第五讲：MySQL 的线程模型

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1. 多进程和多线程

2. 线程生命周期

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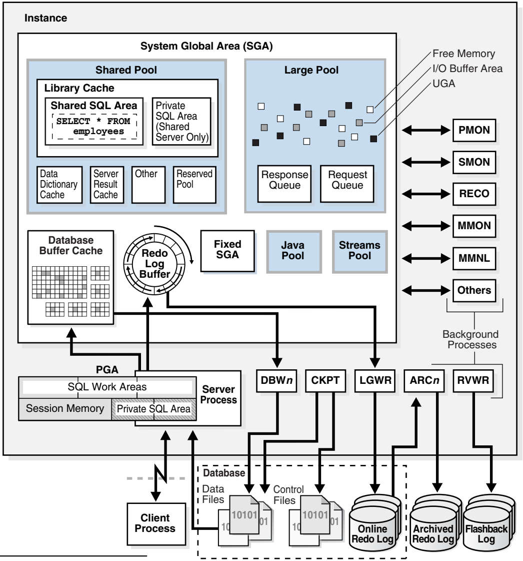
1

多进程和多线程

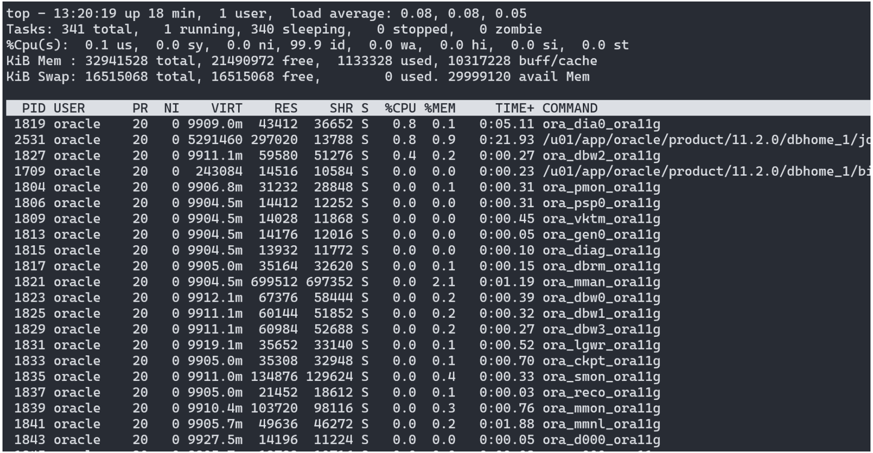
多进程的数据库架构 [1]



[1] https://docs.oracle.com/cd/E11882_01/server.112/e40540/process.htm

查看 ORACLE 进程列表

```
top -u oracle -c
```



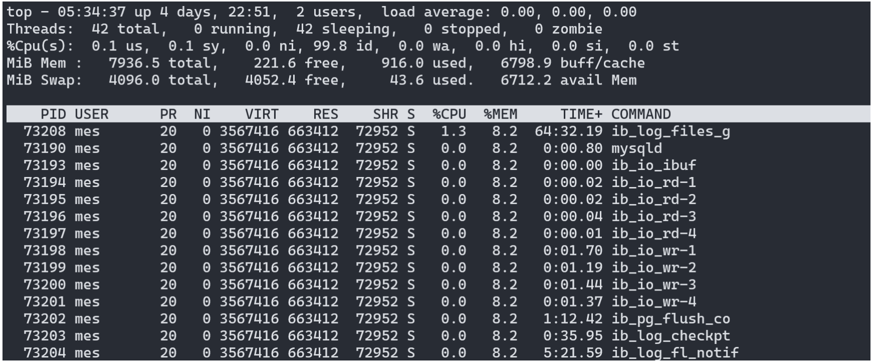
```
top - 13:20:19 up 18 min,  1 user,  load average: 0.08, 0.08, 0.05
Tasks: 341 total,   1 running, 340 sleeping,   0 stopped,   0 zombie
%Cpu(s):  0.1 us,  0.0 sy,  0.0 ni, 99.9 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
KiB Mem : 32941528 total, 21490972 free,  1133328 used, 10317228 buff/cache
KiB Swap: 16515068 total, 16515068 free,        0 used. 29999120 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
 1819 oracle    20   0 9909.0m  43412  36652 S   0.8  0.1   0:05.11 ora_dia0_ora11g
 2531 oracle    20   0 5291460 297020  13788 S   0.8  0.9   0:21.93 /u01/app/oracle/product/11.2.0/dbhome_1/j
 1827 oracle    20   0 9911.1m  59580  51276 S   0.4  0.2   0:00.27 ora_dbw2_ora11g
 1709 oracle    20   0  243084  14516  10584 S   0.0  0.0   0:00.23 /u01/app/oracle/product/11.2.0/dbhome_1/bi
 1804 oracle    20   0 9906.8m  31232  28848 S   0.0  0.1   0:00.31 ora_pmon_ora11g
 1806 oracle    20   0 9904.5m  14412  12252 S   0.0  0.0   0:00.31 ora_psp0_ora11g
 1809 oracle    20   0 9904.5m  14028  11868 S   0.0  0.0   0:00.45 ora_vktm_ora11g
 1813 oracle    20   0 9904.5m  14176  12016 S   0.0  0.0   0:00.05 ora_gen0_ora11g
 1815 oracle    20   0 9904.5m  13932  11772 S   0.0  0.0   0:00.10 ora_diag_ora11g
 1817 oracle    20   0 9905.0m  35164  32620 S   0.0  0.1   0:00.15 ora_dbrm_ora11g
 1821 oracle    20   0 9904.5m 699512 697352 S   0.0  2.1   0:01.19 ora_mman_ora11g
 1823 oracle    20   0 9912.1m  67376  58444 S   0.0  0.2   0:00.39 ora_dbw0_ora11g
 1825 oracle    20   0 9911.1m  60144  51852 S   0.0  0.2   0:00.32 ora_dbw1_ora11g
 1829 oracle    20   0 9911.1m  60984  52688 S   0.0  0.2   0:00.27 ora_dbw3_ora11g
 1831 oracle    20   0 9919.1m  35652  33140 S   0.0  0.1   0:00.52 ora_lgwr_ora11g
 1833 oracle    20   0 9905.0m  35308  32948 S   0.0  0.1   0:00.70 ora_ckpt_ora11g
 1835 oracle    20   0 9911.0m 134876 129624 S   0.0  0.4   0:00.33 ora_smon_ora11g
 1837 oracle    20   0 9905.0m  21452  18612 S   0.0  0.1   0:00.03 ora_reco_ora11g
 1839 oracle    20   0 9910.4m 103720  98116 S   0.0  0.3   0:00.76 ora_mmon_ora11g
 1841 oracle    20   0 9905.7m  49636  46272 S   0.0  0.2   0:01.88 ora_mmnl_ora11g
 1843 oracle    20   0 9927.5m  14196  11224 S   0.0  0.0   0:00.05 ora_d000_ora11g
```

查看 MySQL 的线程列表

1. 自 8.0.27 出现操作系统的线程名称，见发布日志[2]
2. 通过 top 查看线程列表和详细信息

```
top -H -p <MYSQLD_PID>
```



```
top - 05:34:37 up 4 days, 22:51,  2 users,  load average: 0.00, 0.00, 0.00
Threads:  42 total,   0 running,  42 sleeping,   0 stopped,   0 zombie
%Cpu(s):  0.1 us,  0.1 sy,  0.0 ni, 99.8 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
MiB Mem :   7936.5 total,    221.6 free,    916.0 used,   6798.9 buff/cache
MiB Swap:   4096.0 total,   4052.4 free,     43.6 used.   6712.2 avail Mem

    PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
  73208 mes       20   0 3567416 663412  72952 S   1.3   8.2  64:32.19 ib_log_files_g
  73190 mes       20   0 3567416 663412  72952 S   0.0   8.2   0:00.80 mysqld
  73193 mes       20   0 3567416 663412  72952 S   0.0   8.2   0:00.00 ib_io_ibuf
  73194 mes       20   0 3567416 663412  72952 S   0.0   8.2   0:00.02 ib_io_rd-1
  73195 mes       20   0 3567416 663412  72952 S   0.0   8.2   0:00.02 ib_io_rd-2
  73196 mes       20   0 3567416 663412  72952 S   0.0   8.2   0:00.04 ib_io_rd-3
  73197 mes       20   0 3567416 663412  72952 S   0.0   8.2   0:00.01 ib_io_rd-4
  73198 mes       20   0 3567416 663412  72952 S   0.0   8.2   0:01.70 ib_io_wr-1
  73199 mes       20   0 3567416 663412  72952 S   0.0   8.2   0:01.19 ib_io_wr-2
  73200 mes       20   0 3567416 663412  72952 S   0.0   8.2   0:01.44 ib_io_wr-3
  73201 mes       20   0 3567416 663412  72952 S   0.0   8.2   0:01.37 ib_io_wr-4
  73202 mes       20   0 3567416 663412  72952 S   0.0   8.2   1:12.42 ib_pg_flush_co
  73203 mes       20   0 3567416 663412  72952 S   0.0   8.2   0:35.95 ib_log_checkpt
  73204 mes       20   0 3567416 663412  72952 S   0.0   8.2   5:21.59 ib_log_fl_notif
```

[2] https://dev.mysql.com/doc/relnotes/mysql/8.0/en/news-8-0-27.html#mysqld-8-0-27-performance-schema

性能视图 performance_schema

```
select
  thread_id,     -- 线程 ID
  thread_os_id,  -- 操作系统线程 ID
  name           -- 线程名称
from
  performance_schema.threads;
```

查询 threads 表示例 [3]

```
mysql> select thread_id, thread_os_id, name from threads;
+-----------+--------------+----------------------------------------+
| thread_id | thread_os_id | name                                   |
+-----------+--------------+----------------------------------------+
|         1 |        73190 | thread/sql/main                        |
|         3 |        73193 | thread/innodb/io_ibuf_thread           |
|         4 |        73194 | thread/innodb/io_read_thread           |
|         5 |        73195 | thread/innodb/io_read_thread           |
```

[3] https://dev.mysql.com/doc/refman/8.0/en/performance-schema-threads-table.html

2

线程生命周期

gdb 调试多线程程序

- 控制线程启动/退出是打印的事件

```
(gdb) set print thread-events on/off
[New Thread 0x41e02940 (LWP 25582)]
```

- 线程调试命令
  1. `info threads` 查看线程列表和详细信息
  2. `thread <threadno>` 切换到线程 <threadno>

线程注册表

- 注册表结构 `static PSI_thread_info ...`
- ⋆ storage/innobase/handler/ha_innodb.cc

```
static PSI_thread_info all_innodb_threads[] = {
    PSI_THREAD_KEY(log_archiver_thread, "ib_log_arch", PSI_FLAG_SINGLETON, 0,
                   PSI_DOCUMENT_ME),
    PSI_THREAD_KEY(page_archiver_thread, "ib_page_arch", PSI_FLAG_SINGLETON, 0,
                   PSI_DOCUMENT_ME),
    PSI_THREAD_KEY(buf_dump_thread, "ib_buf_dump", PSI_FLAG_SINGLETON, 0,
                   PSI_DOCUMENT_ME),
    PSI_THREAD_KEY(clone_ddl_thread, "ib_clone_ddl", PSI_FLAG_SINGLETON, 0,
                   PSI_DOCUMENT_ME),
```

- `PSI_thread_info` ⇒ `PSI_thread_info_v5` 结构体
  - `PSI_thread_key *m_key` 注册线程的 key
  - `const char *m_name` 注册的名称
  - `const char *m_os_name` 注册线程在操作系统下看的名称
  - …

线程创建

- MySQL 原始的创建线程
- inline_mysql_thread_create() 创建线程函数，调用 my_thread_create()
  - ⋆ include/mysql/psi/mysql_thread.h

```
static inline int inline_mysql_thread_create(
    PSI_thread_key key [[maybe_unused]],
    unsigned int sequence_number [[maybe_unused]], my_thread_handle *thread,
    const my_thread_attr_t *attr, my_start_routine start_routine, void *arg) {
  int result;
#ifdef HAVE_PSI_THREAD_INTERFACE
  result = PSI_THREAD_CALL(spawn_thread)(key, sequence_number, thread, attr,
                                         start_routine, arg);
```

- my_thread_create() 在 Linux 下调用 pthread_create()
  - ⋆ include/mysql/psi/mysql_thread.h

```
int my_thread_create(my_thread_handle *thread, const my_thread_attr_t *attr,
                     my_start_routine func, void *arg) {
#ifndef _WIN32
  return pthread_create(&thread->thread, attr, func, arg);
#else
```

线程创建（续）

- 存储引擎创建 PFS 线程方法
- pfs_spawn_thread() 中调用创建线程函数 create_thread()
  - ⋆ storage/perfschema/pfs.cc

```
extern "C" {
static void *pfs_spawn_thread(void *arg) {
  auto *typed_arg = (PFS_spawn_thread_arg *)arg;
  void *user_arg;
  void *(*user_start_routine)(void *);
```

- create_thread() 函数中分配 PFS_thread 对象内存，并进行基础对象成员的初始化
  - ⋆ storage/perfschema/pfs_instr.cc

```
PFS_thread *create_thread(PFS_thread_class *klass, PSI_thread_seqnum seqnum,
                          const void *identity [[maybe_unused]],
                          ulonglong processlist_id) {
  PFS_thread *pfs;
  pfs_dirty_state dirty_state;
```

线程启动

- pfs_spawn_thread(void *arg) 启动用户代码
  - ★ storage/perfschema/pfs.cc

```
  /*
    Secondly, free the memory allocated in spawn_thread_v1().
    It is preferable to do this before invoking the user
    routine, to avoid memory leaks at shutdown, in case
    the server exits without waiting for this thread.
  */
  user_start_routine = typed_arg->m_user_start_routine;
  user_arg = typed_arg->m_user_arg;
  my_free(typed_arg);

  /* Then, execute the user code for this thread. */
  (*user_start_routine)(user_arg);

  return nullptr;
}
```

查看线程入口函数

1. 以 log_archiver_thread 为例
2. ⋆ storage/innobase/handler/ha_innodb.cc

```
static PSI_thread_info all_innodb_threads[] = {
    PSI_THREAD_KEY(log_archiver_thread, "ib_log_arch", PSI_FLAG_SINGLETON, 0,
                   PSI_DOCUMENT_ME),
```

3. 搜索代码 `log_archiver_thread(`
4. 得到线程入口函数 ⋆ storage/innobase/arch/arch0arch.cc

```
/** Archiver background thread */
void log_archiver_thread() {
  Arch_File_Ctx log_file_ctx;
  lsn_t log_arch_lsn = LSN_MAX;
```

3

常见线程功能

后台线程列表 [4]

mysqld							
connection	connection	connection	evt_sched	sig_handler	gtid_zip		
ib_buf_dump	ib_buf_resize	ib_clone_gtid	ib_dict_stats	ib_fts_opt	ib_io_ibuf		
ib_io_rd-1	ib_io_rd-2	ib_io_rd-3	ib_io_rd-4	ib_io_wr-1	ib_io_wr-2	ib_io_wr-3	ib_io_wr-4
ib_log_checkpt	ib_log_files_g	ib_log_fl_notif	ib_log_flush	ib_log_wr_notif	ib_log_writer	ib_pg_flush_co	
ib_src_main	ib_srv_err_mon	ib_srv_lock_to	ib_srv_mon	ib_srv_purge	ib_srv_wkr-1	ib_srv_wkr-2	ib_srv_wkr-3
xpl_accept-1	xpl_accept-2	xpl_worker-1	xpl_worker-2				

[4] https://github.com/Jeanhwea/mysql-source-course/blob/master/assets/thd-name-ref.org

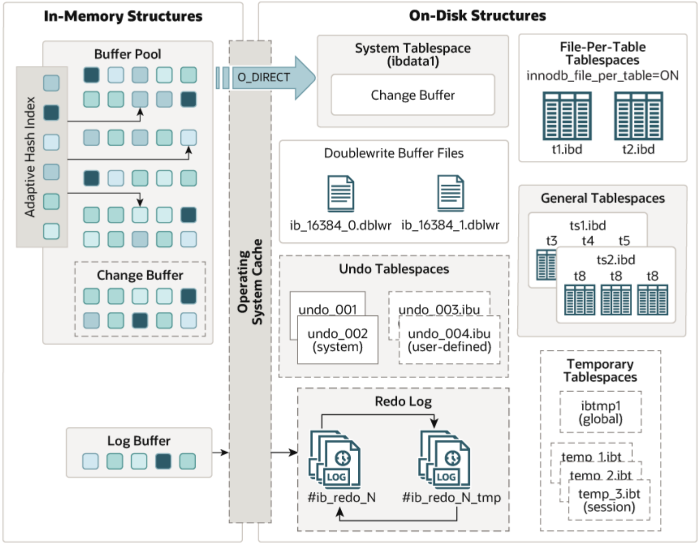
常见线程功能

- mysqld 连接监听主线程，用于监听处理客户端的连接请求
- connection 连接出来线程，客户端建立连接后会分配
- evt_sched 事件调度线程，用来调度执行每个表上定义事件，例如

```
CREATE EVENT myevent
    ON SCHEDULE EVERY 6 HOUR
    COMMENT 'A sample comment.'
    DO UPDATE myschema.mytable SET mycol = mycol + 1;
```

- sig_handler 信号处理线程，用来处理信号
- gtid_zip 开启一个线程用来压缩 GTID_Table
- xpl_accept/xpl_worker mysqlx 实现了 X Protocol 来支持 X Plugin

InnoDB 引擎


In-Memory Structures
Buffer Pool
Adaptive Hash Index
Change Buffer
Log Buffer
Operating System Cache
O_DIRECT
On-Disk Structures
System Tablespace (ibdata1)
Change Buffer
File-Per-Table Tablespaces
innodb_file_per_table=ON
t1.ibd
t2.ibd
Doublewrite Buffer Files
ib_16384_0.dblwr
ib_16384_1.dblwr
General Tablespaces
ts1.ibd
t3
t4
t5
ts2.ibd
t8
t8
t8
Undo Tablespaces
undo_001
undo_002 (system)
undo_003.ibu
undo_004.ibu (user-defined)
Temporary Tablespaces
ibtmp1 (global)
temp_1.ibt
temp_2.ibt
temp_3.ibt (session)
Redo Log
LOG
LOG
#ib_redo_N
#ib_redo_N_tmp

innodb 线程

- ib_src_main 引擎主线程，优先级最高
  1. 其内部包含主循环、后台循环、刷新循环、暂停循环
  2. 会根据其内部运行的相关状态在前述各循环间中进行切换
- ib_io_rd-n 读线程，负责从磁盘上读入数据页
  1. 其由 innodb_read_io_threads 控制
  2. 默认值为 4
- ib_io_wr-n 写线程，负责将数据页写入磁盘，
  1. 其由 innodb_write_io_threads 控制
  2. 默认值为 4
- ib_log_writer 负责把日志缓冲中的内容刷新到 redo log 文件中
- ib_srv_purge 负责删除无用的 undo 页
- ib_log_checkpt 负责在 redo log 发生切换时，执行 checkpoint 操作
- ib_srv_err_mon 负责 mysql 报错的监控
- ib_srv_lock_to 负责 mysql 锁的监控

结束