# Analyzing postgres performance problems using perf and eBPF

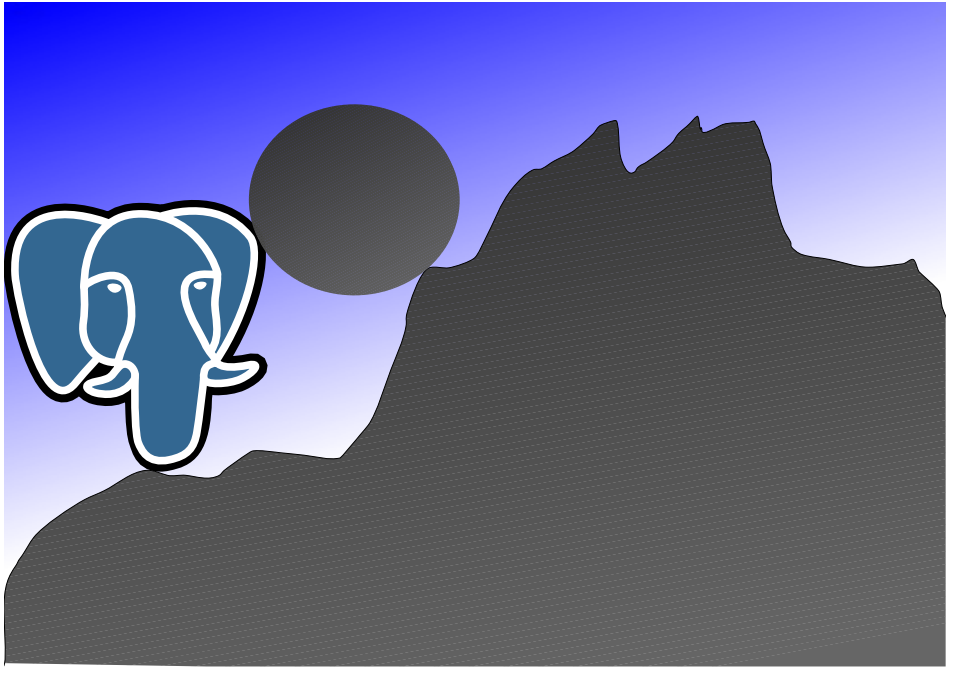
Andres Freund

PostgreSQL Developer, Committer and Core Team Member

andres@anarazel.de

andres.freund@microsoft.com

@AndresFreundTec



https://anarazel.de/talks/2022-04-12-cituscon/perf-bpf.pdf

# Perf

# Perf

- Linux kernel profiling tool
- Requires elevated privileges
- “perf record” – profile workload
  - `-p $pid` – one pid
  - `-a -` everyone
  - `--call-graph dwarf` – call graphs
- “perf report” – look at profile
  - `--children` / `--no-children`
  - `--sort fielda,fieldb`
- Brendan Gregg’s collection of perf links: `https://www.brendangregg.com/perf.html`

# Initial Investigation

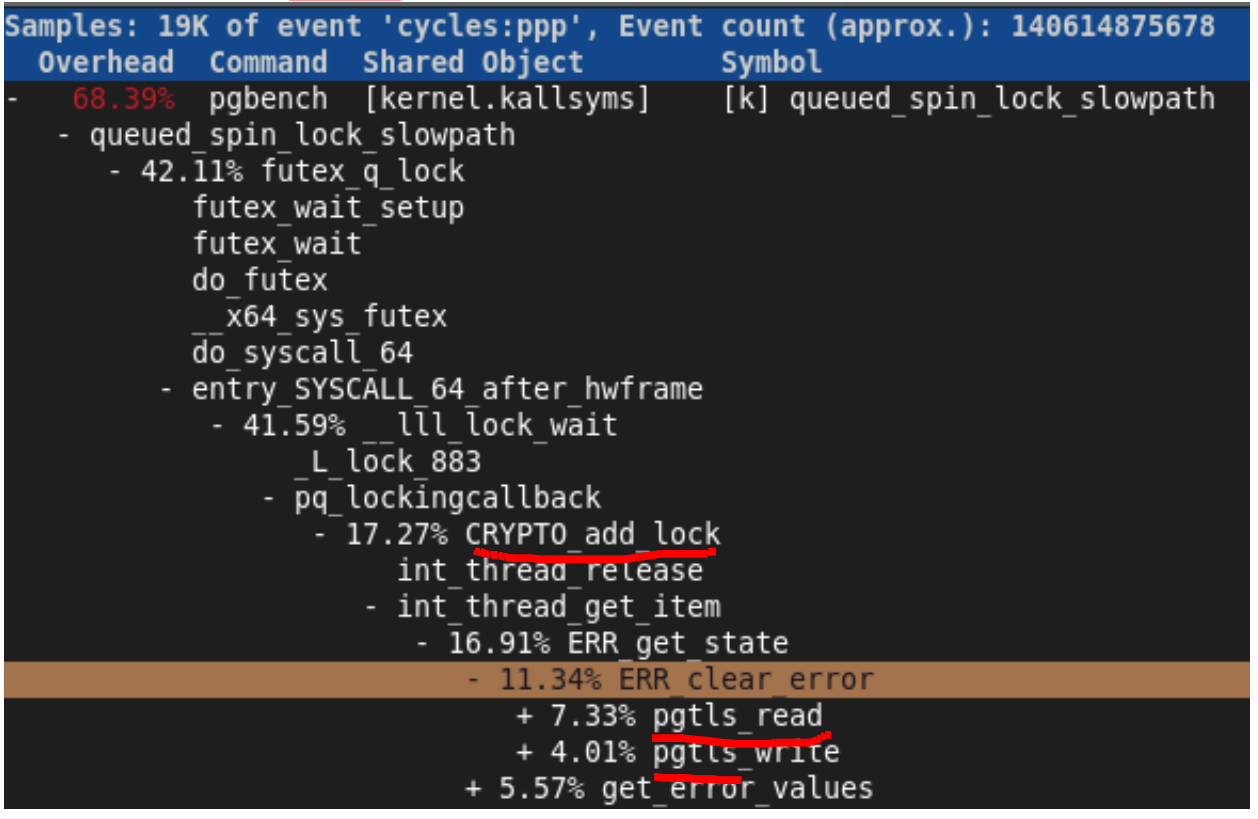
perf record -a sleep 3
perf report --sort comm,dso

```
Samples: 160K of event 'cycles', Event count (approx.): 118788343308
Overhead  Command          Shared Object
  72.15%  pgbench          [kernel.vmlinux]
  10.69%  postgres         postgres
   4.76%  postgres         [kernel.vmlinux]
   2.06%  pgbench          libcrypto.so.1.0.2k
   1.32%  pgbench          libpthread-2.17.so
   1.26%  pgbench          libc-2.17.so
   1.25%  postgres         libcrypto.so.1.1
   1.18%  swapper          [kernel.vmlinux]
   0.99%  pgbench          libpq.so.5.14
   0.91%  postgres         libc-2.33.so
   0.90%  postgres         libssl.so.1.1
   0.69%  pgbench          pgbench
```

perf record -p $pgbench_pid sleep 1
perf report

```
Samples: 153K of event 'cycles', Event count (approx.): 91833386559
Overhead  Command  Shared Object         Symbol
  69.90%  pgbench  [kernel.vmlinux]      [k] queued_spin_lock_slowpath
   1.00%  pgbench  [kernel.vmlinux]      [k] _raw_spin_lock
   0.87%  pgbench  libcrypto.so.1.0.2k   [.] sk_is_sorted
   0.83%  pgbench  [kernel.vmlinux]      [k] try_to_wake_up
   0.82%  pgbench  [kernel.vmlinux]      [k] futex_wake
   0.80%  pgbench  [kernel.vmlinux]      [k] select_task_rq_fair
   0.57%  pgbench  libpthread-2.17.so    [.] __pthread_mutex_lock
   0.56%  pgbench  [kernel.vmlinux]      [k] available_idle_cpu
```

perf record -p $pid_of_pgbench --call-graph dwarf sleep 1
perf report --no-children



openssl lock thread

All Shopping Images Videos News More Tools

About 485,000 results (0.32 seconds)

https://www.openssl.org › blog › blog › 2017/02/21 › t...

## OpenSSL and Threads

Feb 21, 2017 — In short, **OpenSSL** has always, and only, supported the concept of **locking** an object and sometimes it **locks** its internal objects. Read on for more ...

https://www.openssl.org › docs › man1.0.2 › man3 › th...

### threads - OpenSSL

**OpenSSL** can generally be used safely in multi-threaded applications provided that at least two callback functions are set, the locking_function and ...

https://stackoverflow.com › questions › how-do-i-write-...

## How do I write thread-safe OpenSSL code the new way?

Apr 26, 2020 · 1 answer

Actually, you no longer need to set up **locks** in **OpenSSL** 1.1.0 and later. Programming with **OpenSSL** Is **OpenSSL thread**-safe?

| | |
|---|---|
| Tutorial on Using **OpenSSL** with pthreads [closed] - Stack ... | Nov 19, 2011 |
| Do I need to use CRYPTO **locking** functions for **thread** safety ... | Oct 3, 2019 |
| Using **OpenSSL** in a multi-threaded application - c++ - Stack ... | Jun 28, 2012 |
| Multithreaded program using **OpenSSL** and **locks** randomly ... | Mar 17, 2017 |

More results from stackoverflow.com

# OpenSSL Blog



POSTED BY RICH SALZ , FEB 21ST, 2017 11:00 AM

# OpenSSL and Threads

This post talks about OpenSSL and threads. In particular, using OpenSSL in multi-threaded applications. It traces through the history, explains what was changed for the 1.1.0 release, and will hopefully provide some guidance to developers.

# openssl 1.02 vs 1.1/3

- < 1.1: 112k tps
- 2800% CPU

- >= 1.1: 560k tps
- 1300% CPU

- no ssl: 770k tps
- 1200% CPU

- no tcp: 1.1M tps
- 910% CPU

perf record -p $some_backend_pid sleep 1
perf report --sort comm,dso

```
Samples: 3K of event 'cycles', Event count (approx.): 2921279139
Overhead  Command   Shared Object
  83.91%  postgres  postgres
   6.47%  postgres  [kernel.vmlinux]
   5.47%  postgres  libc-2.33.so
   3.23%  postgres  plpgsql.so
   0.33%  postgres  [vdso]
   0.26%  postgres  auto_explain.so
   0.26%  postgres  pg_stat_statements.so
   0.05%  postgres  libm-2.33.so
   0.03%  postgres  libpthread-2.33.so
```

bpftrace

# bpftrace

- attach actions to
  - {kernel, userspace} tracepoints
  - {kernel, userspace} dynamic function probes
  - intervals, begin, end, sampling
- actions execute C-like code to build maps or print statements
- actions execute in kernel, in a [somewhat] sandboxed way

# bpftrace

- References:
  - bpftrace manual:
    https://github.com/iovisor/bpftrace/blob/master/docs/reference_guide.md
  - list of postgres tracepoints:
    https://www.postgresql.org/docs/current/dynamic-trace.html
  - Brendan Gregg blog post:
    https://www.brendangregg.com/ebpf.html#bpftrace
- Repos:
  - Tools in this talk: https://github.com/anarazel/pg-bpftrace
  - flamegraph generation: https://github.com/brendangregg/FlameGraph/

# Cache Hit Ratio

```
usdt:$1:postgresql:smgr__md__read__start
{
    @in_read[tid] = 1;
}
usdt:$1:postgresql:smgr__md__read__done / @in_read[tid] >= 1 /
{
    delete(@in_read[tid]);
}
tracepoint:iomap:iomap_readahead / @in_read[tid] /
{
    @cache_misses = count();
    @cache_miss_bytes = sum(((uint64)args->nr_pages * 4096));
}
```

# Cache Hit Ratio

```
interval:s:1
{
    print(@cache_misses);
    print(@cache_miss_bytes);
    clear(@cache_misses);
    clear(@cache_miss_bytes);
}

END { clear(@in_read); }
```

https://github.com/anarazel/pg-bpftrace/blob/main/pg-cache-hit.bt

# Cache Hit Ratio

```
...
@cache_misses: 0

@cache_misses: 48054
@cache_miss_bytes: 427405312

@cache_misses: 40262
@cache_miss_bytes: 377733120

@cache_misses: 31699
@cache_miss_bytes: 335884288
...
```

https://github.com/anarazel/pg-bpftrace/blob/main/pg-cache-hit.bt

# Cache Hit Ratio by PID

```
tracepoint:iomap:iomap_readahead / @in_read[tid] /
{
    @cache_misses[pid] = count();
    @cache_miss_bytes[pid] = sum(((uint64)args->nr_pages * 4096));
}
```

https://github.com/anarazel/pg-bpftrace/blob/main/pg-cache-hit-pid.bt

# bptrace

- information about a tracepoint:

```
bpftrace -v -l 'tracepoint:block:block_rq_issue'
```

- list user space tracepoints:

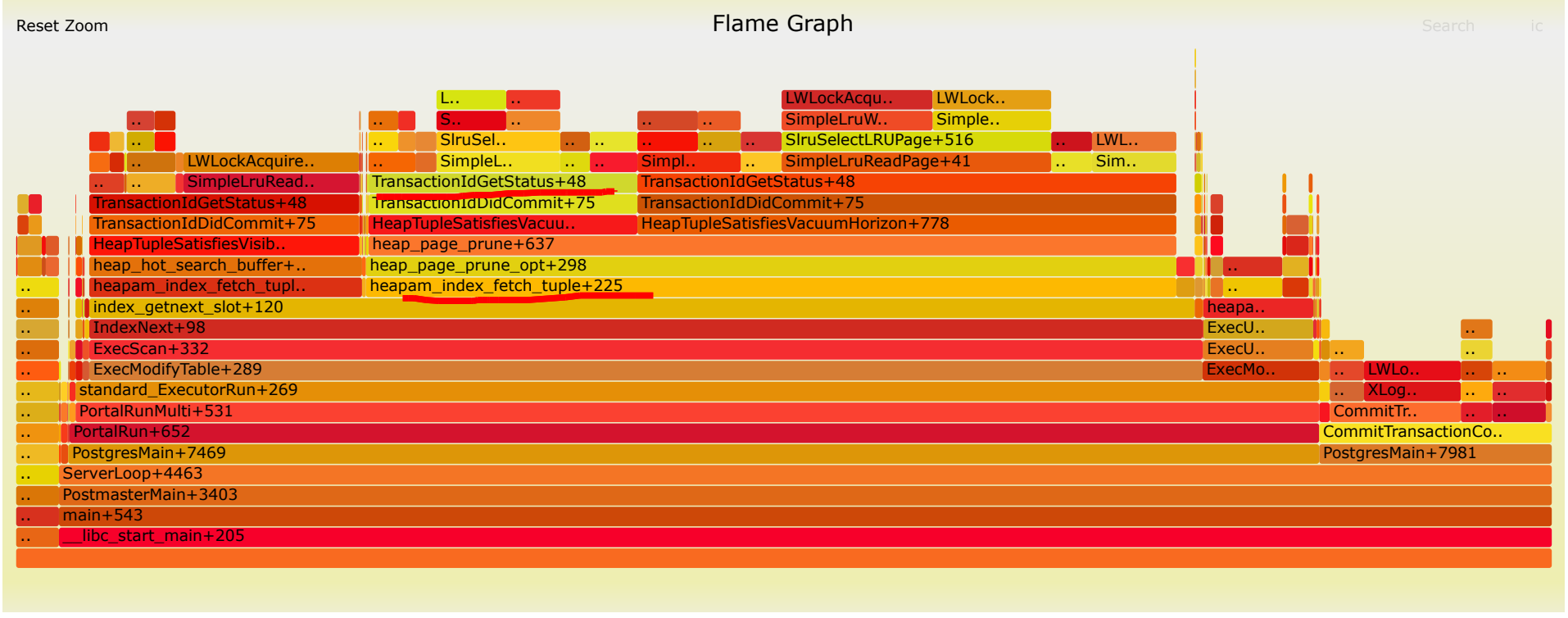
```
bpftrace -v -l 'usdt:/usr/lib/postgresql/14/bin/postgres:*'
```

# Stacks

```
...
usdt:$1:postgresql:lwlock__wait__done
{
    $delta = nsecs - @lock_start[tid];
    delete(@lock_start[tid]);
    @[ustack()] = sum($delta);
}
...
```

https://github.com/anarazel/pg-bpftrace/blob/main/pg-lwlock-wait.bt
https://github.com/anarazel/pg-bpftrace/blob/main/pg-lwlock-stack.bt

# Stacks


Reset Zoom
Flame Graph
Search
ic
L..
LWLockAcqu..
LWLock..
S..
SimpleLruW..
Simple..
SlruSel..
SlruSelectLRUPage+516
LWL..
LWLockAcquire..
SimpleL..
Simpl..
SimpleLruReadPage+41
Sim..
SimpleLruRead..
TransactionIdGetStatus+48
TransactionIdGetStatus+48
TransactionIdGetStatus+48
TransactionIdDidCommit+75
TransactionIdDidCommit+75
TransactionIdDidCommit+75
HeapTupleSatisfiesVacuu..
HeapTupleSatisfiesVacuumHorizon+778
HeapTupleSatisfiesVisib..
heap_page_prune+637
heap_hot_search_buffer+..
heap_page_prune_opt+298
heapam_index_fetch_tupl..
heapam_index_fetch_tuple+225
index_getnext_slot+120
heapa..
IndexNext+98
ExecU..
ExecScan+332
ExecU..
ExecModifyTable+289
ExecMo..
LWLo..
standard_ExecutorRun+269
XLog..
PortalRunMulti+531
CommitTr..
PortalRun+652
CommitTransactionCo..
PostgresMain+7469
PostgresMain+7981
ServerLoop+4463
PostmasterMain+3403
main+543
__libc_start_main+205

# pg_stat_statements

- tracks per-query statistics
  - “query fingerprints”
- https://www.postgresql.org/docs/current/pgstatstatements.html
- lacks many interesting statistics – too expensive, non-portable, etc
  - network input / output
  - lock wait time / congestion
  - cache hit ratio including kernel

# pg_stat_statements + BPF!

```
uprobe:$2:pgss_store / arg1 != 0 /
{
      $queryid = arg1;

      if (@pgss_send[tid, @pgss[tid]] > 0)
      {
          @stat_send[$queryid] = sum(@pgss_send[tid, @pgss[tid]]);
          delete(@pgss_send[tid, @pgss[tid]]);
      }
...
```

# Network IO

```
tracepoint:syscalls:sys_exit_recvfrom
    / @pgss[tid] > 0 /
{
    if (args->ret > 0)
    {
        @pgss_recv[tid, @pgss[tid]] +=
            ((uint64) args->ret);
    }
}
```

```
tracepoint:syscalls:sys_exit_sendto
     / @pgss[tid] > 0 /
{
    if (args->ret > 0)
    {
        @pgss_send[tid, @pgss[tid]] +=
            ((uint64) args->ret);
    }
}
```

# pg_stat_statements + BPF!

```
SELECT socket_send,
  disk_read AS disk_bytes_read,
  shared_blks_read * 8192 AS shared_bytes_read,
  substr(query, 1, 25)
FROM pg_stat_statements_extra
WHERE dbid = (SELECT oid FROM pg_database WHERE datname = current_database())
ORDER BY disk_read DESC NULLS LAST;
```

| socket_send | disk_bytes_read | shared_bytes_read | substr |
|---|---|---|---|
| 382664704 | 163119104 | 1141833728 | COPY public.large (id, da |
| 51159040 | 15073280 | 105512960 | COPY public.pgbench_accou |
| 35717120 | 8126464 | 56885248 | COPY public.pgbench_histo |
| (null) | 1171456 | 8200192 | COPY public.pgbench_branc |

https://github.com/anarazel/pg-bpftrace/blob/main/pg_stat_statements.bt

# Analyzing postgres performance problems using perf and eBPF

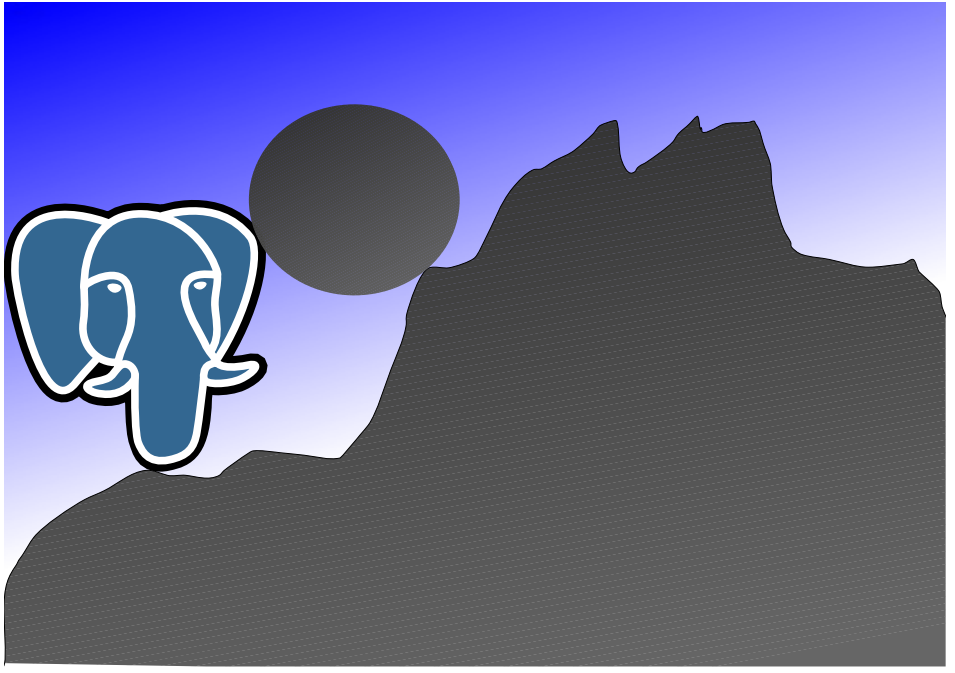
Andres Freund

PostgreSQL Developer, Committer and Core Team Member

andres@anarazel.de

andres.freund@microsoft.com

@AndresFreundTec



https://anarazel.de/talks/2022-04-12-cituscon/perf-bpf.pdf