

POSTGRESQL AT LOW LEVEL

STAY CURIOUS!

DMITRY DOLGOV

07-03-2019





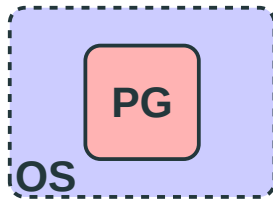
patroni & postgres-operator

pg_stat_*

PG

pg_stat_*

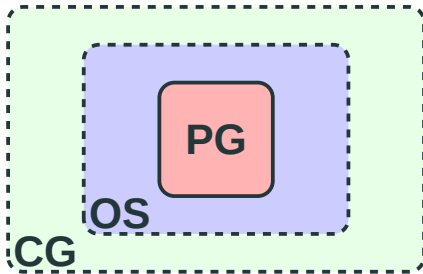
CPU/IO



pg_stat_*

CPU/IO

???

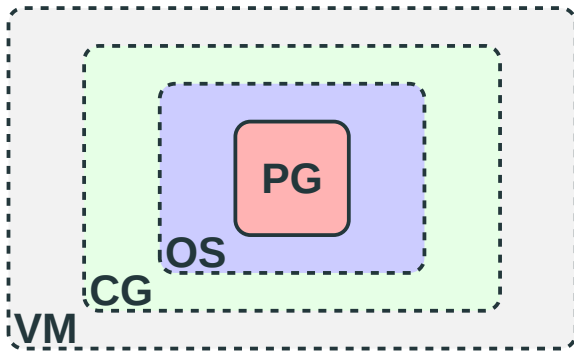


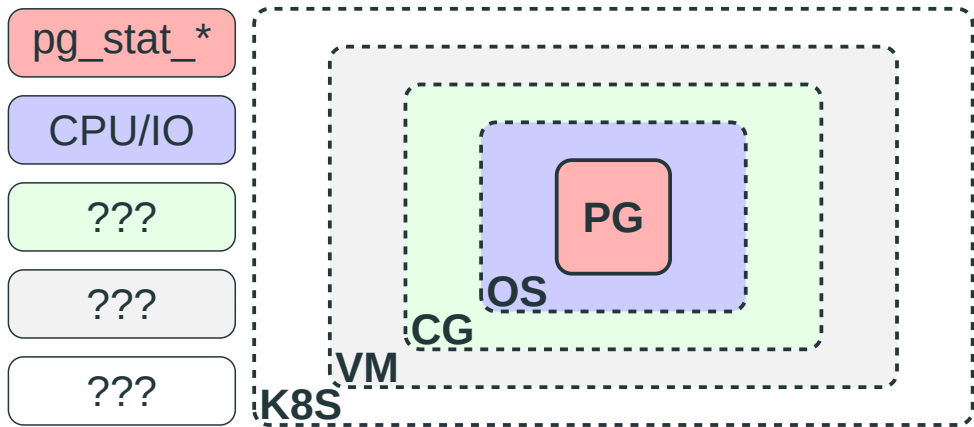
pg_stat_*

CPU/IO

???

???







All right, then. Keep your secrets

Info sources

strace/GDB/Perf

procfs/sysfs

BPF/eBPF/BCC

Shared memory

```
ERROR:  could not resize shared memory segment  
"/PostgreSQL.699663942" to 50438144 bytes:  
No space left on device
```

```
# strace -k -p PID
openat(AT_FDCWD, "/dev/shm/PostgreSQL.62223175"
ftruncate(176, 50438144) = 0
fallocate(176, 0, 0, 50438144) = -1 ENOSPC
> libc-2.27.so(posix_fallocate+0x16) [0x114f76]
> postgres(dsm_create+0x67) [0x377067]
...
> postgres(ExecInitParallelPlan+0x360) [0x254a80]
> postgres(ExecGather+0x495) [0x269115]
> postgres(standard_ExecutorRun+0xfd) [0x25099d]
...
> postgres(exec_simple_query+0x19f) [0x39afdf]
```

vDSO

```
# strace -k -p PID on XEN  
gettimeofday({tv_sec=1550586520, tv_usec=313499}, NULL) = 0  
> [vdso]() [0xef0]
```

Two frequently used system calls are 77% slower on AWS EC2

Experiment 1

transaction type: pg_long.sql

latency average = **1312**.903 ms

Experiment 2

SQL script **1**: pg_long.sql

- weight: **1** (targets **50.0%** of total)

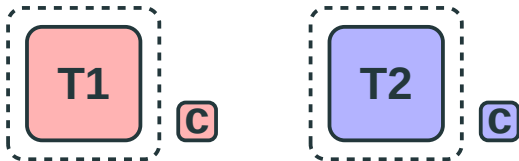
- latency average = **1426**.928 ms

SQL script **2**: pg_short.sql

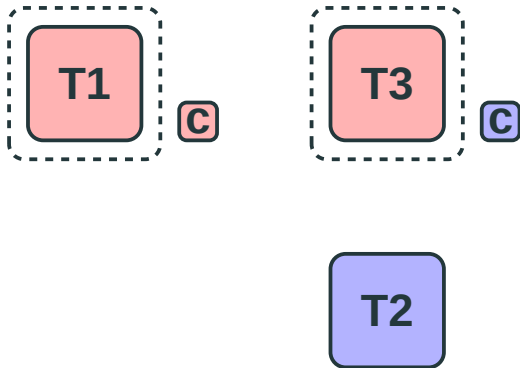
- weight: **1** (targets **50.0%** of total)

- latency average = **303**.092 ms

Scheduling



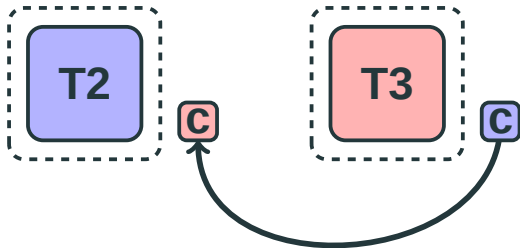
Scheduling



Scheduling



Scheduling



```
# perf record -e cache-misses,cpu-migrations
```

```
# Experiment 1
```

```
12,396,382,649
```

```
2,750
```

```
cache-misses # 28.562%
```

```
cpu-migrations
```

```
# Experiment 2
```

```
20,665,817,234
```

```
10,460
```

```
cache-misses # 28.533%
```

```
cpu-migrations
```

time	cpu	01234	task name [tid/pid]	wait time (msec)	sch delay (msec)	run time (msec)	
4227.834476	[0003]	s	postgres[12935]	0.000	0.000	0.000	
4227.834895	[0003]	s	postgres[12935]	0.000	0.000	0.418	
4227.835478	[0003]	s	postgres[25080]	0.000	0.040	0.583	
4227.836485	[0003]	s	postgres[25080]	0.000	0.000	1.007	
4227.837482	[0003]	s	postgres[25080]	0.000	0.000	0.996	
4227.837784	[0003]	s	postgres[25080]	0.000	0.000	0.302	
4227.837989	[0003]	m	postgres[25080]				migrated: :25077 cpu 1 => 3
4227.837993	[0003]	s	postgres[25080]	0.000	0.000	0.208	
4227.848487	[0003]	s	postgres[25080]	0.000	0.000	10.493	
4227.848991	[0003]	s	postgres[25080]	0.000	0.000	0.504	
4227.849487	[0003]	s	postgres[25080]	0.000	0.000	0.495	
4227.849748	[0003]	s	postgres[25080]	0.000	0.000	0.260	
4227.849912	[0003]	s	postgres[25080]	0.000	0.000	0.164	
4227.851477	[0001]	s	postgres[25082]	0.000	0.000	0.000	
4227.851481	[0002]	s	postgres[25080]	0.000	0.000	0.000	
4227.851778	[0003]	s	postgres[12935]	15.017	0.000	1.866	
4227.852259	[0003]	m	postgres[12935]				migrated: postgres[25083] cpu 1 => 3
4227.852263	[0003]	s	postgres[12935]	0.000	0.000	0.484	
4227.852477	[0003]	s	postgres[25083]	0.000	0.058	0.214	
4227.852478	[0001]	s	postgres[25082]	0.000	0.000	1.001	
4227.852614	[0002]	s	postgres[12935]	0.000	0.000	1.133	

Huge pages

transparent vs classic

TLB misses are faster and less frequent

Huge pages

huge_pages on

Samples: 832K of event 'dTLB-load-misses'

Event count (approx.): **640614445** : ~19% less

Samples: 736K of event 'dTLB-store-misses'

Event count (approx.): **72447300** : ~29% less

huge_pages off

Samples: 894K of event 'dTLB-load-misses'

Event count (approx.): **784439650**

Samples: 822K of event 'dTLB-store-misses'

Event count (approx.): **101471557**

VM

Intel® 64 and IA-32 Architectures Software Developer's Manual, Vol. 3

VM

→ Lock holder preemption problem

Intel® 64 and IA-32 Architectures Software Developer's Manual, Vol. 3

VM

- Lock holder preemption problem
- Lock waiter preemption problem

Intel® 64 and IA-32 Architectures Software Developer's Manual, Vol. 3

VM

- Lock holder preemption problem
- Lock waiter preemption problem
- Intel PLE (pause loop exiting)

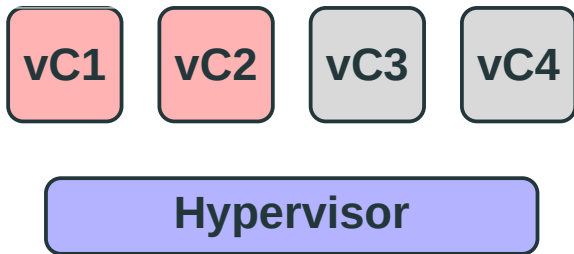
Intel® 64 and IA-32 Architectures Software Developer's Manual, Vol. 3

VM

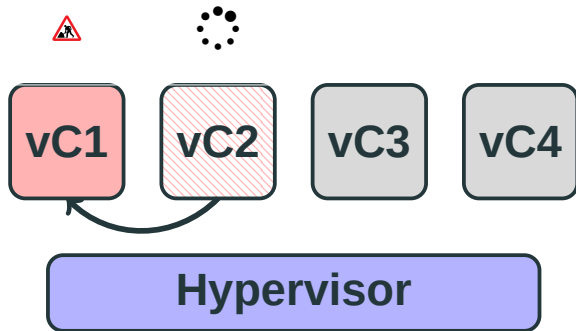
- Lock holder preemption problem
- Lock waiter preemption problem
- Intel PLE (pause loop exiting)
- PLE_Gap, PLE_Window

Intel® 64 and IA-32 Architectures Software Developer's Manual, Vol. 3

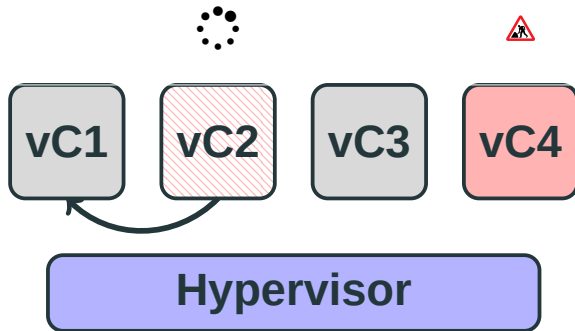
vCPU



vCPU



vCPU



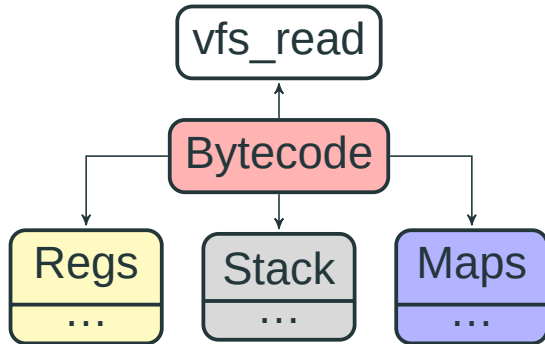
```
# latency average = 17.782 ms
=> modprobe kvm-intel ple_gap=128
=> perf record -e kvm:kvm_exit
reason PAUSE_INSTRUCTION 306795
```

```
# latency average = 16.858 ms
=> modprobe kvm-intel ple_gap=0
=> perf record -e kvm:kvm_exit
reason PAUSE_INSTRUCTION 0
```

Tunables

```
# from /proc/sys/kernel/  
sched_wakeup_granularity_ns  
# default = 1 msec * (1 + ilog(ncpus))
```

Userspace



pgbench and pg_dump

real 1m38.990s
user 1m9.127s
sys 0m2.066s

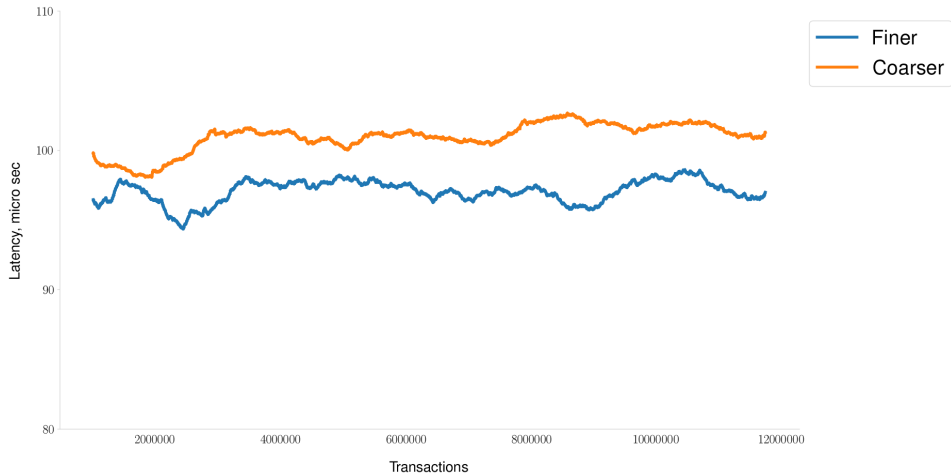
usecs	: count	distribution
0 -> 1	: 16	
2 -> 3	: 4604	**
4 -> 7	: 6812	****
8 -> 15	: 14888	*****
16 -> 31	: 19267	*****
32 -> 63	: 65795	*****
64 -> 127	: 50454	*****
128 -> 255	: 16393	*****
256 -> 511	: 5981	***
512 -> 1023	: 12300	*****
1024 -> 2047	: 48	
2048 -> 4095	: 0	

pgbench and pg_dump

```
real    1m32.030s
user    1m8.559s
sys     0m1.641s
```

usecs	: count	distribution
0 -> 1	: 1	
2 -> 3	: 8	
4 -> 7	: 25	
8 -> 15	: 46	*
16 -> 31	: 189	*****
32 -> 63	: 119	****
64 -> 127	: 96	***
128 -> 255	: 93	***
256 -> 511	: 238	*****
512 -> 1023	: 323	*****
1024 -> 2047	: 1012	*****
2048 -> 4095	: 47	*

Wakeup granularity, microsec



Cache

```
# COS1 4 cache ways, COS 2 next 8 cache ways  
=> pqos -e "llc:1=0x000f;llc:2=0x0ff0;"  
SOCKET 0 L3CA COS1 => MASK 0xf  
SOCKET 0 L3CA COS2 => MASK 0xff0  
Allocation configuration altered.
```

github.com/iovisor/bcc/

github.com/erthalion/postgres-bcc

Cache

=> llcache_per_query.py bin/postgres

PID	QUERY	CPU	REFERENCE	MISS	HIT%
9720	UPDATE pgbench_tellers ...	0	2000	1000	50.00%
9720	SELECT abalance FROM ...	2	2000	100	95.00%
...					

Total References: **3303100** Total Misses: **599100** Hit Rate: **81.86%**

Shared memory

```
ERROR: could not resize shared memory segment  
"/PostgreSQL.699663942" to 5048144 bytes:  
No space left on device
```

Remember?

Shared memory

=> shmem.py bin/postgres

mmap:

[20439]: 142M

anon shm:

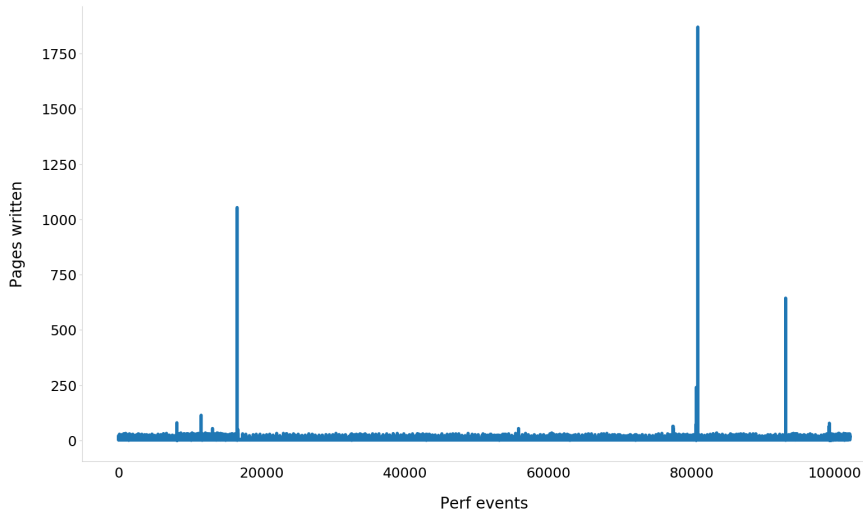
[20439]: 56B

shm:

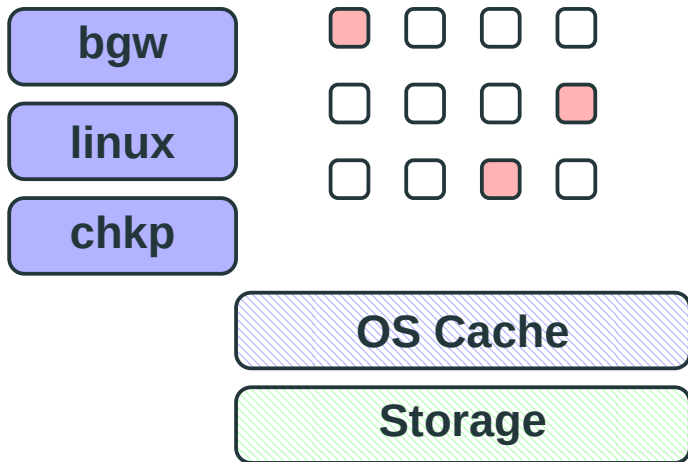
[postmaster.opts]: 0B

[PostgreSQL.57332071]: 7K

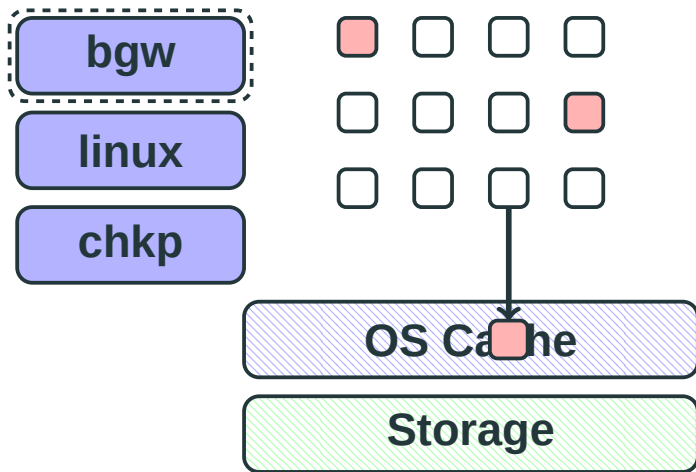
Pages written, kernel



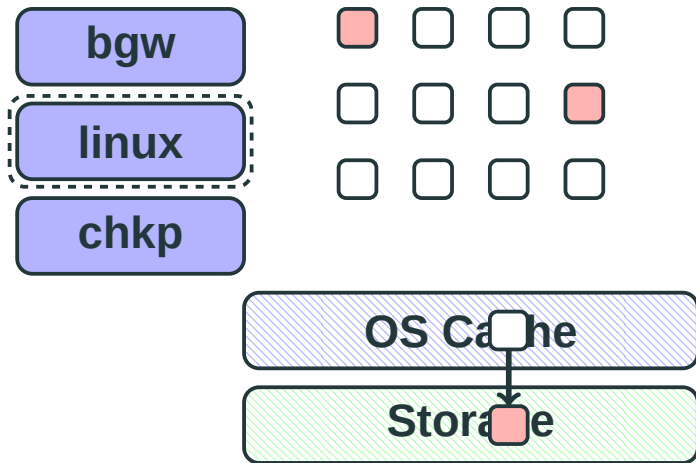
Dirty pages



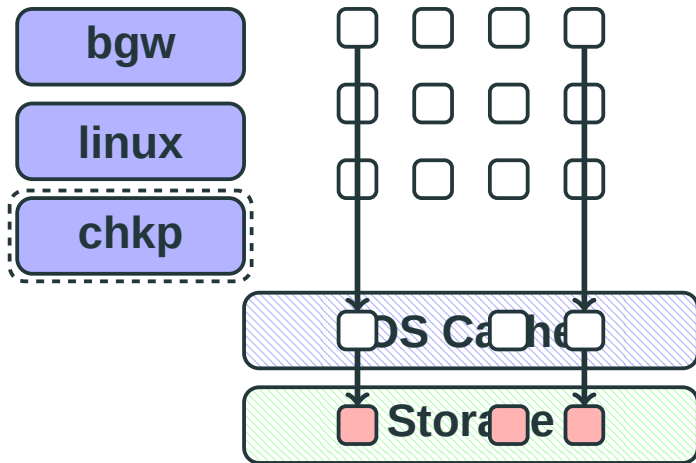
Dirty pages



Dirty pages



Dirty pages



Writeback (cgroup v1)

```
/* vmscan.c */  
/* The normal page dirty throttling mechanism  
 * in balance_dirty_pages() is completely broken  
 * with the legacy memcg and direct stalling in  
 * shrink_page_list() is used for throttling instead,  
 * which lacks all the niceties such as fairness,  
 * adaptive pausing, bandwidth proportional  
 * allocation and configurability.  
 */  
static bool sane_reclaim(struct scan_control *sc)
```

Writeback

```
=> perf record -e writeback:writeback_written
```

```
kworker/u8:1 reason=periodic    nr_pages=101429  
kworker/u8:1 reason=background nr_pages=MAX_ULONG  
kworker/u8:3 reason=periodic    nr_pages=101457
```

Writeback

```
# pgbench insert workload
```

```
=> io_timeouts.py bin/postgres
```

```
[18335] END: MAX_SCHEDULE_TIMEOUT
```

```
[18333] END: MAX_SCHEDULE_TIMEOUT
```

```
[18331] END: MAX_SCHEDULE_TIMEOUT
```

```
[18318] truncate pgbench_history: MAX_SCHEDULE_TIMEOUT
```


Kubernetes

```
resources:  
  requests:  
    memory: "64Mi"  
    cpu: "250m"  
  limits:  
    memory: "128Mi"  
    cpu: "500m"
```

Kubernetes

resources:

requests:

memory: "64Mi"

cpu: "250m"

limits:

memory: "128Mi"

cpu: "500m"



soft_limits_in_bytes



limits_in_bytes

Kubernetes

resources:

requests:

memory: "64Mi"

cpu: "250m"

limits:

memory: "128Mi"

cpu: "500m"

~~soft_limits_in_bytes~~

limits_in_bytes

Memory reclaim

only under the memory pressure

=> page_reclaim.py bin/postgres

[7382] postgres: 928K

[7138] postgres: 152K

[7136] postgres: 180K

[7468] postgres: 72M

[7464] postgres: 57M

[5451] postgres: 1M

How to run?

```
# bcc + postgres-bcc
```

```
CONFIG_BPF=y
```

```
CONFIG_BPF_SYSCALL=y
```

```
CONFIG_NET_CLS_BPF=m
```

```
CONFIG_NET_ACT_BPF=m
```

```
CONFIG_BPF_JIT=y
```

```
CONFIG_BPF_EVENTS=y
```

```
debugfs on /sys/kernel/debug type debugfs (rw)
```

How to run: container?

```
# sometimes you also need to let perf know  
# where to find debugging symbols, e.g. copy  
# from /usr/lib/.debug/  
docker run  
    --privileged  
    --net=container:<container-id>  
    --ipc=container:<container-id>
```

How to run: K8S?

$4 * 65536 + 14 * 256 + 96$

=> `export BCC_LINUX_VERSION_CODE` **265824**

How to break?

```
# unsafe access
```

```
=> perf probe -x bin/postgres --funcs
```

```
=> perf probe -x bin/postgres 'ExecCallTriggerFunc trigdata->?'
```

```
=> perf record probe_postgres:ExecCallTriggerFunc
```


How to break?

non interruptible sleep

=> perf probe -x bin/postgres --funcs

=> perf probe -x bin/postgres 'XLogInsertRecord fpw_lsn'

How to break?

iovisor / bcc

Watch 410 ★ Uns

<> Code **Issues 266** Pull requests 21 Projects 0 Wiki Insights

Ubuntu xenial kernel panic in bpf_map_update_elem using ext4slower #1678


Closed stefreak opened this issue on Apr 12, 2018 · 13 comments


Questions?

 github.com/erthalion

 github.com/erthalion/postgres-bcc

 [@erthalion](https://twitter.com/erthalion)

 [dmitrii.dolgov at zalando dot de](mailto:dmitrii.dolgov@zalando.de)

 [9erthalion6 at gmail dot com](mailto:9erthalion6@gmail.com)