Applying profilers to MySQL

From PMP to perf, and why Performance Schema is not a replacement in all cases

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Who am I?

Valerii (aka **Valeriy**) **Kravchuk**:

- MySQL Support Engineer in MySQL AB, Sun and Oracle, 2005 - 2012
- Principal Support Engineer in Percona, 2012 - 2016
- Principal Support Engineer in MariaDB Corporation since March 2016
- **http://mysqlentomologist.blogspot.com** - my blog about MySQL (a lot about MySQL bugs, but some HowTos as well)
- **https://www.facebook.com/valerii.kravchuk** - my Facebook page, a lot about MySQL (mostly bugs…)
- **http://bugs.mysql.com** - my personal playground. 308 bugs reported in total, 20 since February, 2016
- I like FOSDEM, see slides from my previous talks:
  - http://www.slideshare.net/valeriikravchuk1/fosdem2015-gdb-tips-and-tricks-for-my-sql-db-as
  - http://www.slideshare.net/ValeriyKravchuk/more-on-gdb-for-my-sql-db-as-fosdem-2016

What is this session about?

- It’s about profiling MySQL and some tools (“profilers”) MySQL DBA can use for profiling in production on Linux:
    - Oprofile (including **opcontrol**, **opreport** and **operf**)
    - **perf** (I think it’s the best and easiest to use now)
    - Few words on PMP (**pt-pmp**)
- Some real life use case, along the lines of Bug #39630, Bug #68079 (including studying similar use case with MyRocks), Bug #83912 and maybe more...
- Why not about gprof, Callgrind, Massif, dtrace, SystemTap?
- Why not about Performance Schema?
- Performance impact of profiling

Why not about Performance Schema?

- It may be NOT compiled in (see MySQL from Facebook)
- It may be NOT enabled when server was started (see MariaDB)
- Specific instruments may not be enabled at startup and then it’s too late (see Bug #68097)
- Sizing instruments properly (memory used and performance impact vs details collected) may be problematic (depends on version also)
- Part of the code or 3rd party plugin may not be instrumented at all or in enough details (see Bug #83912)
- It does not give you a system-wide profiling, just for selected parts of MySQL server code
- Other people (including myself) talk and write a lot about it

Not Enough Details in Performance Schema

```
Samples: 52K of event 'cpu-clock', Event
count (approx.): 13037500000
Overhead  Command  Shared Object   Symbol
  43.75%  mysqld   mysqld          [.]
Item_func_mul::int_op
  16.97%  mysqld   mysqld          [.]
Item_func_benchmark::val_int
  14.10%  mysqld   mysqld          [.]
Item_int::val_int
  13.50%  mysqld   mysqld          [.]
Item_func_numhybrid::val_int
...
   2.58%  mysqld   mysqld          [.]
Item_func_numhybrid::result_type
...
```

```
30   SELECT `benchmark` ( ?, ... * ? )
(13055172.39?)
30        stage/sql/init (51.56?)
30        stage/sql/checking permissions
(2.27?)
30        stage/sql/Opening tables (1.00?)
30        stage/sql/After opening tables
(0.62?)
30        stage/sql/init (9.32?)
30        stage/sql/optimizing (7.41?)
30        stage/sql/executing (13055061.32?)
30        stage/sql/end (3.98?)
30        stage/sql/query end (2.34?)
30        stage/sql/closing tables (1.73?)
30        stage/sql/freeing items (4.22?)
30        stage/sql/cleaning up (1.13?)
```

- Yes, this is for primitive **select benchmark(500000000,2*2)** from Bug #39630
- Performance Schema query is like 25 lines long to make it readable

Not Enough Details in Performance Schema

- Now, where the time is spent on “statistics” stage in case presented in Bug #83912?

```
|         26 |       379 |                NULL | SELECT * FROM `t0` WHERE ID = ?  (13072.50ms)
|         26 |       380 |                 379 |  stage/sql/init (0.05ms)
|         26 |       383 |                 379 |  stage/sql/checking permissions (0.00ms)
|         26 |       384 |                 379 |  stage/sql/Opening tables (0.02ms)
|         26 |       386 |                 379 |  stage/sql/After opening tables (0.00ms)
|         26 |       387 |                 379 |  stage/sql/System lock (0.00ms)
|         26 |       389 |                 379 |  stage/sql/Table lock (0.00ms)
|         26 |       391 |                 379 |  stage/sql/init (0.02ms)
|         26 |       392 |                 379 |  stage/sql/optimizing (0.01ms)
|         26 |       393 |                 379 |  stage/sql/statistics (13072.32ms)
|         26 |       396 |                 379 |  stage/sql/preparing (0.00ms)
|         26 |       397 |                 379 |  stage/sql/Unlocking tables (0.02ms)
|         26 |       398 |                 379 |  stage/sql/executing (0.00ms)
|         26 |       399 |                 379 |  stage/sql/Sending data (0.01ms)
|         26 |       400 |                 379 |  stage/sql/end (0.00ms)
|         26 |       401 |                 379 |  stage/sql/query end (0.00ms)
```

Oprofile - Success Stories

- **Oprofile** is historically one of the first statistical profiling tools on Linux (2001)
- It was widely used while working on MySQL performance problems
- Here is the list of some MySQL bugs found or confirmed using **oprofile**:
  - **Bug #33948** - **"performance issue when using sysbench benchmark on a multiple-core system"** - table cache, **LOCK_open** contention etc, resolved in 5.5+ with metadata locks introduced. See **Bug #58037** also.
  - **Bug #49047** - **"InnoDB deadlock detection is CPU intensive with many locks on a single row"** - note that **innodb_deadlock_detect** server variable was added recently (in MySQL 5.7.15!) to disable deadlock detection entirely.
  - **Bug #49169** - "**read_view_open_now is inefficient with many concurrent sessions**" - “It was fixed as part of the kernel mutex split in 5.6”, or not?
  - **Bug #53825** - **"Removing locks from queue is very CPU intensive with many locks"**. It is still **"Verified"** and thus, **probably is not fixed**.
  - **Bug #68818** - "**Large Value List in WHERE Clause Spends Too Much Time in 'statistics' State**" - **oprofile** was used to show where exactly in the code (as opposed to just "statistics" stage) the time was spent
- More examples and details are presented in my blog post

Oprofile - Basic Usage of Versions < 1.0.0

- Check my post, “Oprofile Basics for MySQL Profiling”, for details and references, but basic minimal steps are:
    - Make sure **oprofile** package is installed: `dpkg -l | grep oprofile`
    - Load the OProfile module if required and make the OProfile driver interface available:

      ```
      sudo opcontrol --init
      ```
    - Start data collection (daemon is started if was not running):

      ```
      sudo opcontrol --start --no-vmlinux
      ```
    - Run your problematic load against MySQL server
    - *Samples are collected in* ***--session-dir*** *(if it was set), or* ***`pwd`/oprofile_data****, or, if that directory does not exist, the standard session-dir of* ***/var/lib/oprofile*** *is used*
    - Stop data collection:

      ```
      sudo opcontrol --stop
      ```
    - Flush collected daemon data:

      ```
      sudo opcontrol --dump
      ```
    - Run **opreport** to see the data collected:

      ```
      sudo opreport --demangle=smart --symbols --merge tgid path_to_mysqld
      ```
    - Check **pt-stalk** source code for the way **--collect-oprofile** option is implemented

Oprofile - Basic Usage of Versions >= 1.0.0

- No need for daemon (since 0.9.8), no **opcontrol**. **operf** allows to profile a single process (**--pid**, may work for normal user) or every currently running process (**--system-wide**). **operf** interfaces with the kernel to collect samples via the Linux Kernel Performance Events Subsystem (see **perf**).
- Less steps needed:
  - Start system-wide data collection :
    ```
    sudo operf -s
    ```
  - Run your problematic load against MySQL server
  - Interrupt the **operf** process (**Ctrl-C** works if it was foreground):
    ```
    sudo kill -SIGINT pid_of_operf
    ```
  - Run **opreport** to see the data collected:
    ```
    sudo opreport --demangle=smart --symbols --merge tgid path_to_mysqld
    ```
- My naive experience with **--pid `pidof mysqld`** option on Ubuntu 14.04 and Fedora 25 was negative, use system-wide profiling
- Check this pull request for **pt-stalk** (one day it will work with **oprofile** 1.0.0+)

Oprofile - Results You Get (Primitive Example)

- Profiling **select benchmark(500000000, 2*2)**:

```
openxs@ao756:~$ sudo operf -s
operf: Press Ctl-c or 'kill -SIGINT 12723' to stop profiling
operf: Profiler started
^C
Profiling done.
openxs@ao756:~$ sudo opreport --demangle=smart --symbols --merge tgid
/home/openxs/dbs/maria10.1/bin/mysqld | head -20
Using /home/openxs/oprofile_data/samples/ for samples directory.
warning: /no-vmlinux could not be found.
CPU: Intel Sandy Bridge microarchitecture, speed 1.5e+06 MHz (estimated)
Counted CPU_CLK_UNHALTED events (Clock cycles when not halted) with a unit mask of 0x00
(No unit mask) count 100000
samples   %             image name                 symbol name
96078     32.0059  mysqld                         Item_func_mul::int_op()
51487     17.1516  mysqld                         Item_hybrid_func::result_type() const
51407     17.1249  mysqld                         Item_func_hybrid_field_type::val_int()
47570     15.8467  mysqld                         Item_func_benchmark::val_int()
31575     10.5184  mysqld                         Item_int::val_int()
10925      3.6394  mysqld                         Type_handler_int_result::cmp_type() const
10659      3.5508  mysqld                         Type_handler_int_result::result_type() const
448        0.1492  no-vmlinux                     /no-vmlinux
...
```

pt-pmp (Poor Man's Profiler)

- http://www.percona.com/doc/percona-toolkit/2.2/pt-pmp.html

```
pt-pmp [-i 1] [-s 0] [-b mysqld] [-p pidofmysqld] [-l 0] [-k file]  [--version]
```

- It is based on original idea by **Domas**, **http://poormansprofiler.org/**
- One of the recent examples how it is used: Bug #78277 - InnoDB deadlock, thread stuck on kernel calls from transparent page compression, "Open"
- When **mysqld** hangs or is slow, you can get some insight quickly: for example, Bug #75028 (HandlerSocket "hangs" on shutdown)
- When there are stalls, use **pt-pmp** to find out why (or what threads mostly do at the moment): Bug #69810
- **Use in production as a last resort (**may hang **mysqld**, **--SIGCONT)**
- **pt-pmp** surely **slows server down** :) Hints:
  - https://bugs.launchpad.net/percona-toolkit/+bug/1320168 - partial workaround
  - Use **quickstack** instead of **gdb** (check this discussion)

pt-pmp Applied to “statistics” Case of Bug #83912

```
MariaDB [test]> select * from t0 where id = 15;
+----+------+--------------------+
| id | c1   | c2                 |
+----+------+--------------------+
| 15 |  290 | 0.7441205286831786 |
+----+------+--------------------+
1 row in set (52.27 sec)
     1
select(libc.so.6),os_thread_sleep(os0thread.cc:303),srv_conc_enter_innodb_wi
th_atomics(srv0conc.cc:298),srv_conc_enter_innodb(srv0conc.cc:298),innobase
_srv_conc_enter_innodb(ha_innodb.cc:1906), ha_innobase::index_read(ha_innodb.
cc:1906),handler::index_read_idx_map(handler.cc:5441),handler::ha_index_rea
d_idx_map(handler.cc:2646),join_read_(handler.cc:2646),join_read__table(han
dler.cc:2646),make_join_statistics(sql_select.cc:3935),JOIN::optimize_inner(
sql_select.cc:1366),JOIN::optimize(sql_select.cc:1045),mysql_select(sql_sele
ct.cc:3430),handle_select(sql_select.cc:372),execute_sqlcom_select(sql_pars
e.cc:5896),mysql_execute_command(sql_parse.cc:2971),mysql_parse(sql_parse.c
c:7319),dispatch_command(sql_parse.cc:1488),do_command(sql_parse.cc:1109),d
o_handle_one_connection(sql_connect.cc:1349),handle_one_connection(sql_conn
ect.cc:1261),pfs_spawn_thread(pfs.cc:1860),start_thread(libpthread.so.0),cl
one(libc.so.6)
```

```
...
```

Is PMP Always Useful?

```
[openxs@fc23 ~]$ pt-pmp
Fri Jan 27 10:53:28 EET 2017
     10
__io_getevents_0_4(libaio.so.1),os_aio_linux_collect(os0file.cc:5432),os_ai
o_linux_handle(os0file.cc:5432),fil_aio_wait(fil0fil.cc:6231),io_handler_th
read(srv0start.cc:546),start_thread(libpthread.so.0),clone(libc.so.6)
     1
Type_handler_hybrid_field_type::cmp_type,Item_hybrid_func::cmp_type, Item_fu
nc_hybrid_field_type::val_int,Item_func_benchmark::val_int(item_func.cc:4482)
,Item::send(item.cc:6561),Protocol::send_result_set_row(protocol.cc:914),se
lect_send::send_data(sql_class.cc:2830),JOIN::exec_inner(sql_select.cc:2589
),JOIN::exec(sql_select.cc:2510),mysql_select(sql_select.cc:3444),handle_se
lect(sql_select.cc:372),execute_sqlcom_select(sql_parse.cc:5896),mysql_exec
ute_command(sql_parse.cc:2971),mysql_parse(sql_parse.cc:7319),dispatch_comm
and(sql_parse.cc:1488),do_command(sql_parse.cc:1109),do_handle_one_connecti
on(sql_connect.cc:1349),handle_one_connection(sql_connect.cc:1261),pfs_spaw
n_thread(pfs.cc:1860),start_thread(libpthread.so.0),clone(libc.so.6)
...
     1
select(libc.so.6),os_thread_sleep(os0thread.cc:303),srv_master_sleep(srv0sr
v.cc:3139),srv_master_thread(srv0srv.cc:3139),start_thread(libpthread.so.0)
,clone(libc.so.6)
...
```

perf - Success Stories

- **perf** (sometimes called **perf_events** or **perf tools**, originally **Performance Counters for Linux**, **PCL**) is a new performance analyzing tool for Linux, available from kernel version 2.6.31 (supported by RHEL6 since 2010)
- It is easier to use (IMHO) and more popular recently for MySQL
- Here is the list of some MySQL bugs by **Mark Callaghan** confirmed using **perf**:
  - **Bug #69236** - **"performance regressions for single-threaded workloads, part 2"** - MySQL 5.6 is spending a lot more time in **rec_get_offsets_func**, **trx_undo_report_row_operation**, **btr_cur_optimistic_insert**. Same in 5.7.8, “Verified”
  - **Bug #74325** - “**updates to indexed column much slower in 5.7.5**” - nice **perf** outputs there. It’s about **innodb_fill_factor=100** (that leaves 1/16 free space since 5.7.8).
  - **Bug #74280** - “**covering secondary scans worse than PK scan at high concurrency**” - the mutex contention that isn't visible in P_S output because the block rw-lock isn't instrumented. Verified regression since 5.7.5 vs 5.6.x. See also:
    Bug #74283 - “**Non-covering secondary index scans degrade more in 5.7 than 5.6**”
  - **http://smalldatum.blogspot.com/2014/10/details-on-range-scan-performance.html** - on two bugs above, **perf** allows to see the difference

perf - Basic Usage

- Check my post, “perf Basics for MySQL Profiling”, for details and references, but basic minimal steps are:
  - Make sure **perf**-related packages are installed (**perf** with RPMs) for your kernel:

    ```
    sudo apt-get install linux-tools-generic
    ```
  - *Make sure debug symbols are installed and software is built with **-fno-omit-frame-pointer***
  - Start data collection for some time using **perf record**:

    ```
    sudo perf record -a [-g] [-F99] [-p `pidof mysqld`] sleep 30
    ```

    Run your problematic load against MySQL server
  - *Samples are collected in **`pwd`/perf.data** by default*
  - Process samples and display the profile using **perf report**:

    ```
    sudo perf report [-n] [-g] --stdio
    ```
- Alternatively, run in foreground and interrupt any time with Ctrl-C:

  ```
  [root@centos ~]# perf record -ag
  ^C
  ```
- Or run in background and send **-SIGINT** when done:

  ```
  [root@centos ~]# perf record -ag &
  [1] 2353
  [root@centos ~]# kill -sigint  2353
  ```
- Let’s see how it works alive… (demo). We’ll see **perf top**, **perf record -g** etc

perf - Call Graphs

Use **-g** option of **perf record** to get call graphs/backtraces with **perf**, then:

```
openxs@ao756:~/dbs/maria10.1$ sudo perf report --stdio
...
     31.02%         mysqld  mysqld                          [.] Item_func_mul::int_op()
                    |
                    --- Item_func_mul::int_op()
                         |
                         |--94.56%-- Item_func_hybrid_field_type::val_int()
                         |         Item_func_benchmark::val_int()
                         |         Item::send(Protocol*, String*)
                         |         Protocol::send_result_set_row(List<Item>*)
                         |         select_send::send_data(List<Item>&)
                         |         JOIN::exec_inner()
                         |         JOIN::exec()
                    |         mysql_select(THD*, Item***, TABLE_LIST*, ...
                         |         handle_select(THD*, LEX*, select_result*, unsigned
long)

                         |         execute_sqlcom_select(THD*, TABLE_LIST*)
                         |         mysql_execute_command(THD*)
                         |         mysql_parse(THD*, char*, unsigned int, Parser_state*)
                         |         dispatch_command(enum_server_command, THD*, char*,
...)

                         |         do_command(THD*)
...
```

On perf vs Oprofile

- These days **perf** is, IMHO, better than **oprofile/operf** for MySQL profiling:
  - **perf** has a lot of features and requires less steps for basic usage
  - Call graphs are easier to get and more useful with **perf**
  - Classical **oprofile** (with daemon etc) has more severe impact on performance
  - In some environments **operf** just doesn’t work (while **perf** does):

```
[root@centos ~]# operf --version
Your kernel's Performance Events Subsystem does not support your processor
type.
Please use the opcontrol command instead of operf.
```

- Check the following blog post and discussion:
  - “perf: the good, the bad, the ugly”, by **Robert Haas**
  - Oprofile vs Perf from **oprofile-list@lists.sf.net**
- **--collect-oprofile** in **pt-stalk** may not work well for Galera (see **lp:1152571**)
- Time to add **--collect-perf** to **pt-stalk**!
- PMP is special (ease of use for specific tasks vs performance impact/hangs)

Studying Hanging in “statistics” Case(s)

- See my blog post for details and full outputs:

```
|        |--71.70%-- srv_conc_enter_innodb(trx_t*)
|        |        ha_innobase::index_read(...)
|        |        handler::index_read_idx_map(...)
|        |        handler::ha_index_read_idx_map(...)
|        |        join_read_const(st_join_table*)
|        |        join_read_const_table(THD*, ...)
|        |        make_join_statistics(JOIN*, ...)
|        |        JOIN::optimize_inner()
|        |        JOIN::optimize()
|        |        mysql_select(THD*, ...)
...
```

- We can see that time to do **SELECT** is mostly spent waiting to enter InnoDB queue while reading data via index (dive) to get statistics for the optimizer
- We can also see what **UPDATE**s are doing at the moment (**-g caller** ?)
- We can see where the time is spent by kernel and other processes (**-a**)

Studying MyRocks Performance - Test Case

- See my blog post “**Profiling MyRocks with perf: Good Old Bug #68079 Use Case**” for details
- Essentially, why this query:

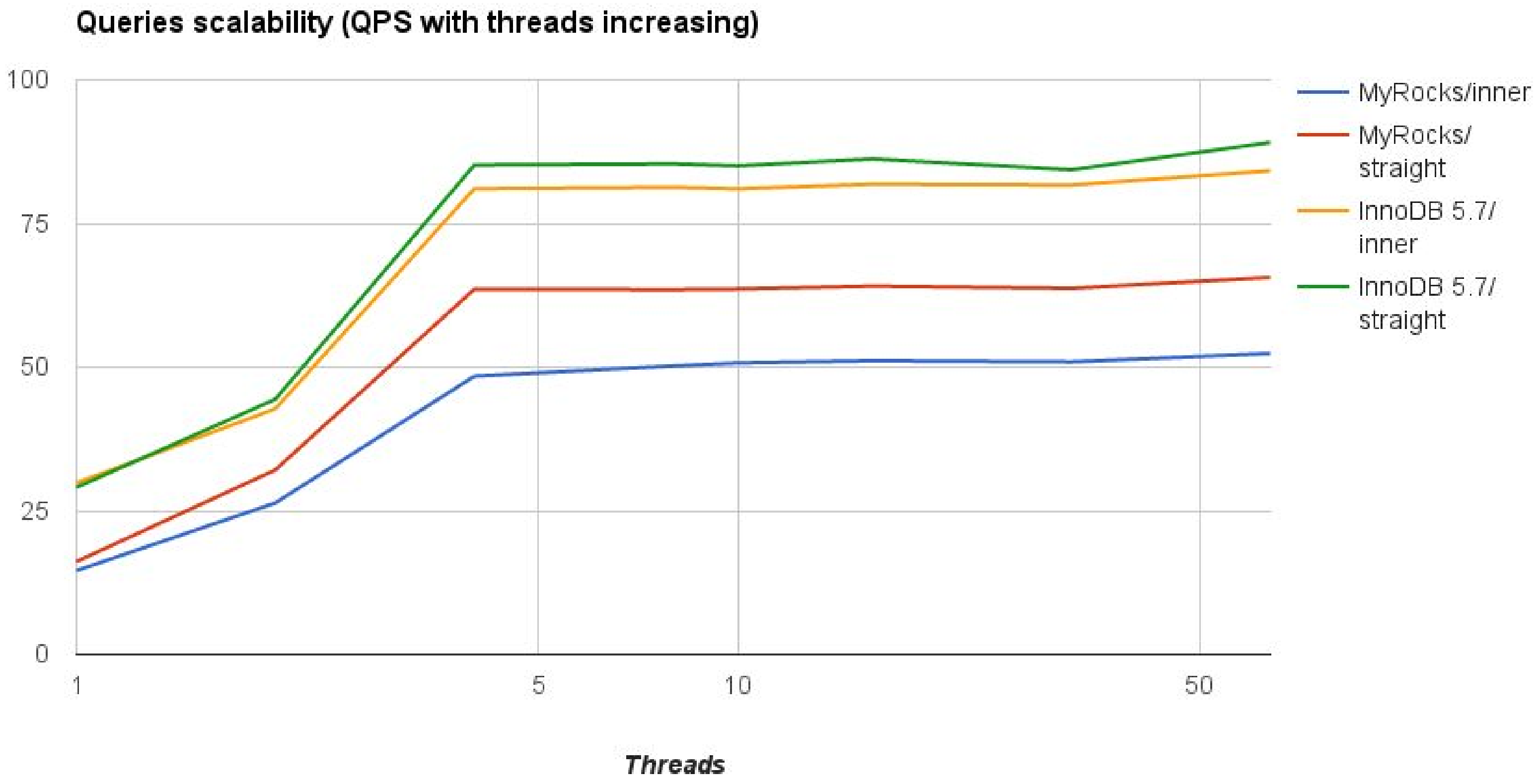
```
mysql> explain select count(*), category from task straight_join incident on
task.sys_id=incident.sys_id group by incident.category;
...
|  1 | SIMPLE      | task     | index  | PRIMARY                   | PRIMARY | 96
     | NULL             | 8292 | Using index; Using temporary; Using filesort |
|  1 | SIMPLE      | incident | eq_ref | PRIMARY,incident_category | PRIMARY | 96
     | test.task.sys_id |    1 | NULL                                         |
```

runs faster (scales better?) than this one with MyRocks (unlike with InnoDB):

```
mysql> explain select count(*), category from task inner join incident on
task.sys_id=incident.sys_id group by incident.category;
...
|  1 | SIMPLE      | incident | index  | PRIMARY,incident_category |
incident_category | 123  | NULL               | 8192 | Using index |
|  1 | SIMPLE      | task     | eq_ref | PRIMARY                   | PRIMARY
     | 96     | test.incident.sys_id | 1 | Using index |
```

Studying MyRocks Performance - Results

- See my blog post “**Profiling MyRocks...**” for details



Studying MyRocks Performance - Profiling...

Top functions for STRAIGHT_JOIN:

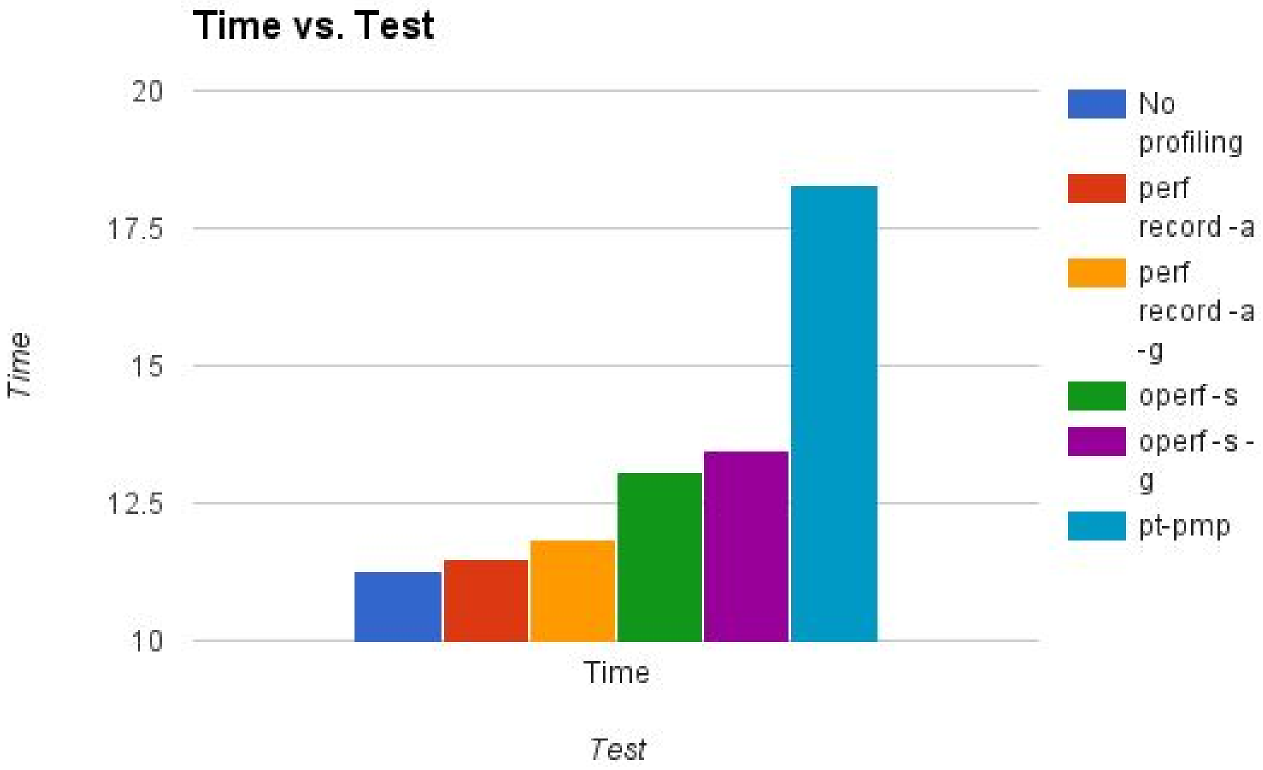
```
5.32%  ... __memcmp_sse4_1
4.68%  ... __memcpy_ssse3
4.04%  ... rocksdb::BlockIter::Seek
3.33%  ... my_strnxfrm_unicode
3.11%  ... rocksdb::BlockBasedTable::Get
2.96%  ... myrocks::Rdb_pk_comp..::Compare
2.54%  ... rocksdb::BlockIter::BinarySeek
2.14%  ... rocksdb::Int.KeyComp.::Compare
2.00%  ... rocksdb::Stat.Impl::recordTick
1.99%  ... rocksdb::MergingIterator::Next
1.95%  ... rocksdb::HistogramStat::Add
1.51%  ... join_read_key
1.51%  ... myrocks::rdb_unpack_utf8_str
1.41%  ... myrocks::Rdb_key_def::unp._rec.
1.36%  ... sub_select
1.32%  ... my_uni_utf8
1.29%  ... rocksdb::Version::Get
1.22%  ... _int_malloc
1.22%  ... rocksdb::TableCache::Get
1.22%  ... rocksdb::BlockIter::Next
```

Top functions INNER JOIN:

```
5.90%  ... __memcpy_ssse3
4.38%  ... pthread_mutex_lock
3.69%  ... __memcmp_sse4_1
3.58%  ... rocksdb::BlockIter::Seek
2.53%  ... pthread_mutex_unlock
2.47%  ... rocksdb::Stat.Impl::recordTick
2.35%  ... rocksdb::BlockBasedTable::Get
2.28%  ... my_strnxfrm_unicode
2.08%  ... rocksdb::BlockIter::BinarySeek
1.84%  ... rocksdb::HistogramStat::Add
1.84%  ... rocksdb::Version::Get
1.71%  ... myrocks::rdb_unpack._or_utf8_var.
1.69%  ... rocksdb::LRUCacheShard::Lookup
1.67%  ... my_uni_utf8
1.61%  ... rocksdb::Int.KeyComp.::Compare
1.52%  ... myrocks::Rdb_pk_comp.::Compare
1.47%  ... rocksdb::.FilePicker::GetNextFile
1.23%  ... rocksdb::BlockIter::Next
1.15%  ... rocksdb::MergingIterator::Next
1.10%  ... join_read_key
```

Some More on Performance Impact of Profiling

- Check this doc. for the details of primitive single threaded test (Bug #39630)



Thank you!

Questions and Answers?

Please, report bugs at:

http://bugs.mysql.com

https://jira.mariadb.org