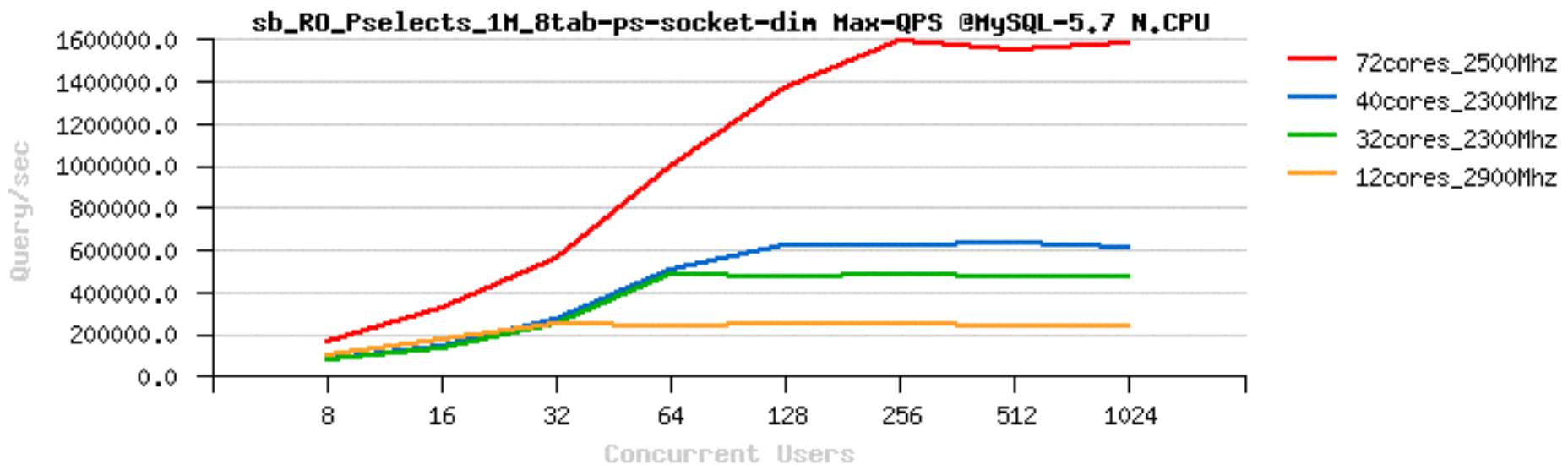
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Behind the numbers...

- Up to you to decide what is less or more significant for you..
- If for ex. [x1000(!) Point-Select Queries] in transaction is OK
 - as was done by MariaDB to show their 1M QPS result..
 - hm.. and nobody called this Marketing ?..

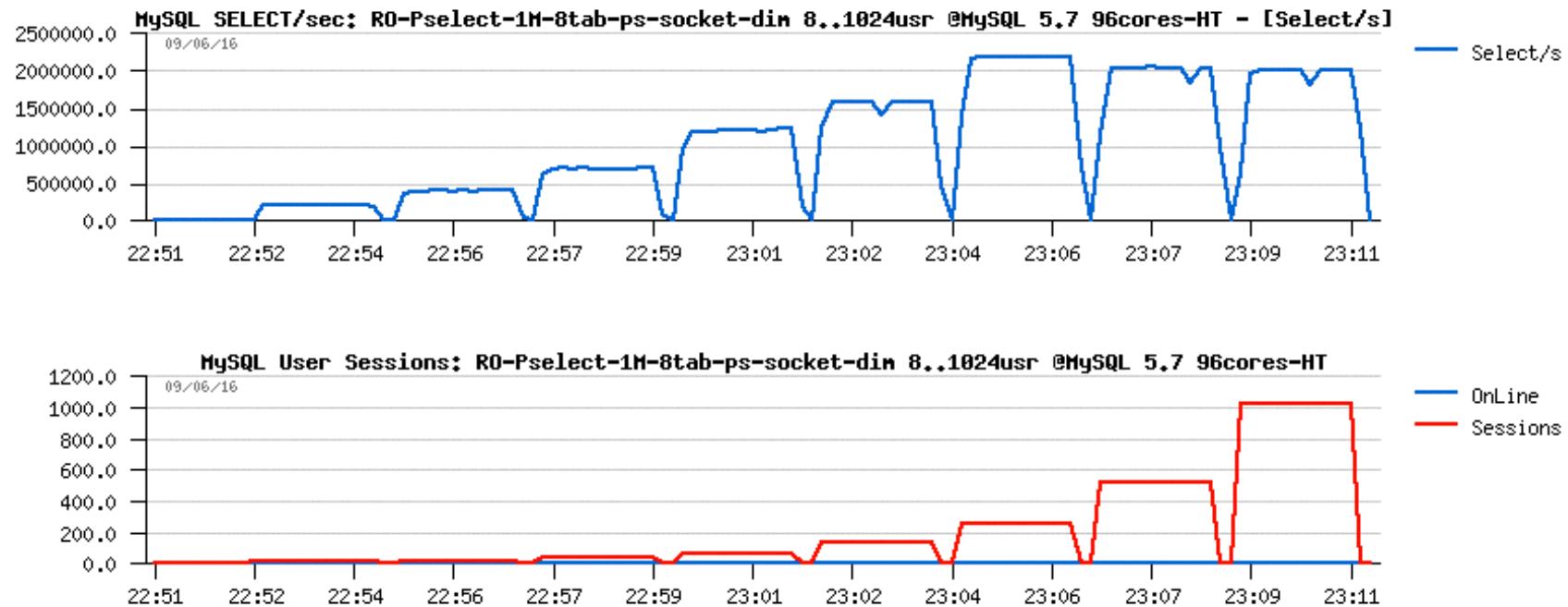
RO Point>Selects @MySQL 5.7

- Sysbench Point-Selects 8-tab => HW Progress :
 - new Intel CPU chips rock! (on 72cores-HT server here)



RO Point-Selects @MySQL 5.7 (One more thing..)

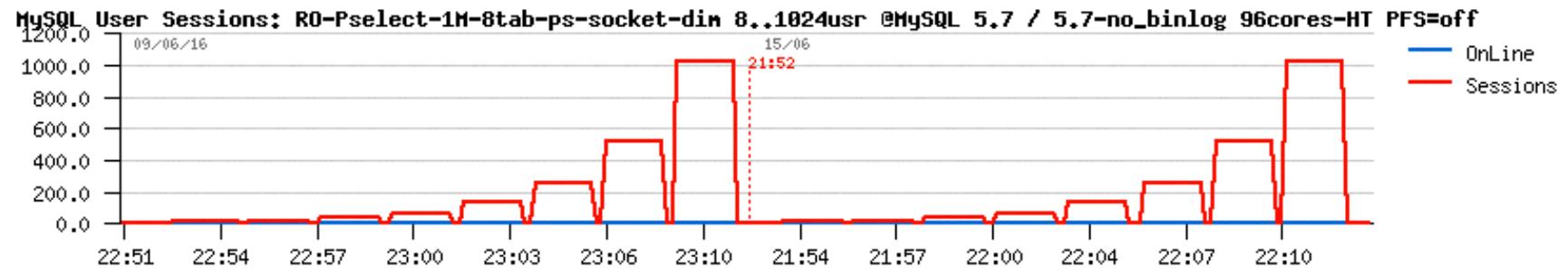
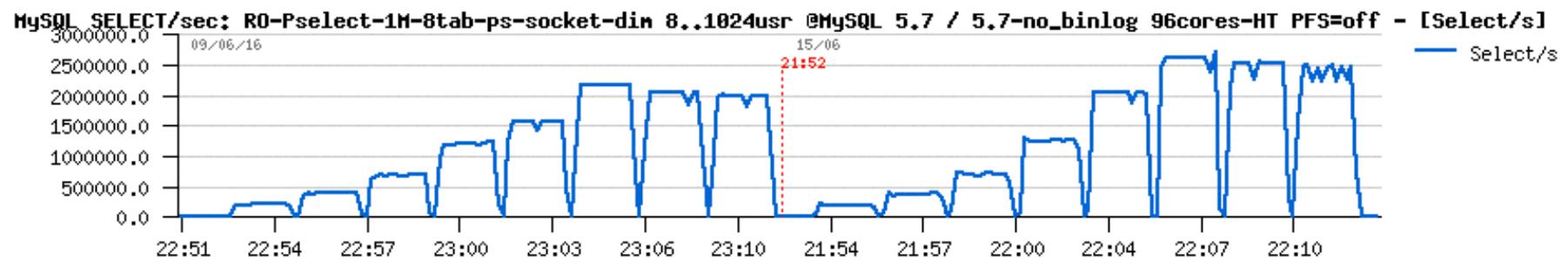
- Sysbench Point-Selects 8-tab => HW Progress : **2.2M QPS**
 - new Intel CPU chips rock! (the same 72cores-HT server upgraded to 96cores-HT)



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RO Point-Selects @MySQL 5.7 (One more thing..)

- Sysbench Point-Selects 8-tab => HW Progress : **2.5M QPS ;-))**
 - the same upgraded to **96cores-HT** server + some tweaking..



RO Pending Issues...

- PK vs Secondary Indexes lookup
 - lookups via PK are faster than via Secondary Indexes
 - sometimes x10 times faster (or even more)..
 - directly depending on the amount of rows to read..
 - AHI is helping here (but not solving)
 - “covering” indexes are solving, but needing more space + impacting writes
- InnoDB Adaptive Hash Index (AHI)
 - implemented with a global RW-lock
 - InnoDB RW-locks are not scaling by design (CPU cache syncs)
 - using table partitions helps to split indexes
 - using AHI partitions (5.7) helps to split RW-locks (coop. with Percona)
 - NOTE: and this is creating **20% regression** on DBT3 benchmark (single-thread)..
 - just to mention how the code is sensible today ;-)
 - yet far from fixed..

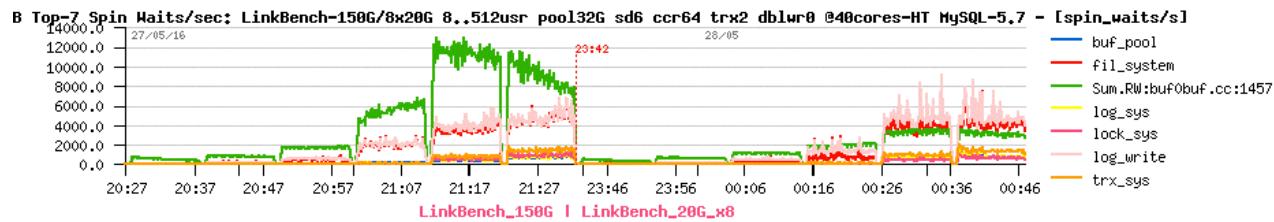
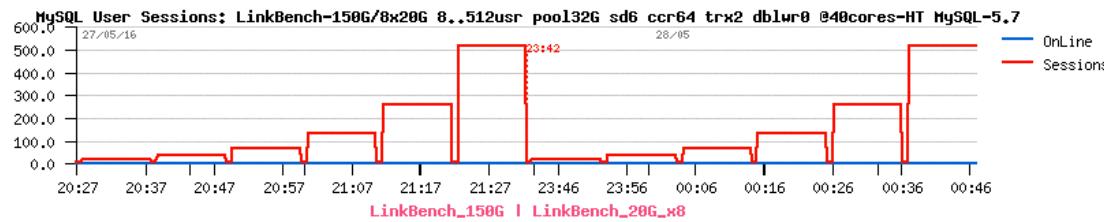
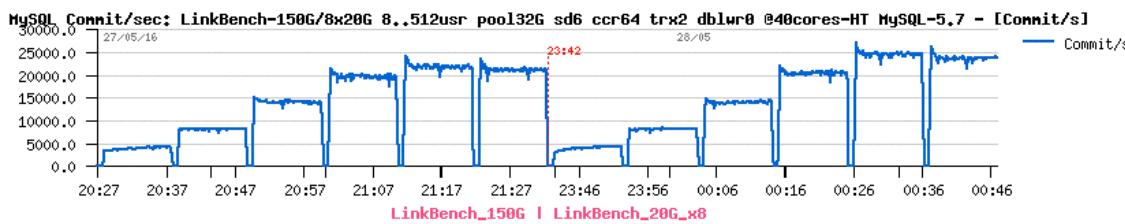
RO Pending Issues...

- InnoDB Block Locks

- seen when the same pages are accessed concurrently..
- how to see : “show mutex” is back ;-)
- **workarounds :**
 - avoid such an access pattern, don’t do this ;-)
 - use a smart query cache (like ProxySQL), or row cache (memcached, etc.)..
- expected to be fixed in v.xx.0 ..
 - requires a full page re-design..
 - so, nothing yet promised.. ;-)
- **NOTE :**
 - impacts not only RO, but also RW ..

LinkBench-150GB

- IO-bound (150GB dataset with BP=32GB)
 - single 150GB database -vs- 8 x 20GB databases

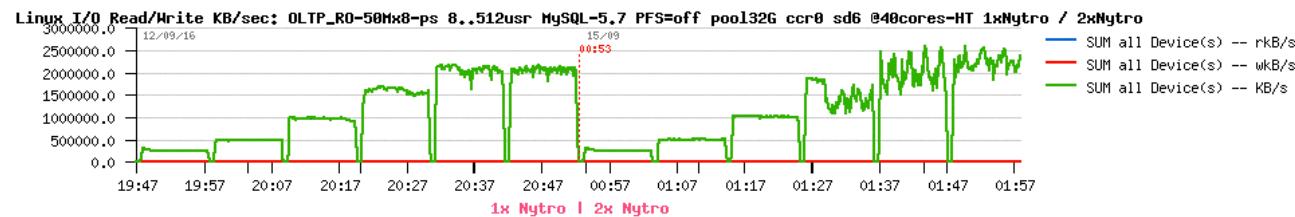
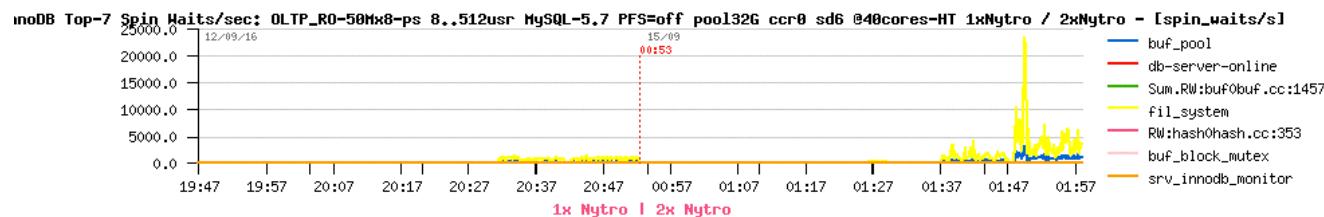
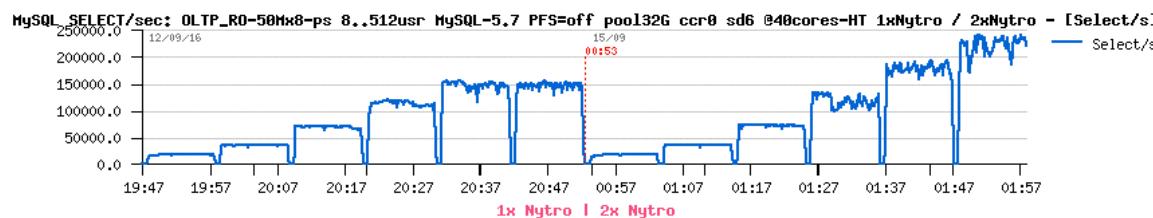


Read-Only : IO-bound @MySQL

- 5.5 : hmm..
- 5.6 / 5.7 :
 - LRU driven : just page eviction, see METRICS stats
 - HDD : limited by your I/O layer..
 - SSD : limited by your I/O layer..
 - Really Fast Flash (LSI, Fusion-io, Seagate, etc.) :
 - avg load : follow I/O performance
 - high load: fil_sys mutex contention + kernel / FS locks !
 - also consider : innodb_old_blocks_time & innodb_old_blocks_pct
- 5.7 :
 - excessive page scan is fixed

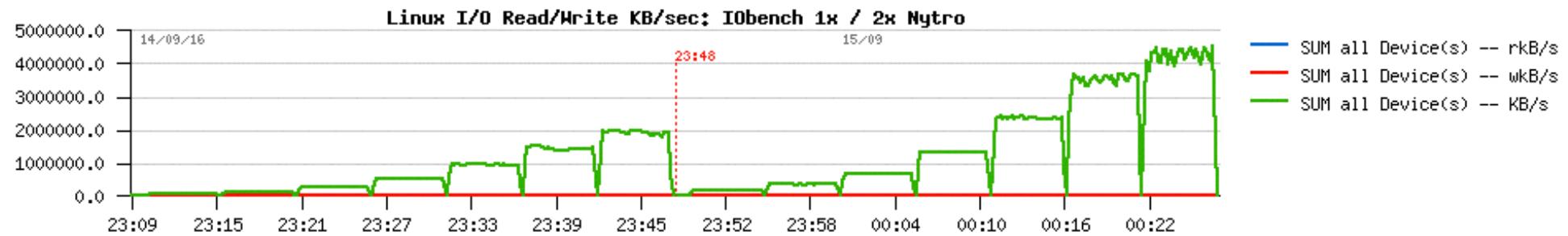
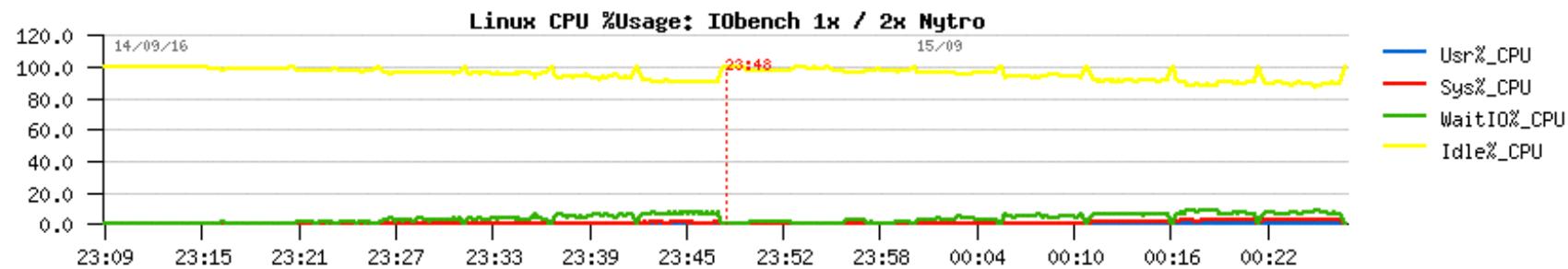
Read-Only IO-bound @MySQL 5.7

- OLTP_RO 8x50M tables BP=32GB Seagate Flash “Nytro”
 - 1x flash card -vs- 2x flash cards



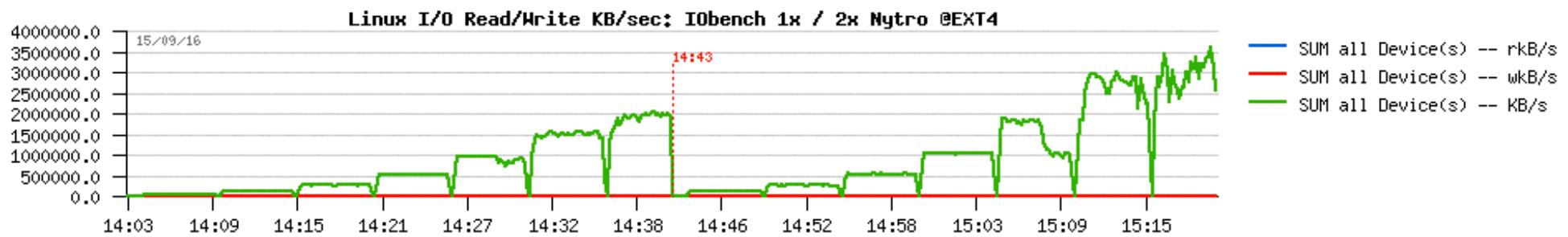
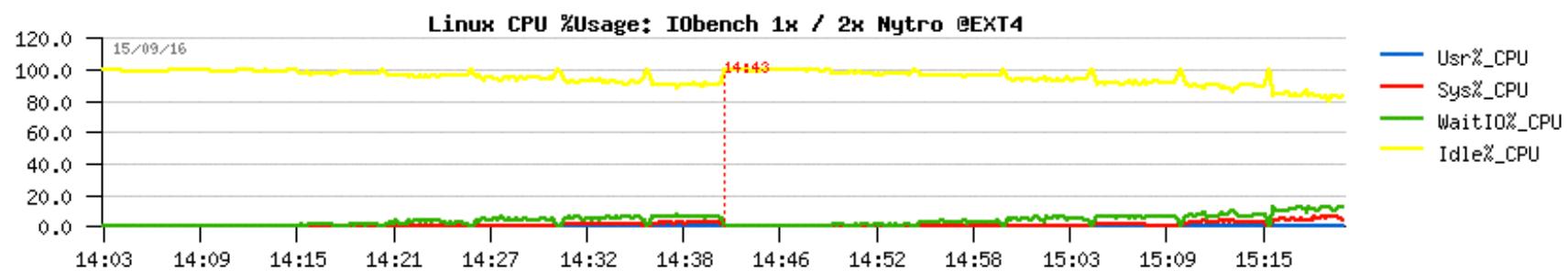
IO Reads Raw@Seagate Flash “Nytro” 1x -vs- 2x

- IOBench 16K Random-Reads from 128GB dataset
 - concurrency : 1,2,4 .. 64



IO Reads EXT4@Seagate Flash “Nytro” 1x -vs- 2x

- IOBench 16K Random-Reads from 128GB file(s)
 - concurrency : 1,2,4 .. 64



Hope it was not boring yet ?.. ;-)

- Because I'll need all your full attention since now! ;-)



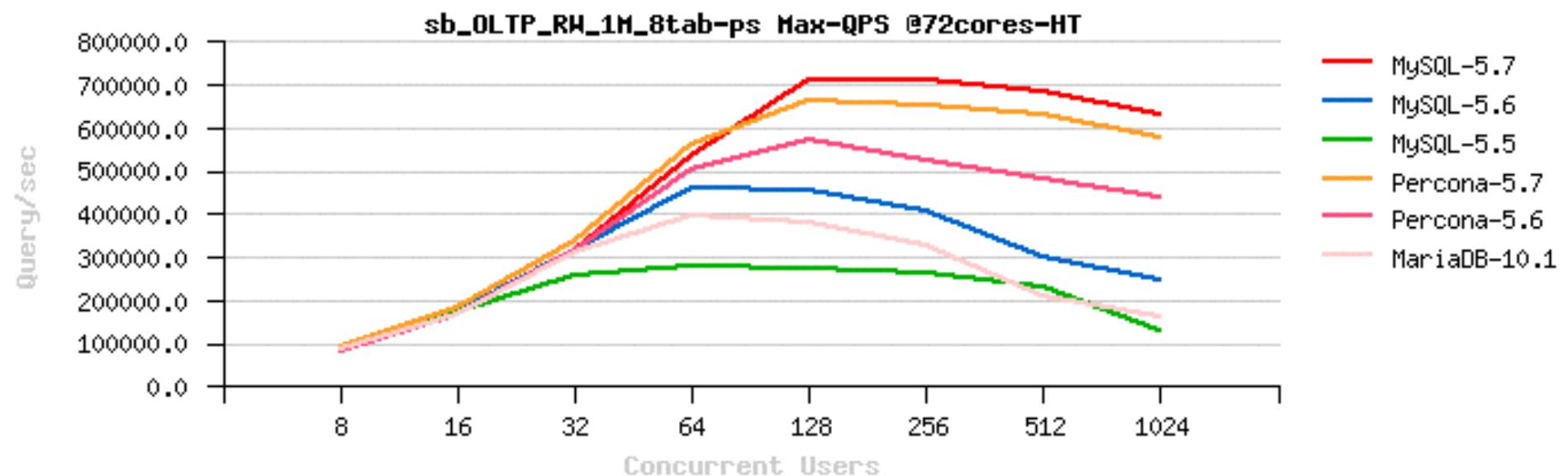
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ReadWrite (RW) Workloads Scalability @MySQL 5.7

- Huge progress is already here too!
 - improved index locking
 - reduced lock_sys mutex contention
 - parallel flushing + improved flushing design
 - much better observability of internals
 - etc..
- However, not yet as good as Read-Only..
 - Performance continues to increase with more CPU cores
 - But on move from 16 to 32cores-HT you may gain only 50% better
 - Better performance on a faster storage as well
 - **On OLTP_RW can use a full power of fast flash for today! (sometimes)**
 - **More work in progress ;-)**
 - Internal contentions & Design limitations are the main issues here..
 - still many things are in pipe & prototype..

OLTP_RW : 8-tables

- Sysbench OLTP_RW 1Mx8-tables
 - 72cores-HT
 - and the winner is: MySQL 5.7 !! (or Percona-5.7 + patch ;-))



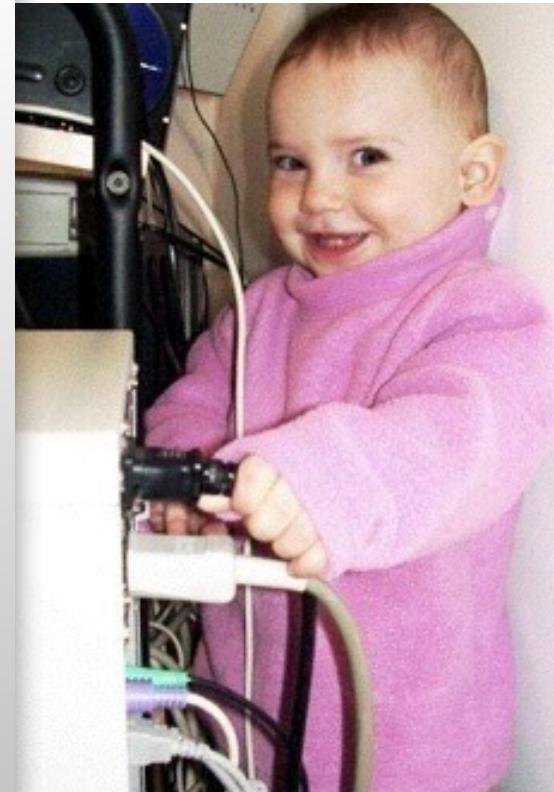
ReadWrite Performance @MySQL / InnoDB

- Transactional processing
 - your CPU-bound transactional processing defines your Max possible TPS
 - with a bigger volume / more IO / etc. => Max TPS will not increase ;-)
- Pending issues :
 - same as RO + REDO (log_sys), locks (lock_sys), TRX (trx_sys), AHI=off, etc..
 - Purge lagging, more improved Adaptive Flushing
- Data Safety
 - binlog : overhead + bottleneck (be sure you have binlog group commit)
 - InnoDB checksums : overhead (reasonable since crc32 is used)
 - innodb_flush_log_at_trx_commit = 1 : overhead + bottleneck
 - **InnoDB double write buffer : KILLER ! overhead + huge bottleneck..**
 - Fusion-io atomic writes is one of (true support in MySQL 5.7)
 - good news : the improved & more advanced DBLWR is coming for 5.7 & 8.0 ;-))

RW related starter configuration settings

- my.conf :

```
innodb_file_per_table  
innodb_log_file_size=1024M  
innodb_log_files_in_group=3 / 12 / ...  
innodb_checksum_algorithm= none / crc32  
innodb_doublewrite= 0 / 1  
innodb_flush_log_at_trx_commit= 2 / 1  
innodb_flush_method=0_DIRECT_N0_FSYNC  
innodb_use_native_aio=1  
innodb_adaptive_hash_index=0  
  
innodb_adaptive_flushing = 1  
innodb_flush_neighbors = 0  
innodb_read_io_threads = 16  
innodb_write_io_threads = 16  
innodb_io_capacity=15000  
innodb_max_dirty_pages_pct=90  
innodb_max_dirty_pages_pct_lwm=10  
innodb_lru_scan_depth=4000  
innodb_page_cleaners=4  
  
innodb_purge_threads=4  
innodb_max_purge_lag_delay=30000000  
innodb_max_purge_lag= 0 / 1000000  
  
binlog ??
```



RW Workloads : Checklist..

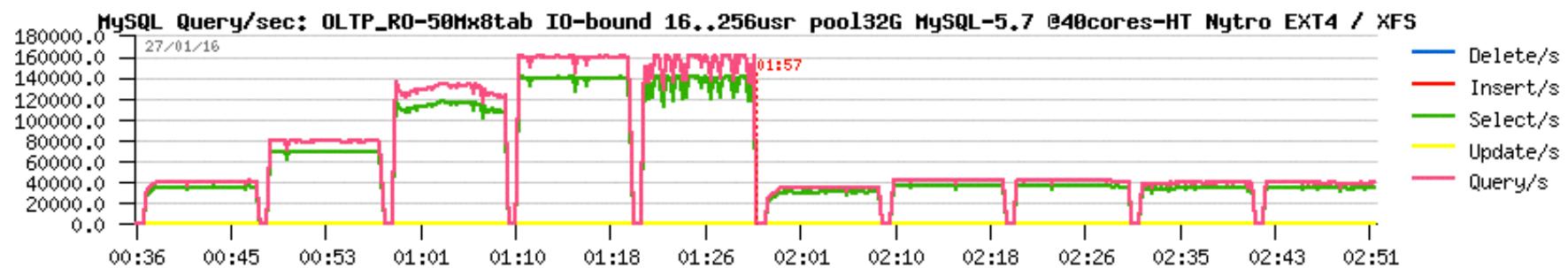
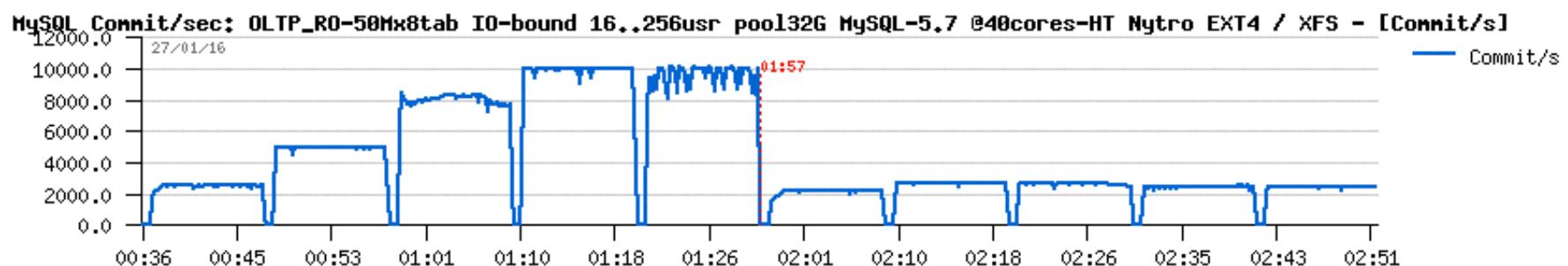
- To keep in mind :
 - FS choice
 - Flushing tuning
 - Double Write (DBLWR)
 - Purge
 - Massive INSERTs
 - UPDATE performance
 - etc..

RW Workloads : Test your Filesystem before to deploy

- Do first a pure IO test to know your FS + Storage limits
 - RO first (random 16K IO reads)
 - RW next
 - compare several FS to be sure you did not miss something ;-)
- Then run on them MySQL workload
 - same, RO first
 - RW next
 - do your own conclusions..
 - **NOTE** : it's not because that something is good for others that the same thing will be good for you.. — **test yourself !!!**

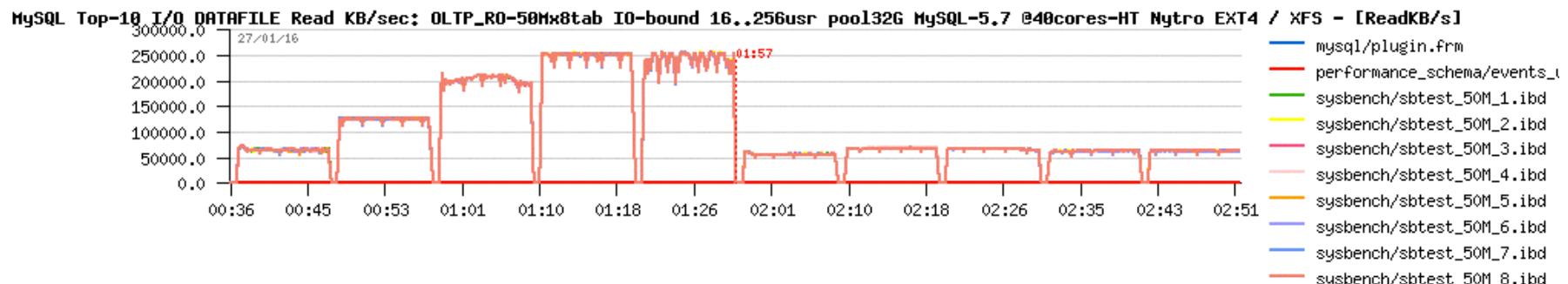
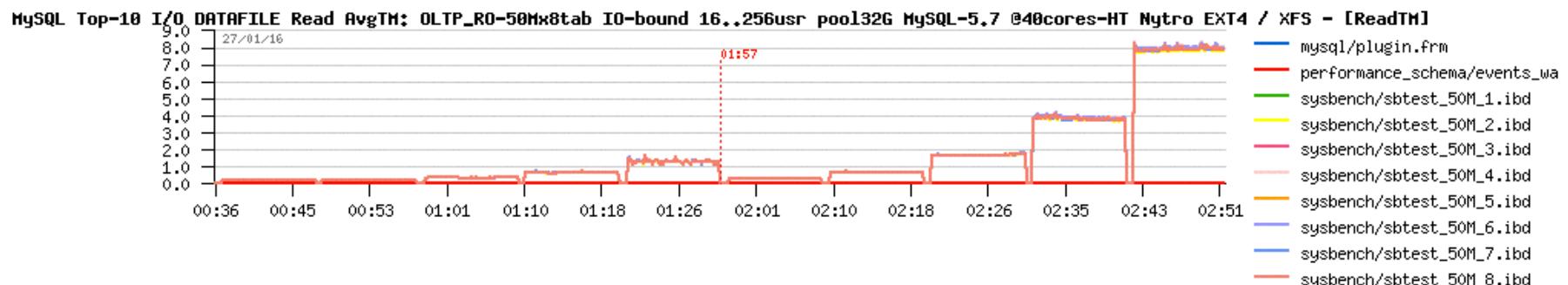
RW IO-Bound : Test your Filesystem before to deploy

- EXT4 vs XFS
 - OLTP_RW 50M x8-tab OL6.5 @ 40cores-HT, pool 32GB, trx2 :



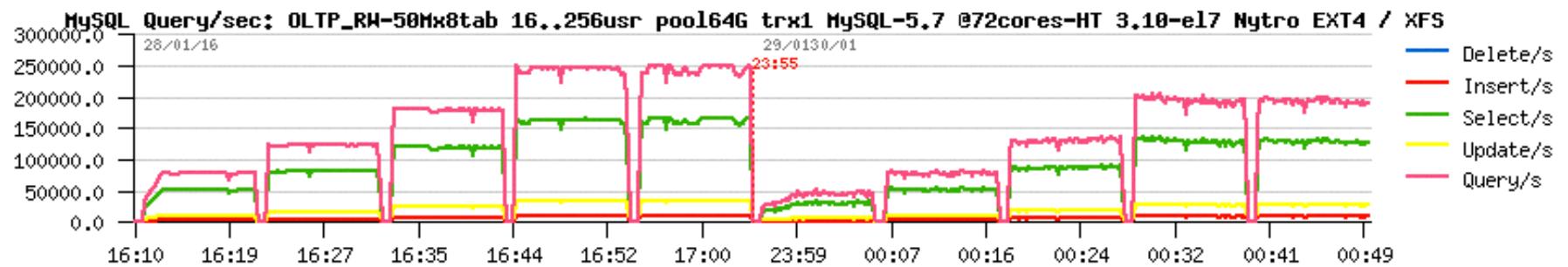
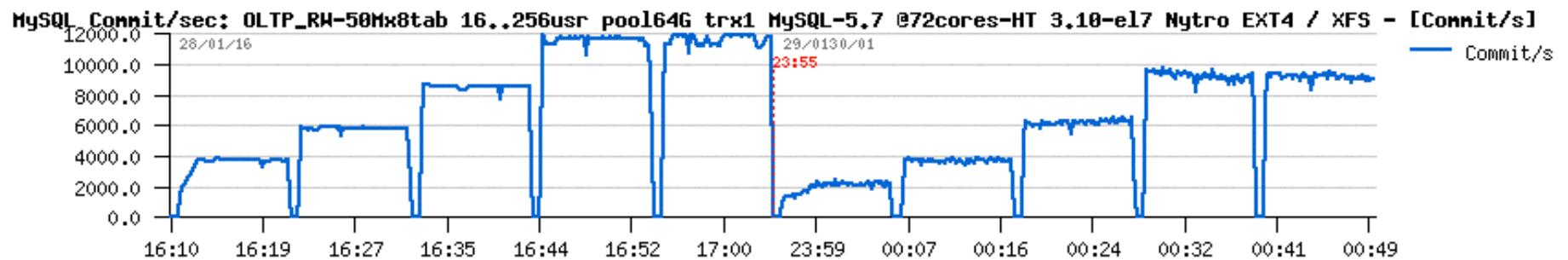
RW IO-Bound : Test your Filesystem before to deploy

- EXT4 vs XFS
 - OLTP_RW 50M x8-tab OL6.5 @ 40cores-HT, pool 32GB, trx2 :



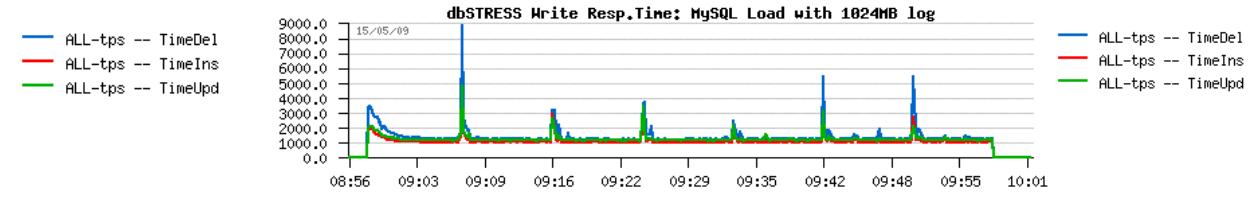
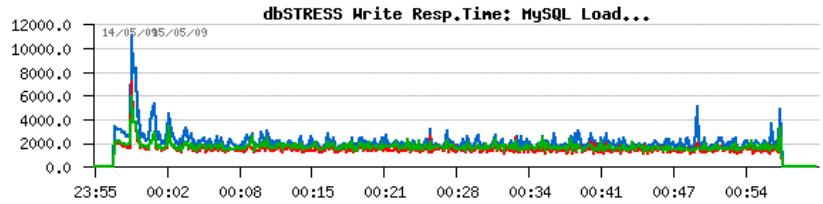
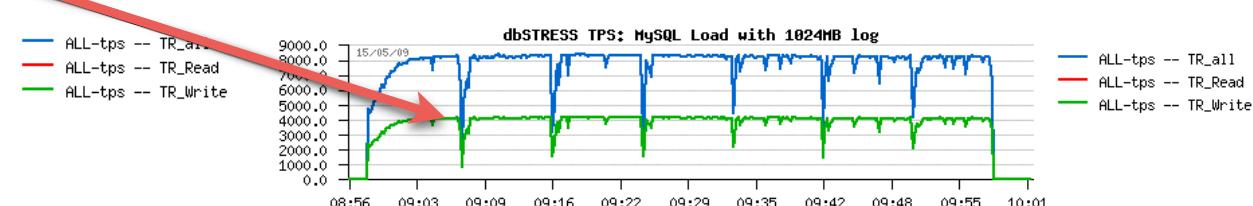
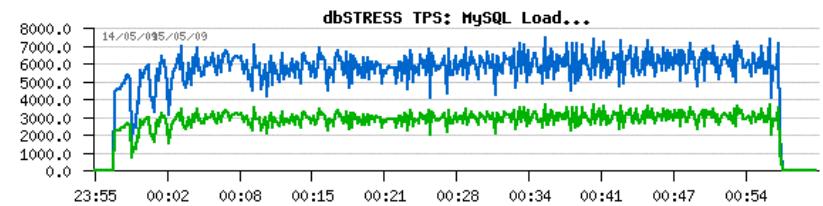
RW IO-Bound : Test your Filesystem before to deploy

- EXT4 vs XFS
 - OLTP_RW 50M x8-tab OL7.2 @ 72cores-HT, pool 64GB, trx1 :



Read+Write Workloads : InnoDB REDO size

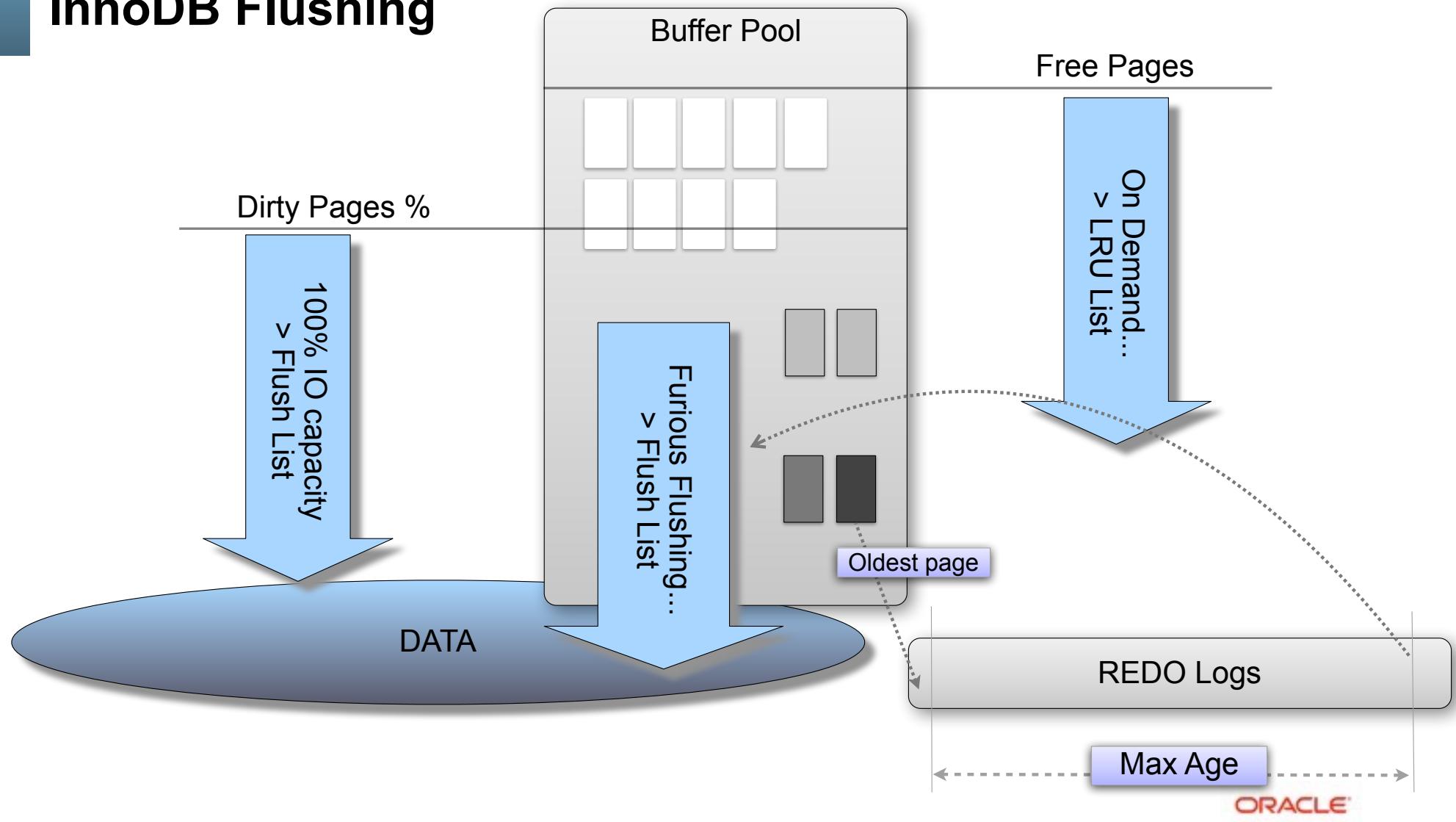
- REDO log size impact in the past (pre-MySQL-5.5) :
 - 128M vs 1024M
 - 6000 TPS => 8000 TPS and more stable
 - 2ms resp. time => 1ms
 - Why periodic TPS drops ?.. <= purge in Master Thread.. - fix: dedicated Purge Thread



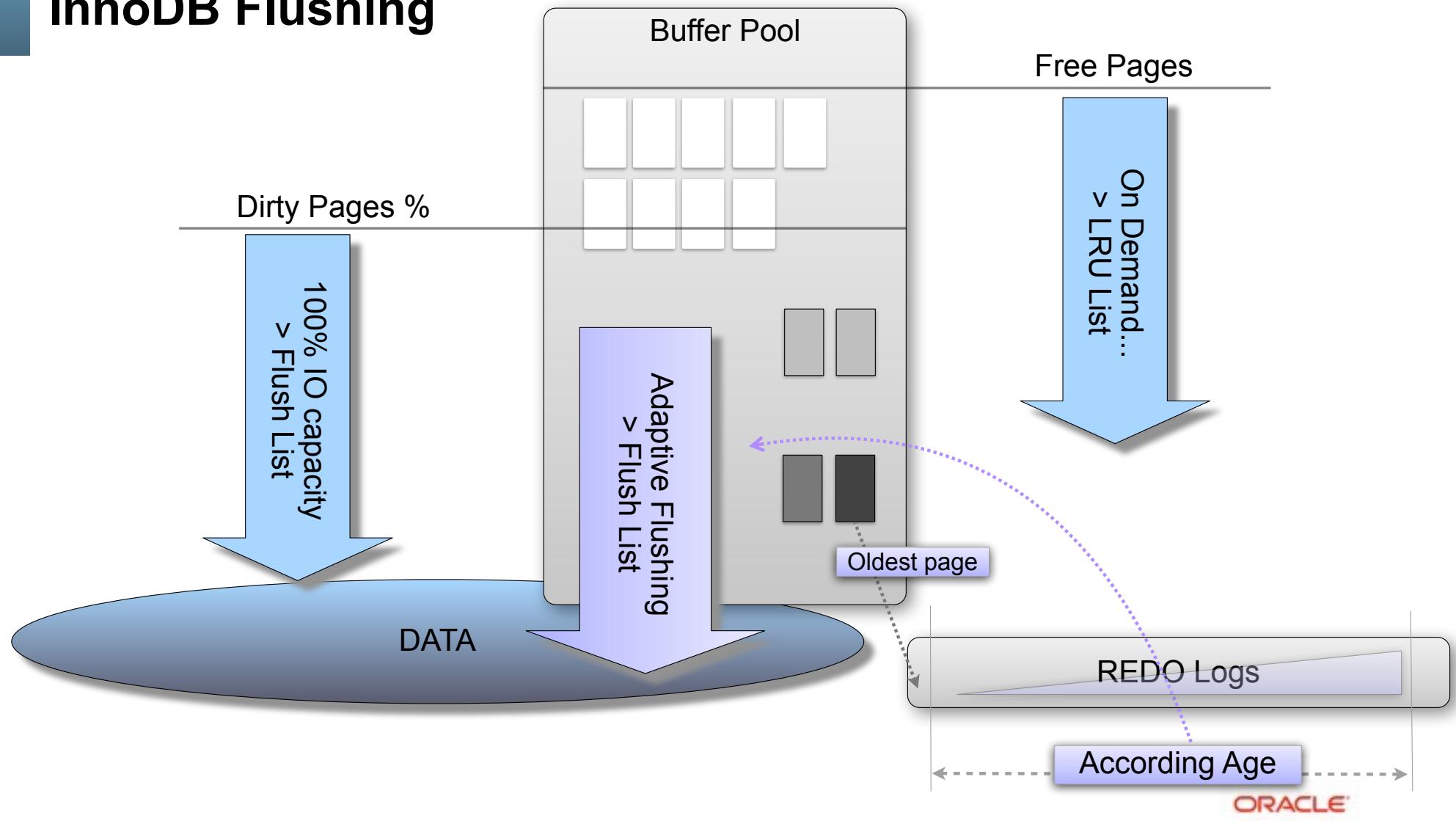
Read+Write Workloads : InnoDB Flushing

- InnoDB Flushing...
 - 5.5 : no comments.. ;-)
 - io capacity !!
 - 5.6 :
 - Improved Adaptive Flushing (step 1)
 - Cleaner Thread
 - io capacity max !!
 - LRU depth !!
 - 5.7 :
 - multiple Cleaner Threads
 - improved LRU flushing
 - improved Adaptive Flushing Design (step 2)

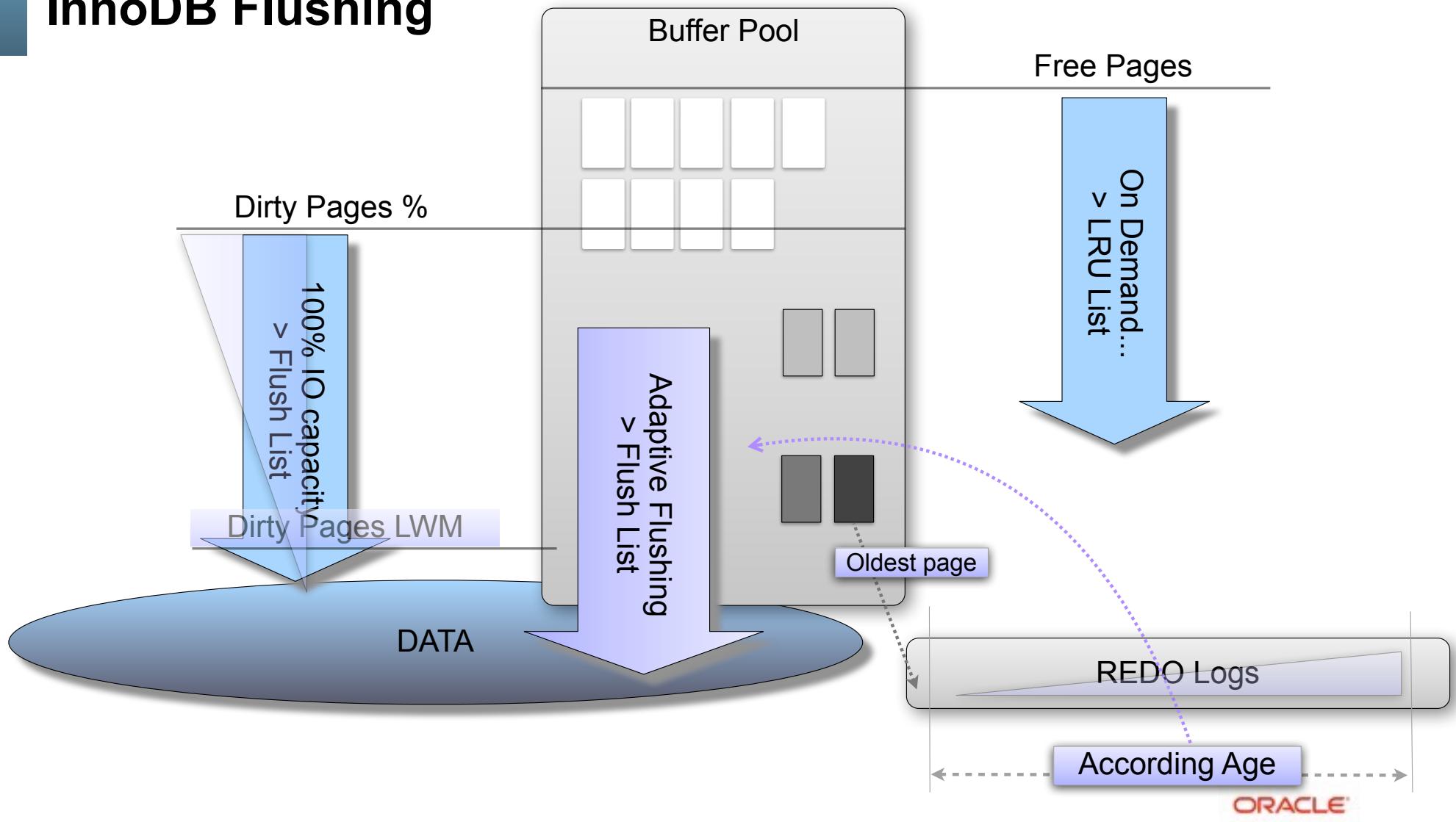
InnoDB Flushing



InnoDB Flushing

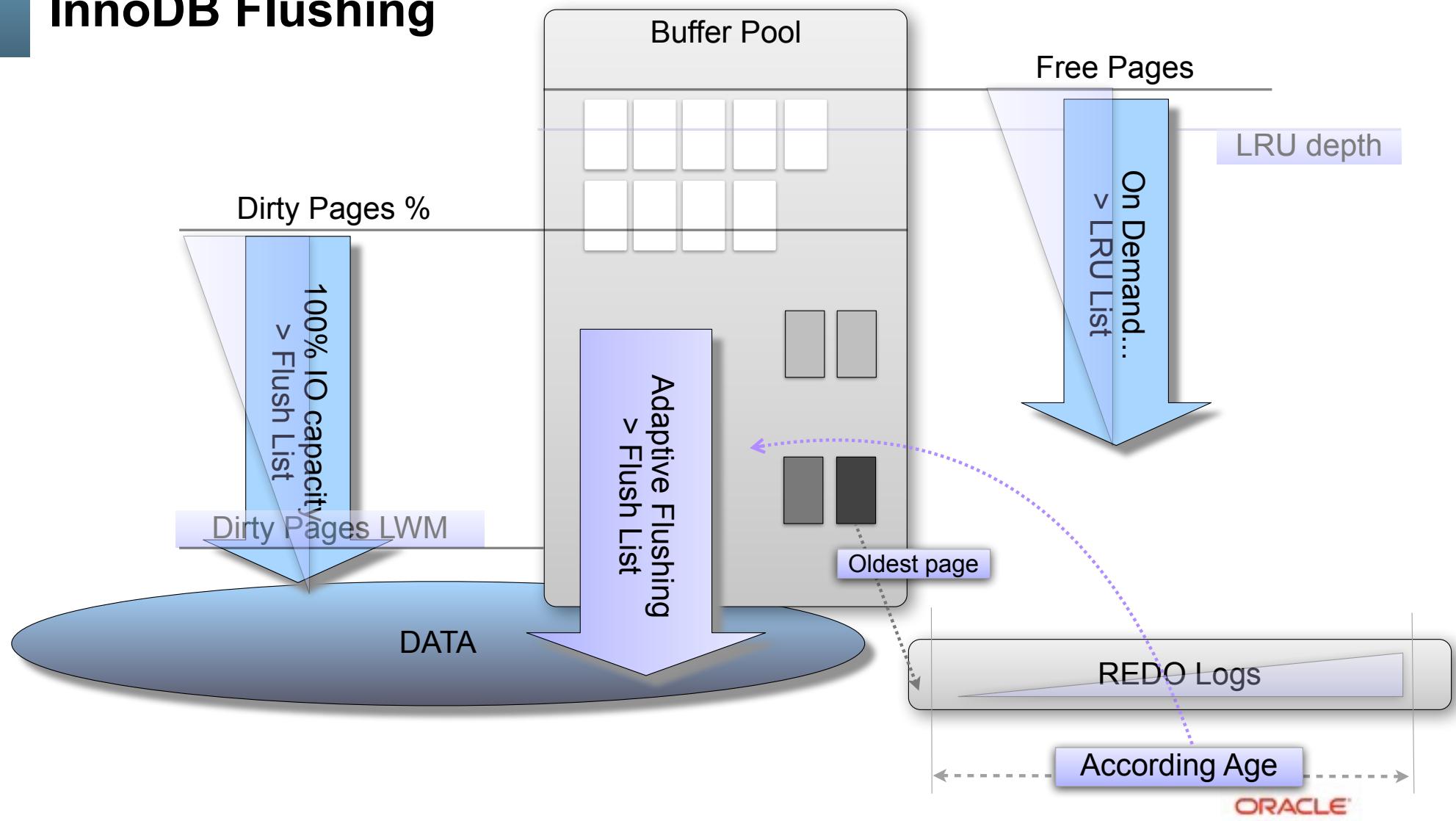


InnoDB Flushing



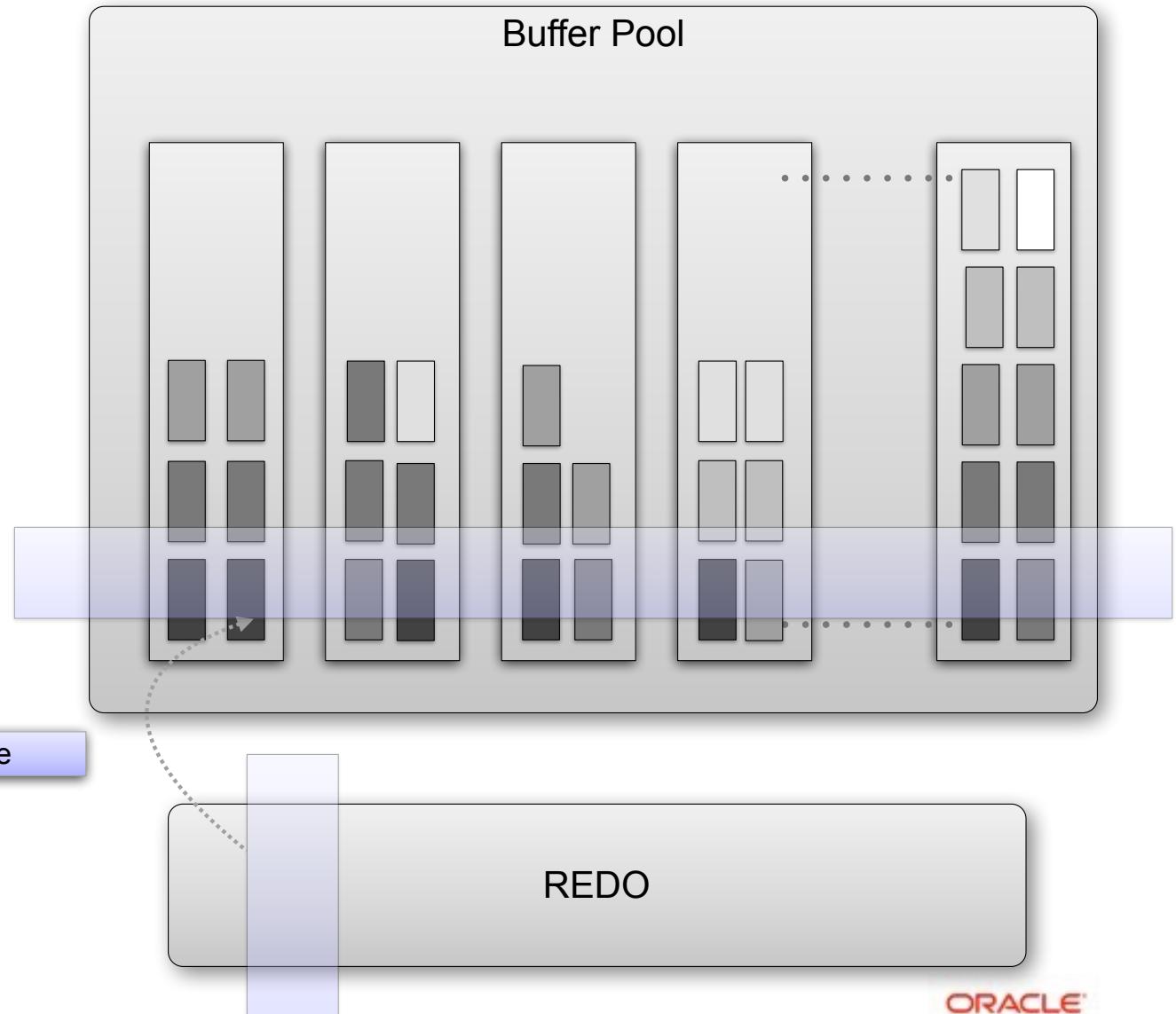
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InnoDB Flushing



InnoDB Flushing

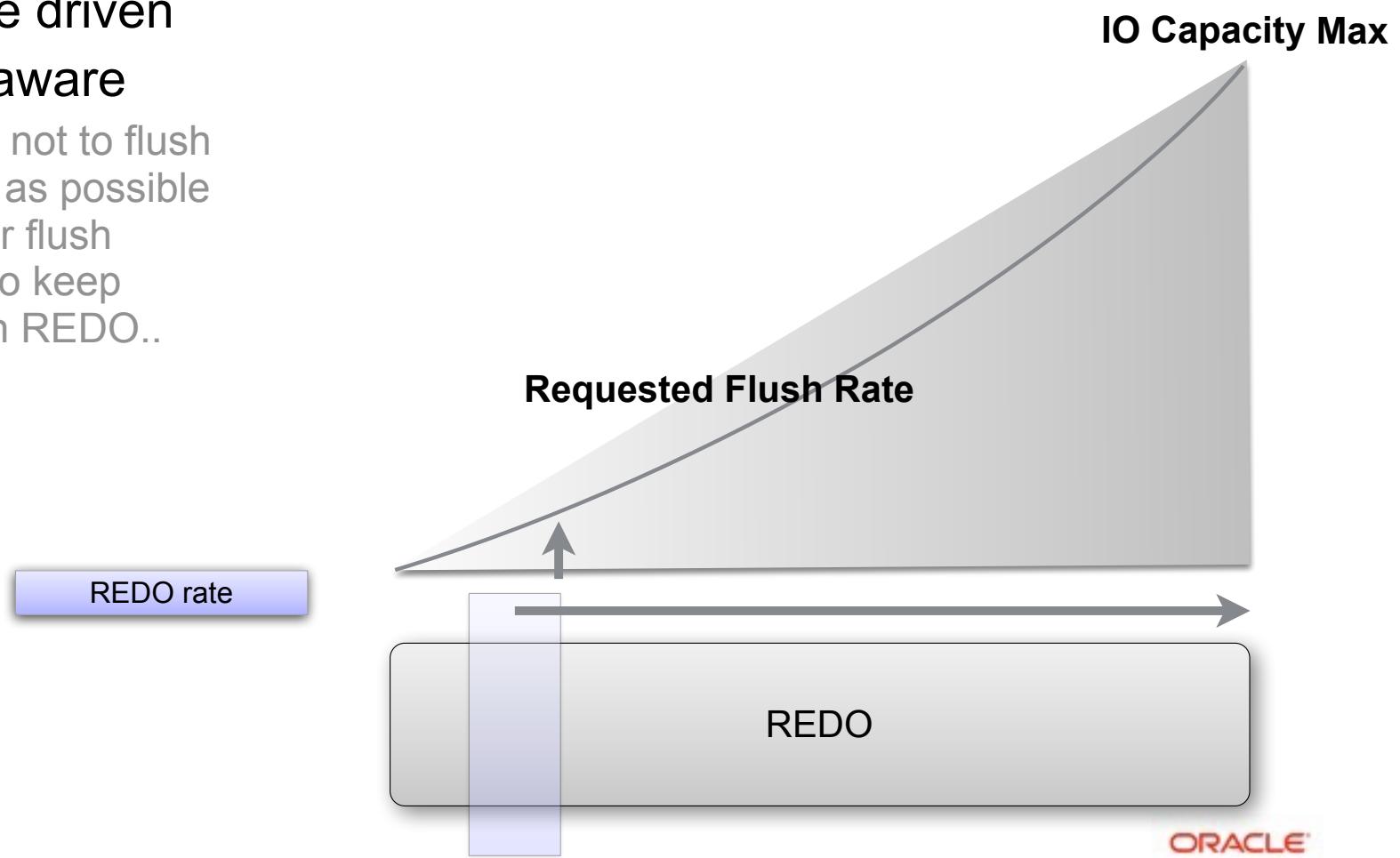
- REDO rate driven
- LSN Age aware
 - the goal is not to flush as much as possible but rather flush enough to keep a room in REDO..



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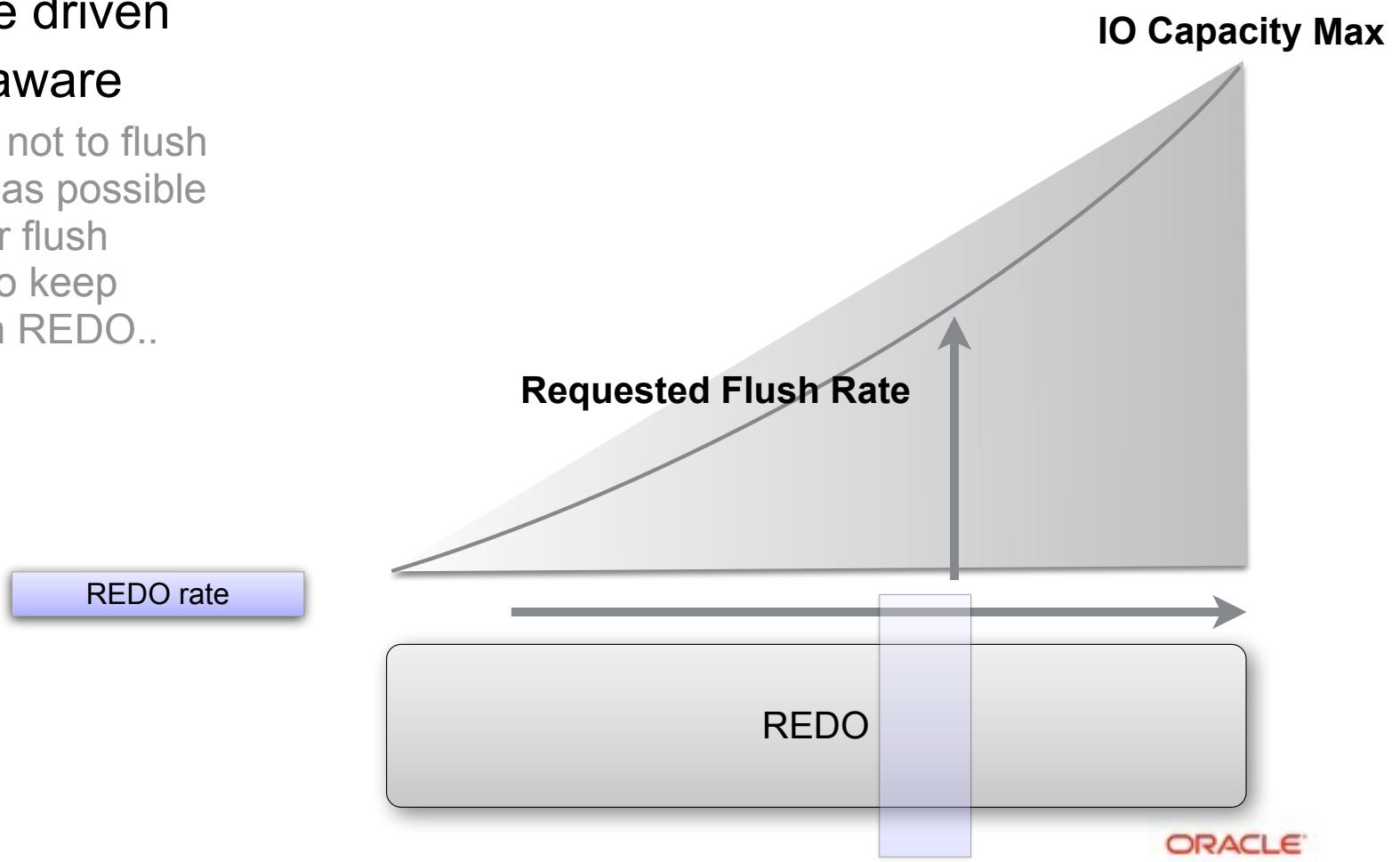
InnoDB Flushing

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InnoDB Flushing

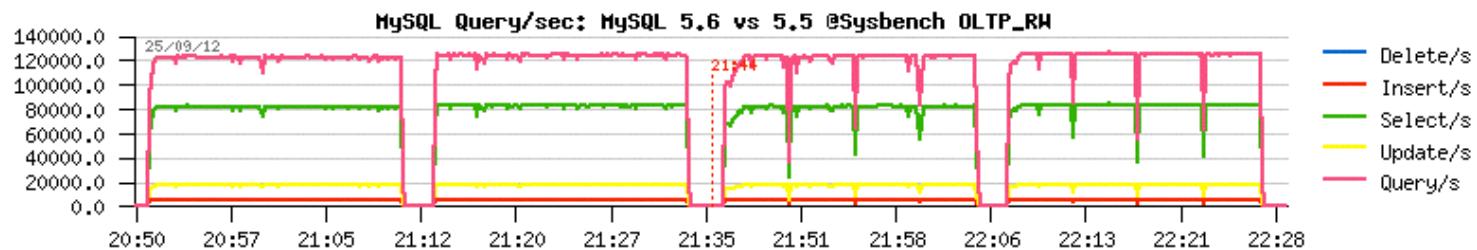
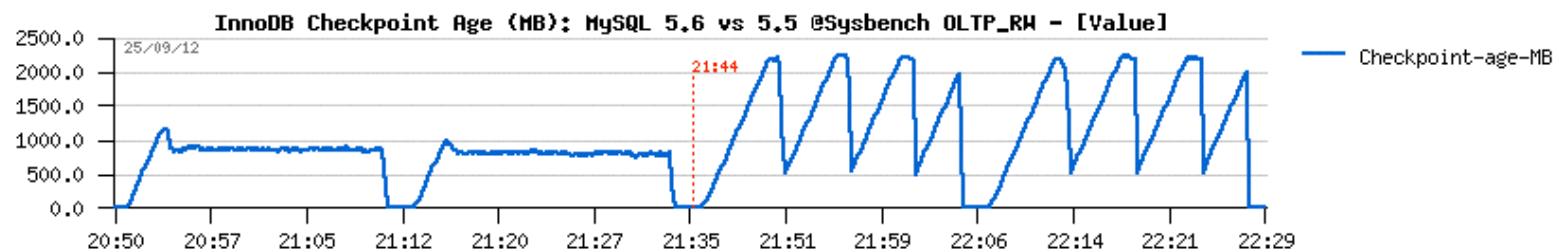
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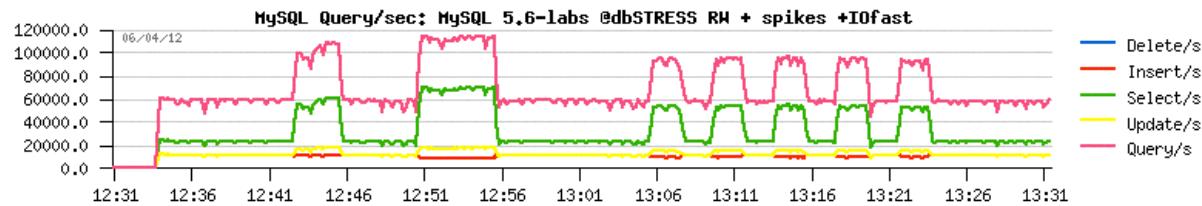
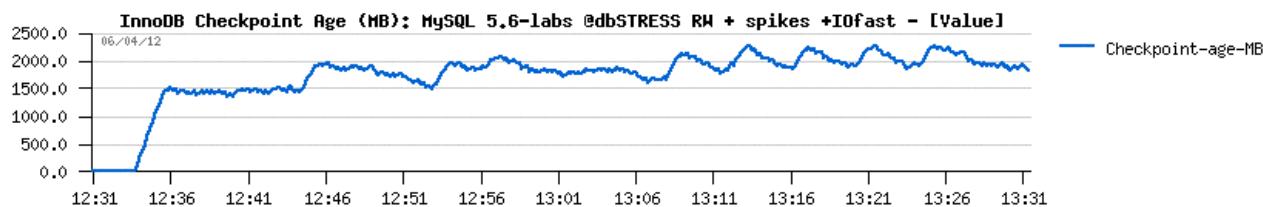
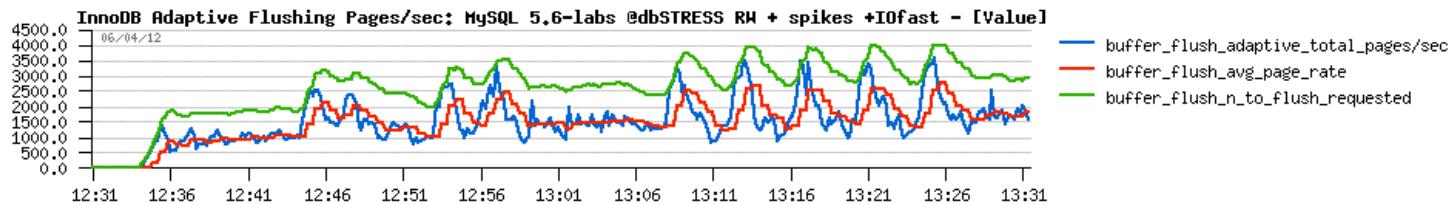
Adaptive Flushing: MySQL 5.6 vs 5.5

- OLTP_RW Workload:
 - Same IO capacity
 - Different logic..



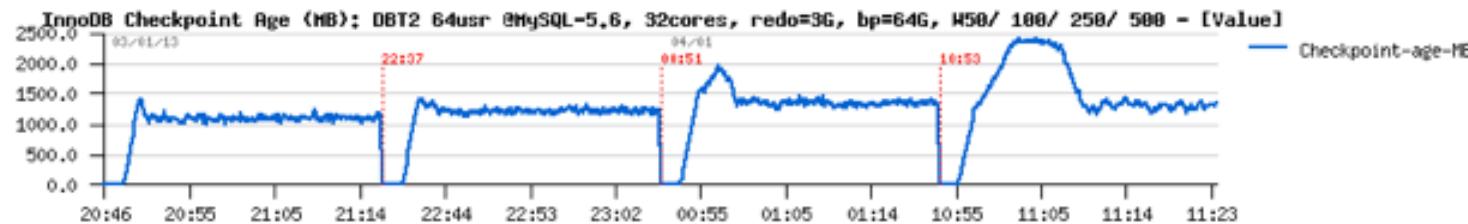
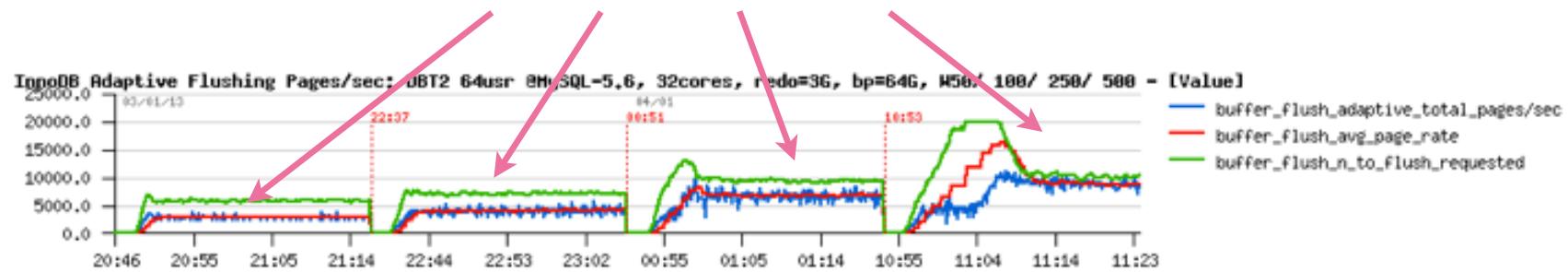
InnoDB : Resisting to activity spikes in 5.6

- dbSTRESS RW with spikes
 - having a big enough Checkpoint Age marge allowing to resist to spikes



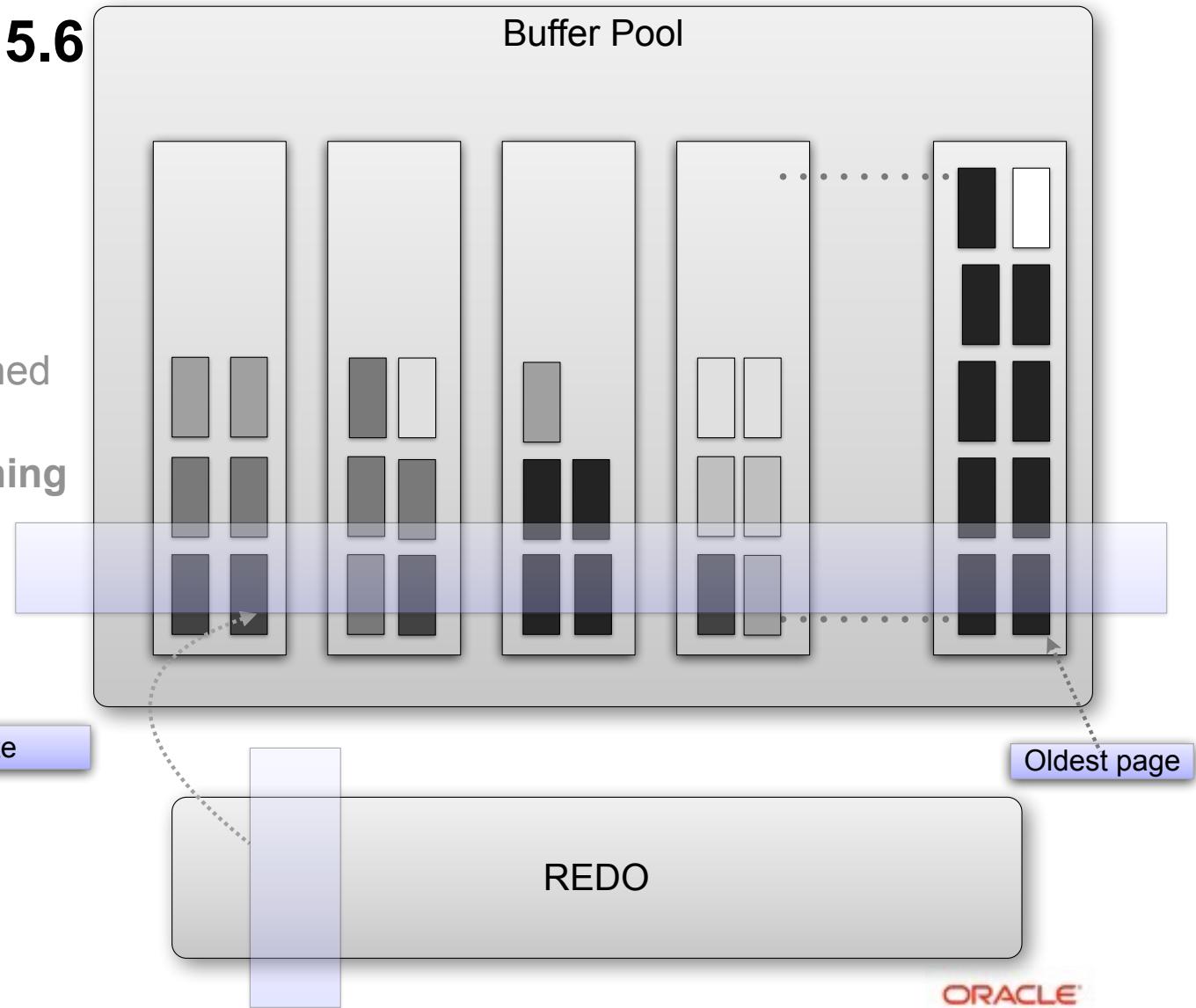
RW IO-bound “In-Memory”

- Impact of the database size
 - with a growing db size the TPS rate may be only the same or worse ;-)
 - and required Flushing rate may only increase.. <= need parallel flushing !
- DBT2 workload :
 - 64 users, db volume: 50W, 100W, 250W, 500W



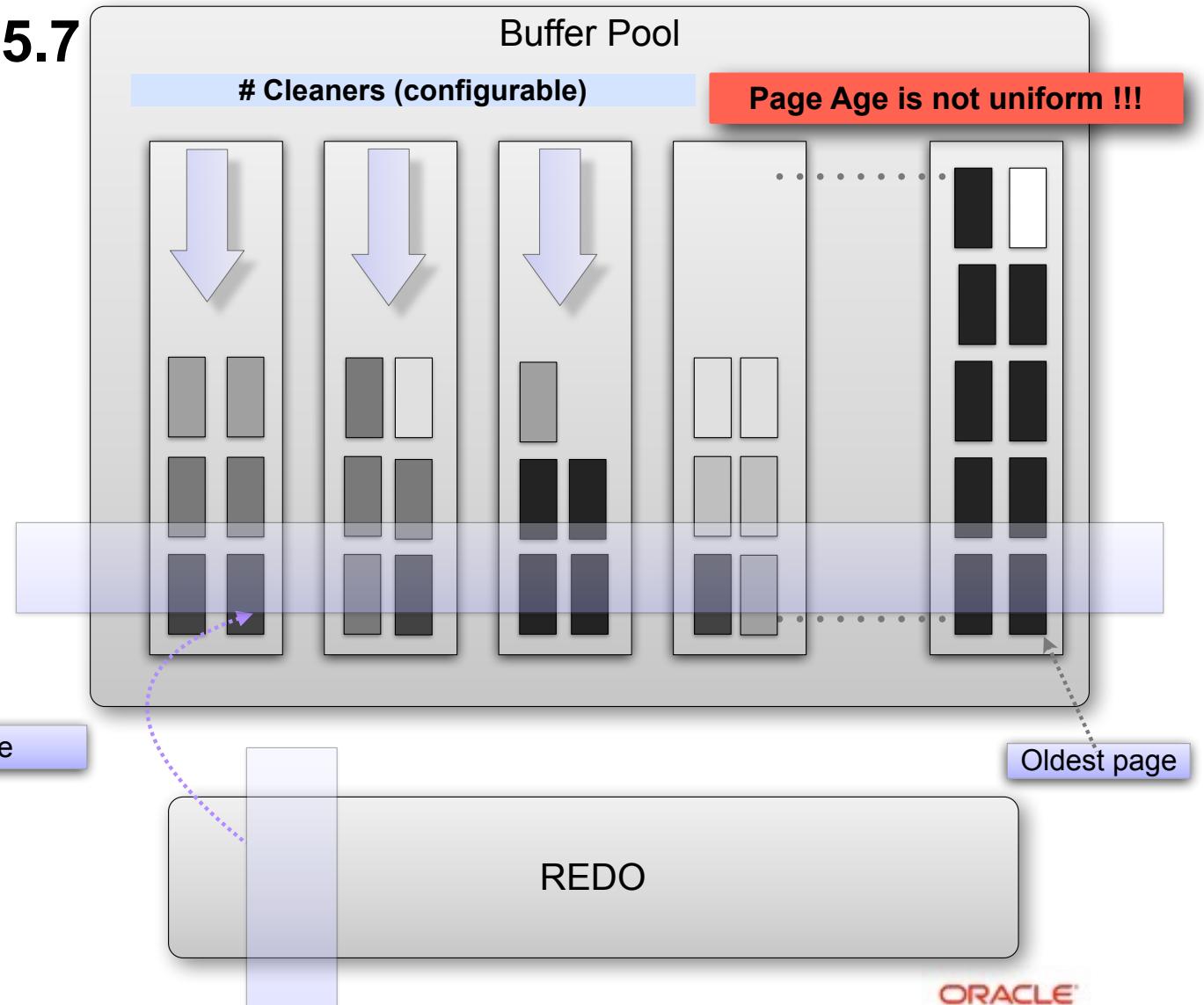
InnoDB Flushing 5.6

- REDO rate driven
- LSN Age aware
- 5.6 :
 - BP Instances are flushed **sequentially..**
 - can't follow **high flushing demand..**



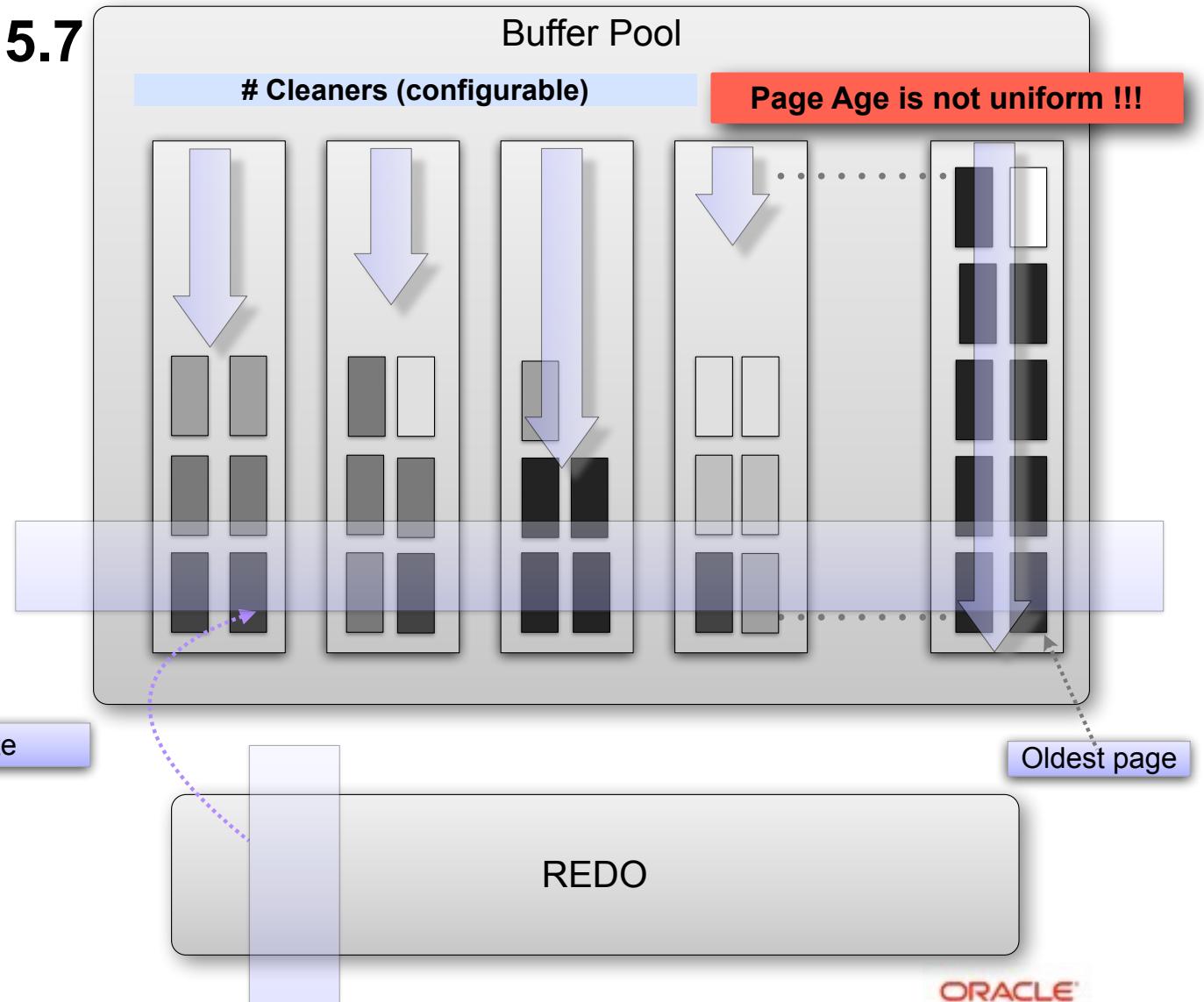
InnoDB Flushing 5.7

- REDO rate driven
- LSN Age aware
- 5.7 :
 - BP Instances are flushed in parallel !!!



InnoDB Flushing 5.7

- REDO rate driven
- LSN Age aware
- 5.7 :
 - BP Instances are flushed in **parallel !!!**
 - Flushing rate is **adapted to Age distribution within each BP instance !!!**



InnoDB Adaptive Flushing Tuning in 5.7

- Config :

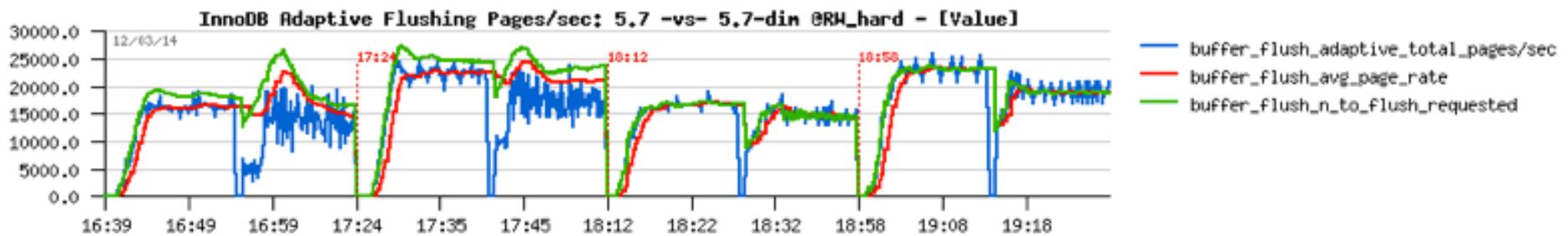
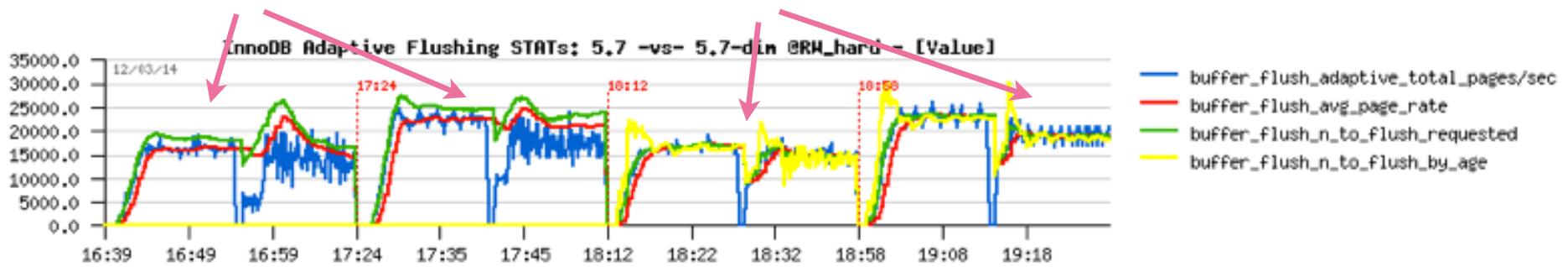
- innodb_adaptive_flushing = 1 (=> Linux: also allow cleaner threads priority !!)
- REDO log size —> use big ;-) (ex: 12GB, 32GB)
- innodb_page_cleaners = 4
- innodb_io_capacity_max = ... (max allowed (10000 ?))
- innodb_io_capacity = 1/2 innodb_io_capacity_max (or according your needs)
- innodb_max_dirty_pages_pct_lwm = 5
- innodb_max_dirty_pages_pct = 90

- Monitor :

- Checkpoint Age < REDO total size
- buffer_flush_sync_waits && buffer_flush_sync_pages == 0
- buffer_flush_avg_time < 1sec
- buffer_flush_adaptive_avg_pass == 30 (def. avg loops)
- buffer_flush_adaptive_total_pages/sec == buffer_flush_n_to_flush_requested

InnoDB Flushing in 5.7

- Considering Age distribution :
 - Parallel Only -vs- Parallel + Age aware



RW IO-bound

- **REDO**-driven : Still data In-Memory, but much bigger volume
 - more pages to flush for the **same** TPS rate
- **LRU**-driven : Data bigger or much bigger than Memory / cache / BP
 - the amount of free pages becomes short very quickly..
 - and instead of mostly only IO writes, you're starting to have IO reads too
 - these reads are usually random reads
 - if your storage is slow - reads will simply kill your TPS ;-)
 - if your storage can follow - once you're hitting `fil_sys` mutex you're done
 - as well LRU flushing may become very heavy..
- **NOTE:**
 - on Linux : **AIO + O_DIRECT_NO_FSYNC** seems to be the most optimal for RW IO-bound
 - but always check yourself ;-)

RW IO-bound “Out-of-Memory” LRU-driven

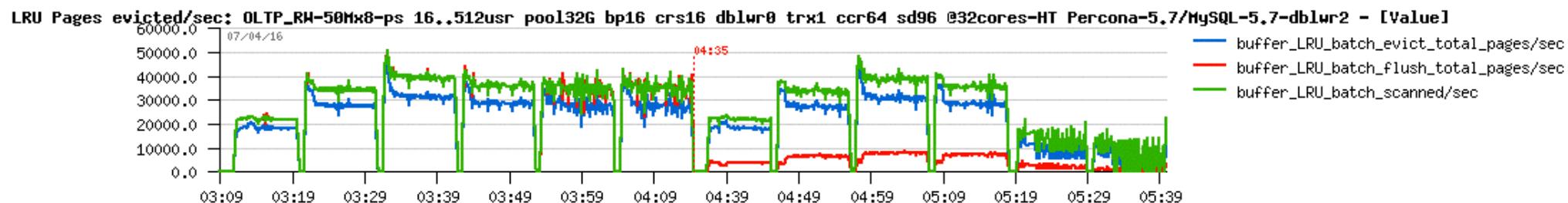
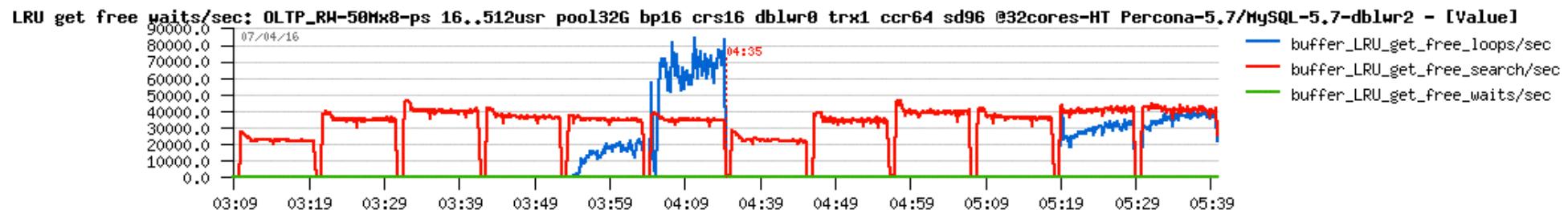
- The “entry” limit here is storage performance
 - as you'll have a lot of IO reads..
 - => and to be able to read a new data you need a free page in BP
 - => if there no more free pages :
 - => you can evict a clean page from LRU tail
 - => you can flush & evict a dirty page from LRU tails
 - => e.g. to allow IO reads you must process first your IO writes

RW IO-bound “Out-of-Memory” LRU-driven

- Config :
 - `innodb_buffer_pool_instances` = 8 (16, 32..)
 - `innodb_page_cleaners` = 4 or 8 or eq. BP instances (depends on free page demand)
 - `innodb_lru_scan_depth` = 4K or more (according free page demand)
 - NOTE: `innodb_lru_scan_depth` is per BP instance !!!
 - NOTE: it also defines your free pages target !!!
- Tuning <=> Monitoring :
 - `buffer_LRU_get_free_search/sec` <== your free pages demand
 - so, align your LRU depth according this to match the demand
 - `buffer_LRU_get_free_loops/sec` <== loop waits on free pages...
 - `buffer_LRU_get_free_waits/sec` <== sleep waits on free pages..
 - `buffer_LRU_single_flush_num_scan/sec` <== single page flush/evict by no-cleaner..
 - `buffer_LRU_batch_evict_total_pages/sec` <== pages evicted by cleaner
 - `buffer_LRU_batch_flush_total_pages/sec` <== pages flushed by cleaner
 - `buffer_LRU_batch_scanned/sec` <== pages scanned by cleaner

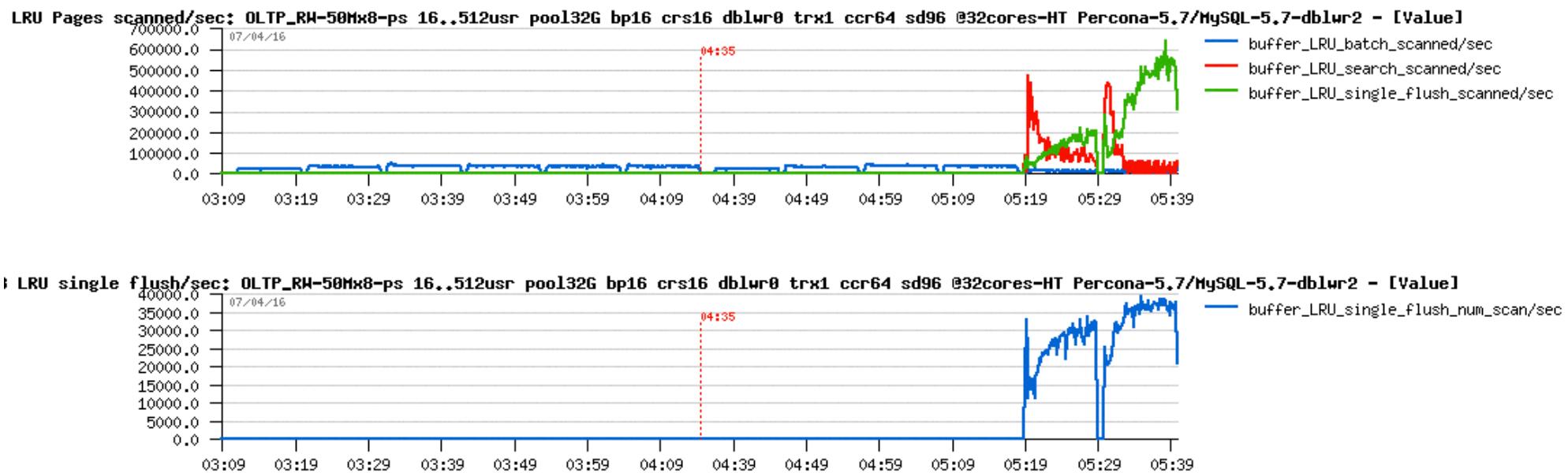
RW IO-bound LRU-driven

- OLTP_RW 50M x8-tab IO-bound LRU-driven
 - Percona-5.7 / MySQL-5.7
 - => the “optimal” solution is somewhere in the middle..



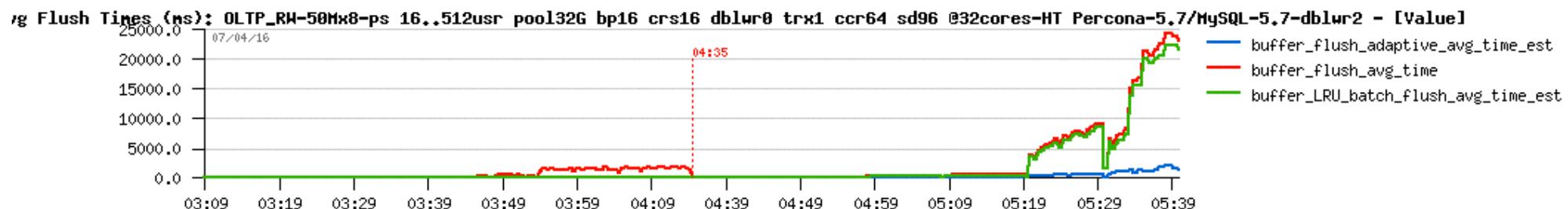
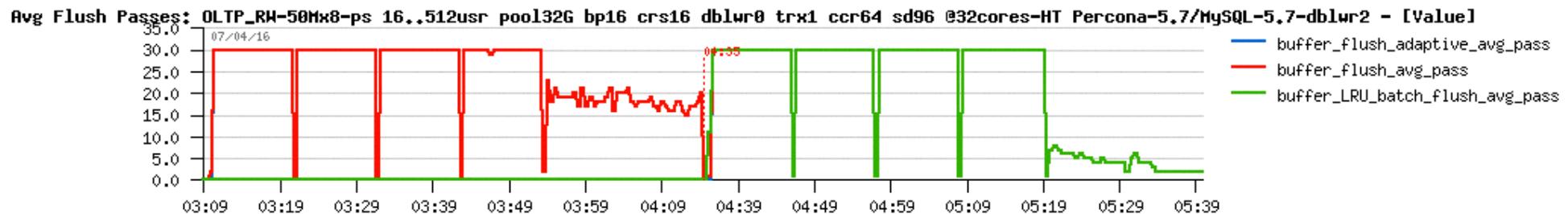
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- OLTP_RW 50M x8-tab IO-bound LRU-driven
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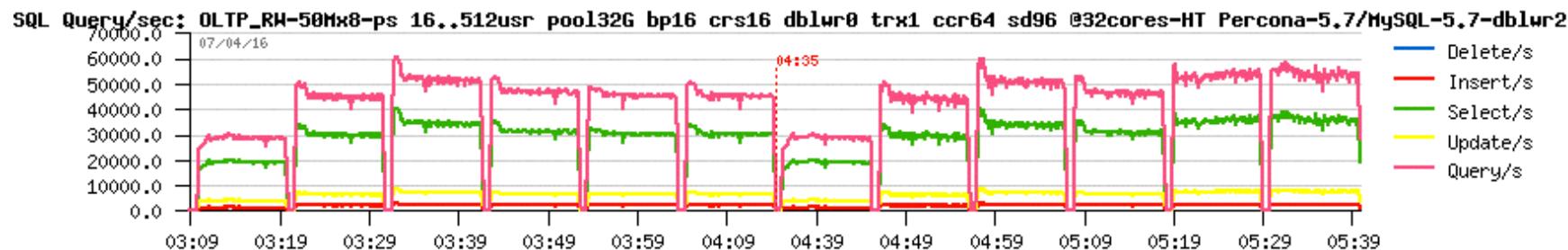
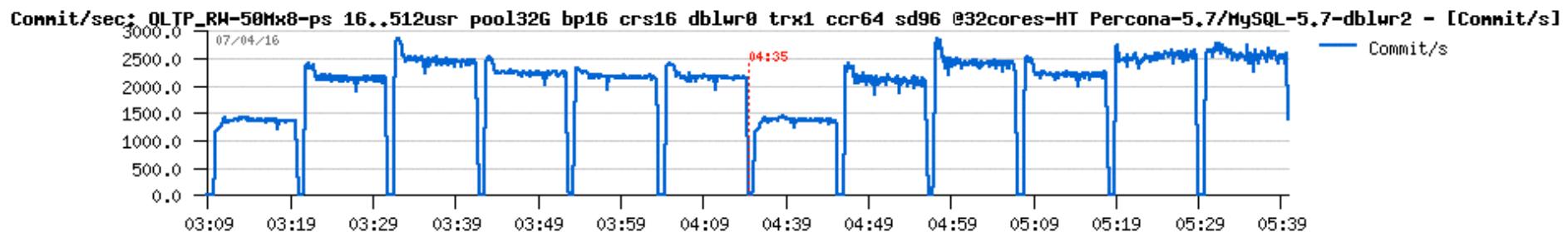
RW IO-bound LRU-driven

- OLTP_RW 50M x8-tab IO-bound LRU-driven
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 - => the “optimal” solution is somewhere in the middle..



RW IO-bound LRU-driven

- OLTP_RW 50M x8-tab IO-bound LRU-driven
 - Percona-5.7 / MySQL-5.7
 - => the “optimal” solution is somewhere in the middle..
 - => as MySQL-5.7 “looked” bad, but delivered a higher TPS..



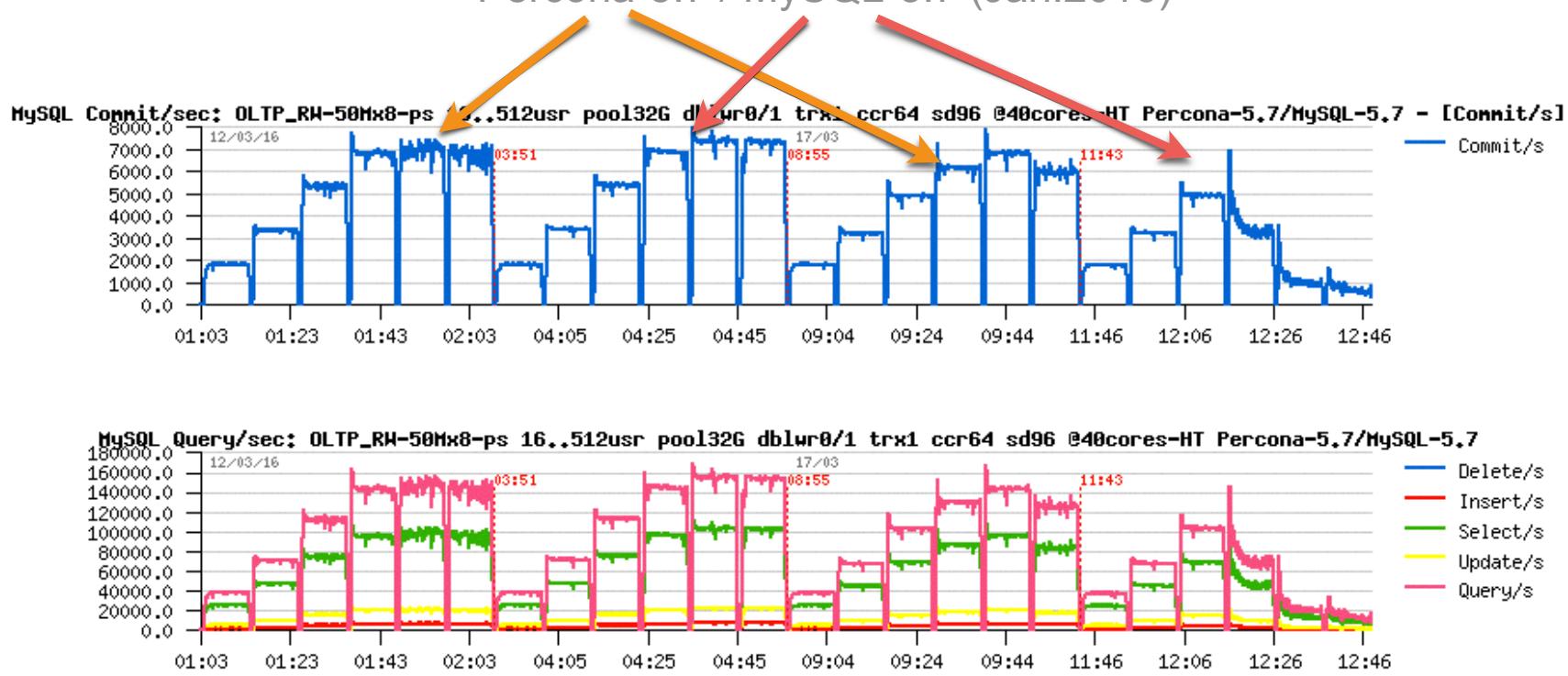
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InnoDB Double-Write (DBLWR)

- Why ?
 - the only InnoDB feature to protect from partially written pages
 - each page is written **twice** (first into DBLWR zone, then to data file)
 - on recovery:
 - if corrupted page is detected => InnoDB is seeking DBLWR
 - if no “good” page image found => you’re in trouble ;-))
- impact :
 - page write latency is growing at least x2 times..
 - flash storage life expectation becomes x2 times lower (due x2 more writes)
- solution :
 - allow placing DBLWR to other storage (ex: \$5 USB-stick / SD, \$50 SSD, etc.)
 - allow more parallel writes to hide increased IO page write latency
 - => DBLWR path / size / threads config options (coming as 5.7+ fix)

InnoDB Double-Write (DBLWR)

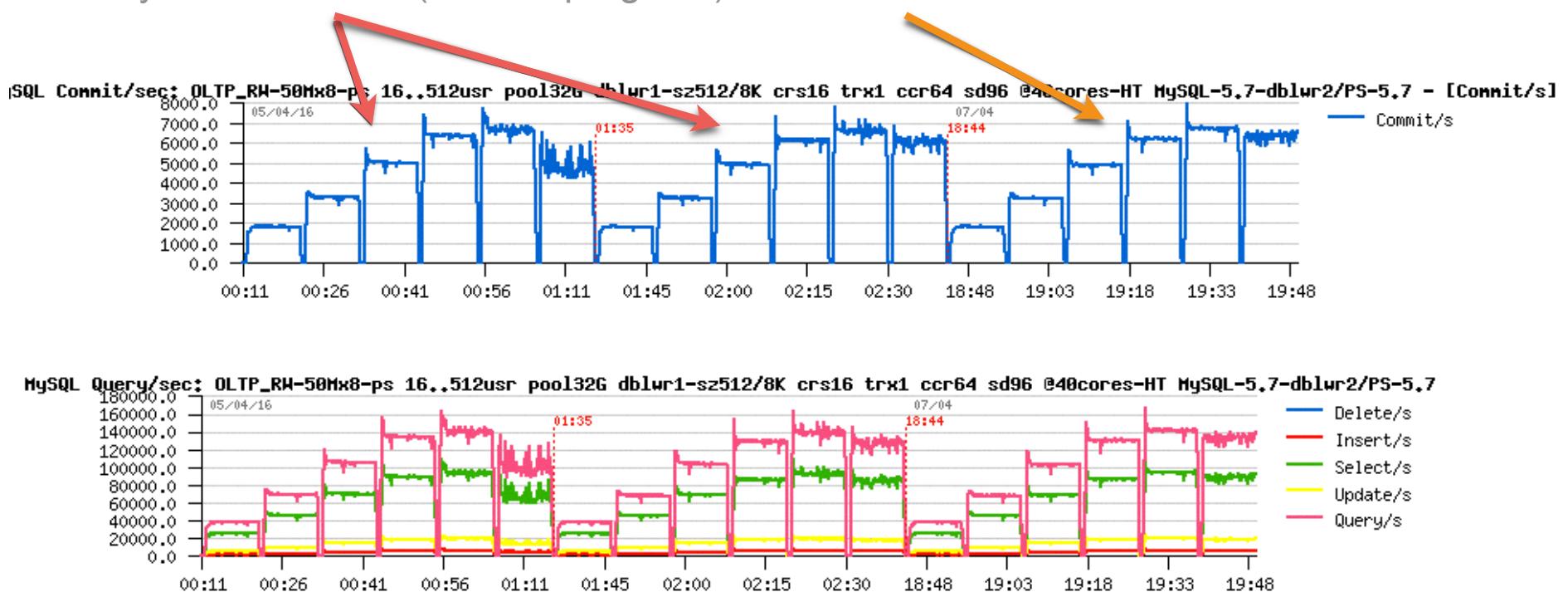
- OLTP_RW 50M x8-tables (120G dataset)
 - BP=32G, trx=1, dblwr=0/1, checksum=crc32, Flash “Nytro” Seagate-XP6500
 - Percona-5.7 / MySQL-5.7 (Jan.2016)



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InnoDB Double-Write (DBLWR)

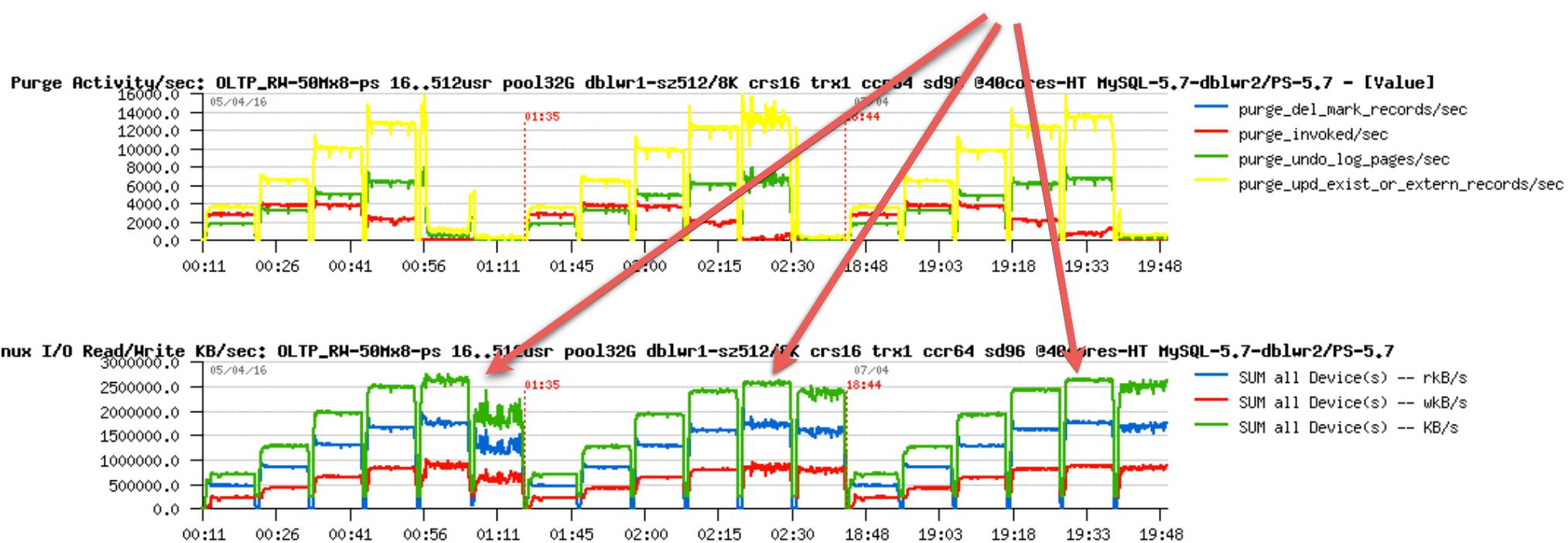
- OLTP_RW 50M x8-tables (120G dataset)
 - BP=32G, trx=1, dblwr=1, checksum=crc32, Flash “Nytro” Seagate-XP6500
 - MySQL-5.7-dblwr (work-in-progress) / Percona-5.7



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InnoDB Double-Write (DBLWR) - Side Note..

- OLTP_RW 50M x8-tables (120G dataset)
 - Purge lagging can be a very serious issue..
 - 5.7 with Flash “Nytro” Seagate-XP6500 => over 2500 MB/sec (16K InnoDB pages)

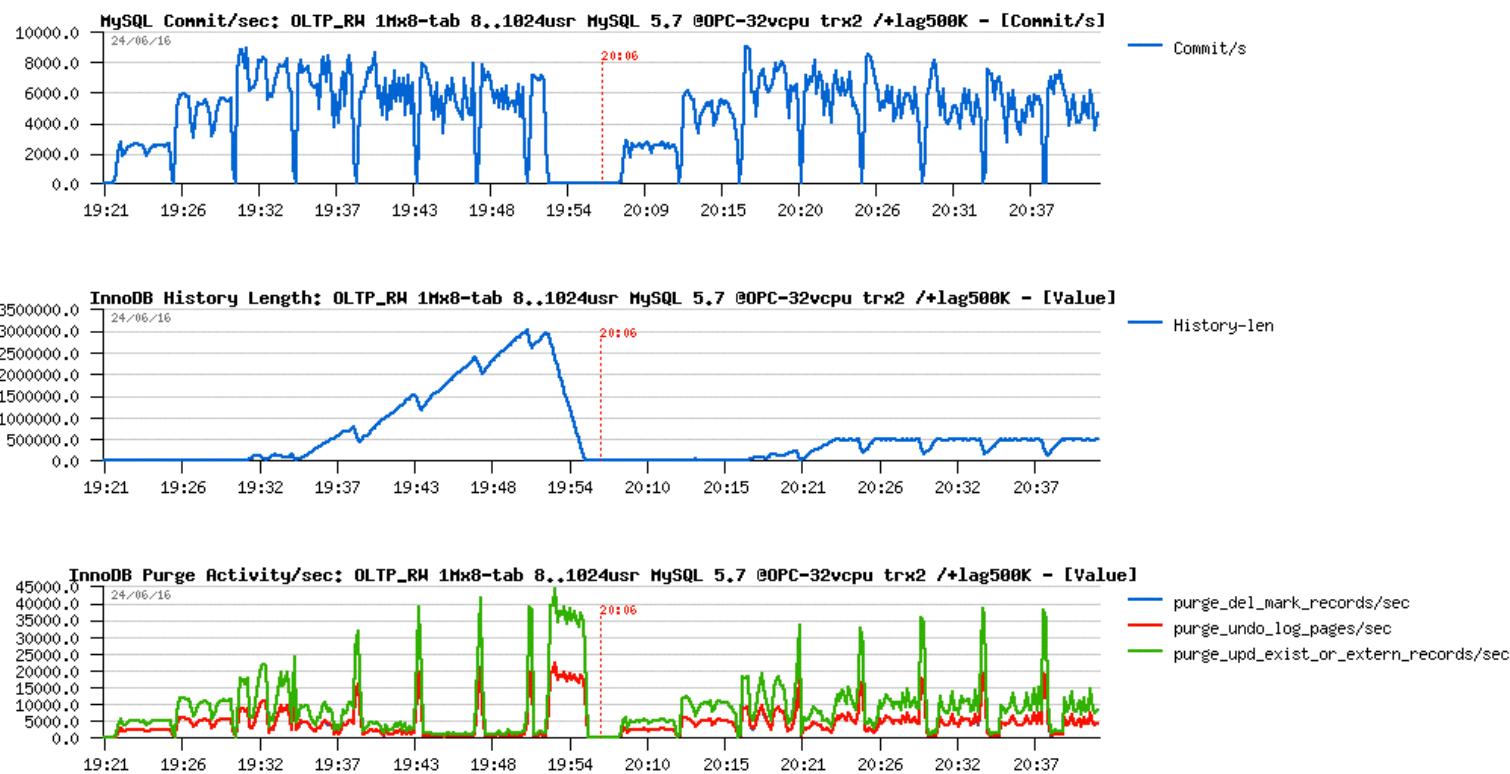


Read+Write Workloads : InnoDB Purge

- InnoDB Purge...
 - 5.5 : Purge Thread !!! ;-)
 - 5.6 : Multi-Threaded Purge + fix for purge lag code !
 - 5.7 : UNDO space **can be auto-dropped !!** (RTFM..)
 - monitor InnoDB History Length **ALWAYS !** ;-)
 - if NO purge lagging : excellent! (& be happy! ;-))
 - if purge is lagging : use a purge lag config setting.. (write throttling)
- Example of config for 5.6 and 5.7 to avoid purge lagging:
 - innodb_max_purge_lag = 500000 (500K max, ex.)
 - innodb_max_purge_lag_delay = 30000000
 - innodb_purge_threads = 4

InnoDB Purge Lag

- OLTP_RW @MySQL 5.7
 - purge lag = 0 -vs- purge lag = 500K



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InnoDB : be sure your TPS is fair ;-)

- Purge lagging impact on IO-bound OLTP_RW 10Mx32-tab:
 - moving from 3200 to 4000 TPS... - cool, right? ;-) but not fair...



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INSERT Performance in MySQL 5.7

- B-Tree impact + InnoDB data compactness..
 - over a time of INSERTS, B-Tree is growing & growing..
 - at some moment it'll be out of memory..
 - this will involve IO re-reads (mostly IO RR !!)
 - which will slowdown an overall performance..
- Workaround(s)
 - size a bigger memory for InnoDB Buffer Pool (BP)
 - use partitions :
 - this will keep an overall BTree(s) smaller
 - once you filled up a partition and switching INSERTs to the next one, the previous partition index data are no more required during INSERT, and BP will cache index pages mostly from the active partition..
- MySQL 8 : stay tuned ;-)

UPDATE Performance in MySQL 5.7

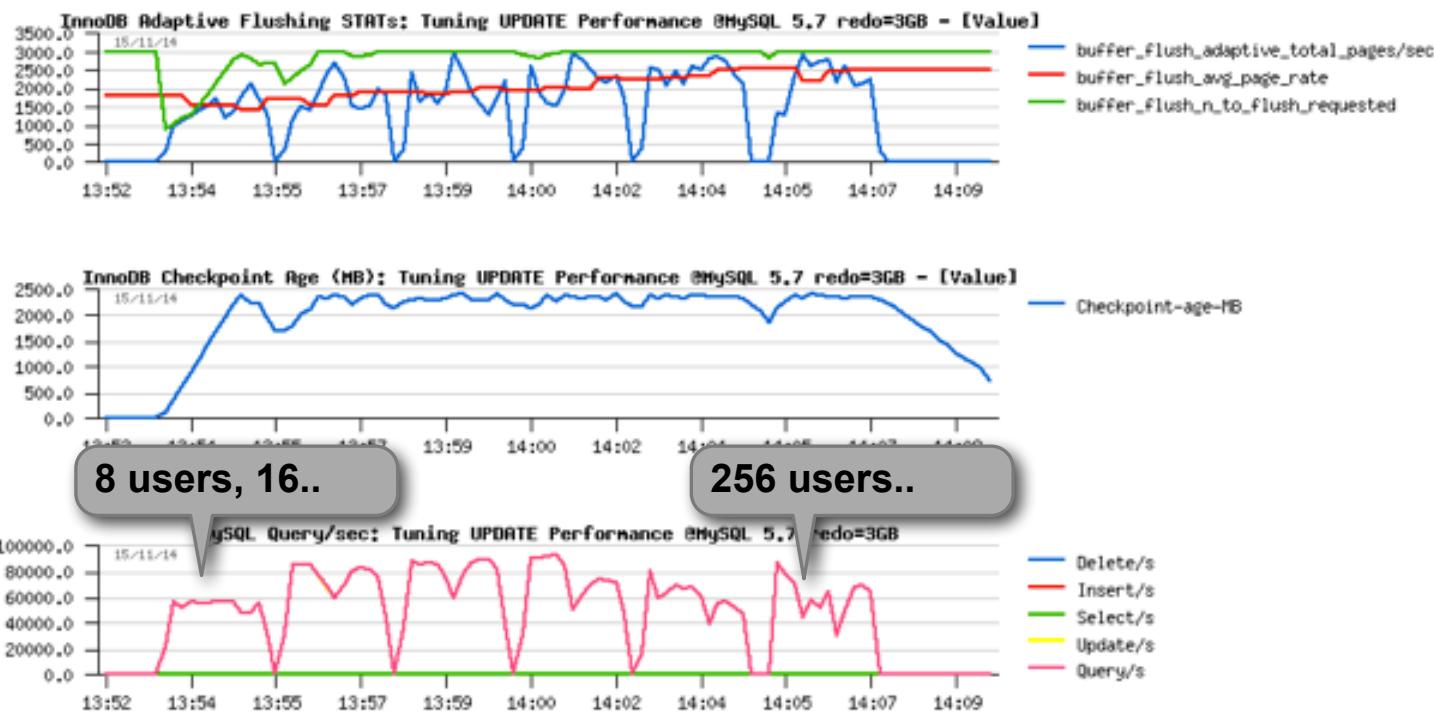
- Low load : slower than in MySQL 5.6
 - pure overhead in many functions due code changes..
- Higher load : much better than in MySQL 5.6
 - so, have to manage to do more and more stuff in parallel !!
 - and this is a general tendency...

Test Case: Tuning UPDATE Performance

- Test conditions :
 - Workload : Sysbench UPDATE
 - CPU config : 12cores-HT
 - IO subsystem : EXT4 on SSD
 - Users : 8, 16, 32 .. 256

Test Case: Tuning UPDATE Performance (2)

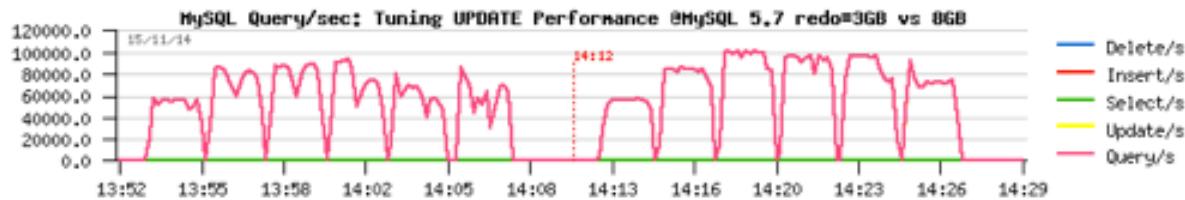
- Tuning :
 - starting with REDO size=3GB, io capacity max=3000
 - Performance: looks poor..



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Test Case: Tuning UPDATE Performance (3)

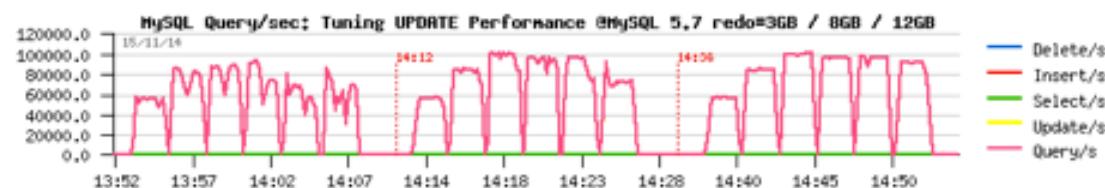
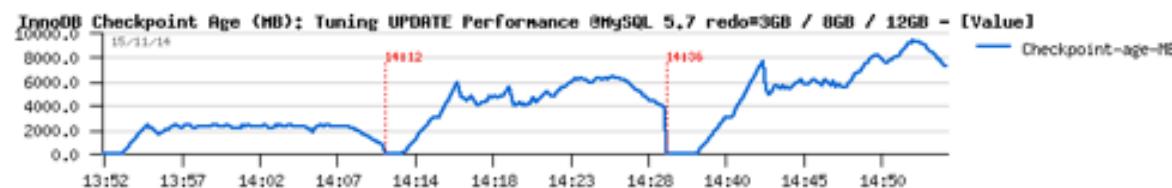
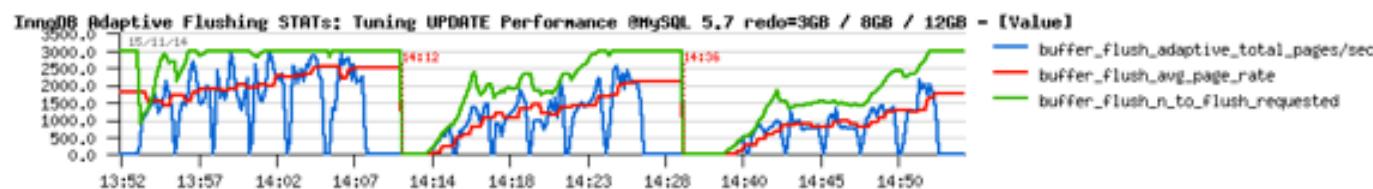
- Tuning :
 - moving to REDO size=8GB..
 - Performance: looks better, but still poor on a higher load..



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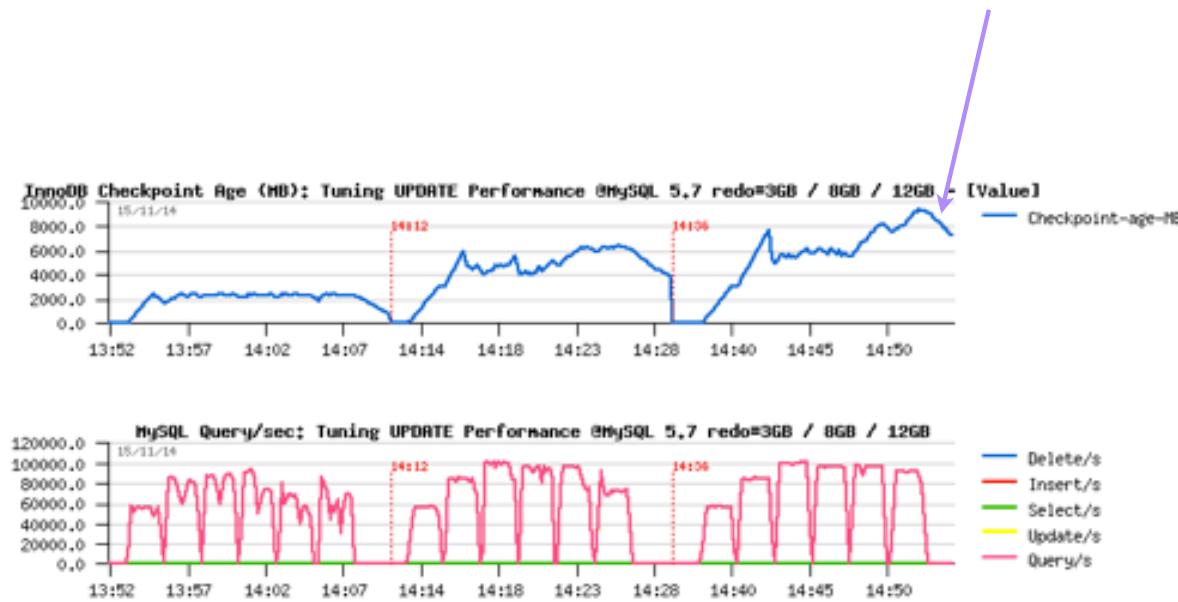
Test Case: Tuning UPDATE Performance (4)

- Tuning :
 - moving to REDO size=12GB..
 - Performance: looks good, but Checkpoint Age continues to grow..



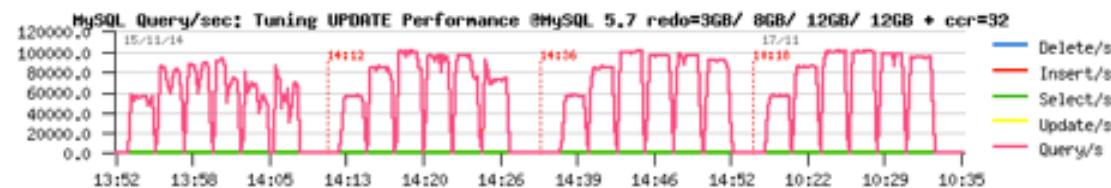
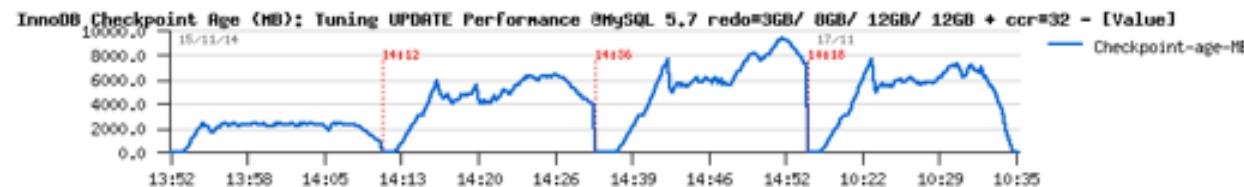
Test Case: Tuning UPDATE Performance (5)

- Tuning :
 - moving to REDO size=12GB..
 - Performance: looks good, but Checkpoint Age continues to grow..
 - Analyze: up to 128 users all is going well..
 - So, we have to reduce the user's concurrency here



Test Case: Tuning UPDATE Performance (6)

- Tuning :
 - REDO size=12GB + innodb thread concurrency=32
 - Performance: just fine! ;-)



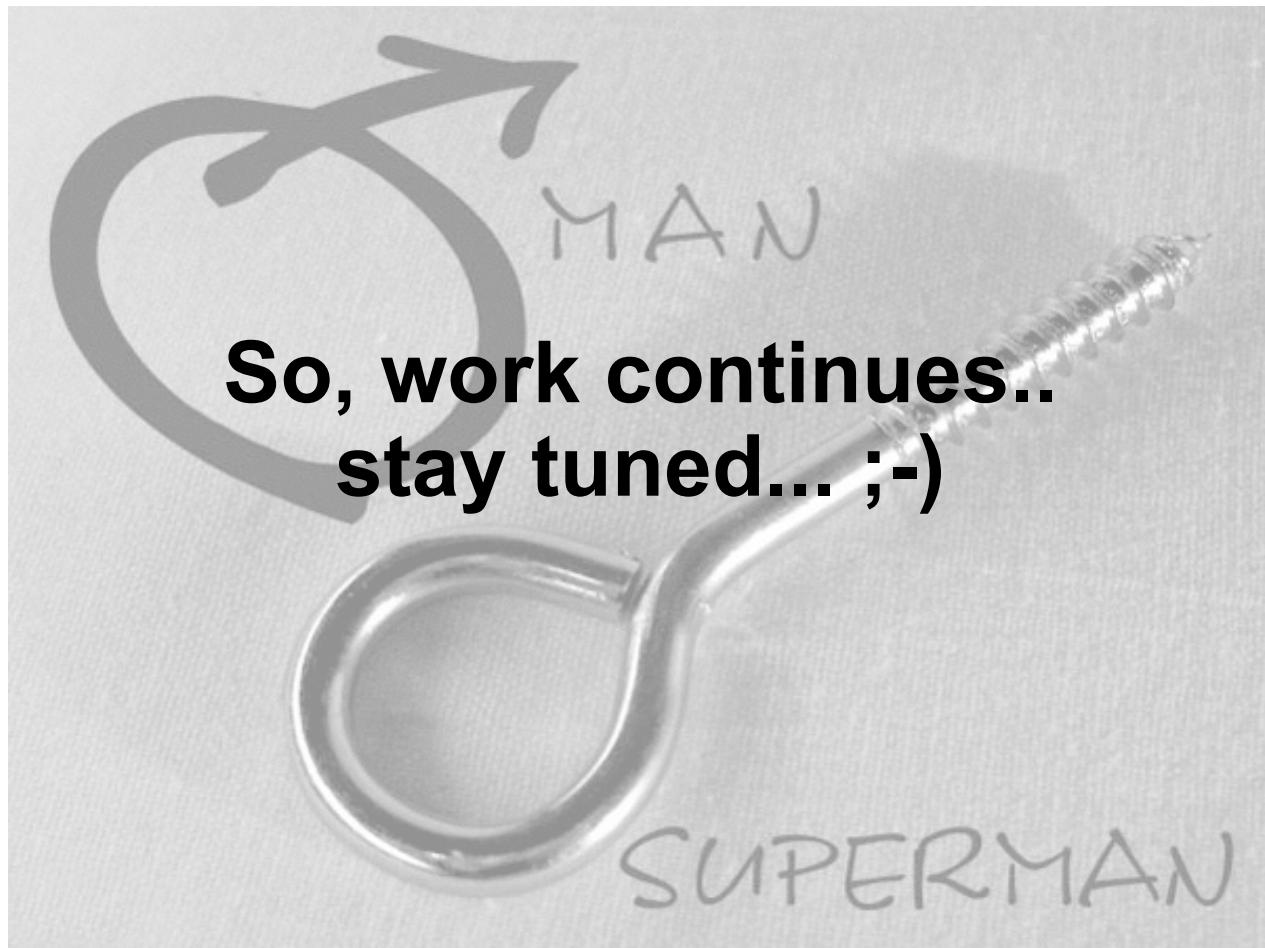
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Hope you're seeing much more clear now ;-)

- And there is less mystery for you around MySQL Performance Tuning
- Most of stuff is available since MySQL 5.7 only..
- So, what do you wait to upgrade ?.. :-)



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One more thing ;-)

- All graphs are built with dim_STAT (<http://dimitrik.free.fr>)
 - All System load stats (CPU, I/O, Network, RAM, Processes,...)
 - Manly for Linux, Solaris, OSX (and any other UNIX too :-)
 - Add-Ons for MySQL, Oracle RDBMS, PostgreSQL, Java, etc.
 - MySQL Add-Ons:
 - mysqlSTAT : all available data from “show status”
 - mysqlLOAD : compact data, multi-host monitoring oriented
 - mysqlWAITS : top wait events from Performance SCHEMA
 - InnodbSTAT : most important data from “show innodb status”
 - innodbMUTEX : monitoring InnoDB mutex waits
 - innodbMETRICS : all counters from the METRICS table
 - And any other you want to add! :-)
- Links
 - <http://dimitrik.free.fr> - dim_STAT, dbSTRESS, Benchmark Reports, etc.
 - <http://dimitrik.free.fr/blog> - Articles about MySQL Performance, etc.