PgBouncer and a Bit of Queueing Theory

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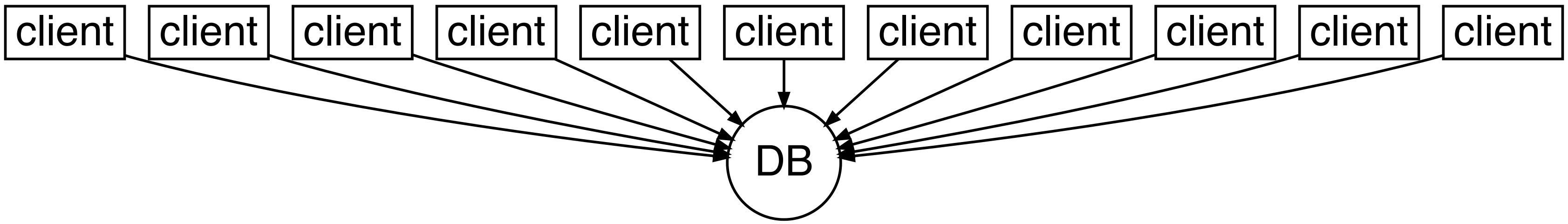

client
client
client
client
client
client
client
client
client
client
client
DB

```
max_connections = 10000
```

~~`max_connections = 10000`~~

- RAM
- I/O
- CPUs
- ...

How many then?

And what to do with the rest?

How many then?

https://wiki.postgresql.org/wiki/Number_Of_Database_Connections
(ca. 2012):

```
((core_count * 2) + effective_spindle_count)
```

max_connections vs. connection limit

```
ALTER ROLE ... CONNECTION LIMIT xxx;
```

Some benchmarking

server: AWS EC2 m5d.2xlarge (8 core, 32 GiB, 300 GB)
pgbench: same

database fits in RAM: `pgbench -i -s 1024` = 17 GB

```
pgbench -T 60 -j32 -c32
latency average = 2.655 ms
tps = 12080.052280 (including connections establishing)
tps = 12083.253808 (excluding connections establishing)
```

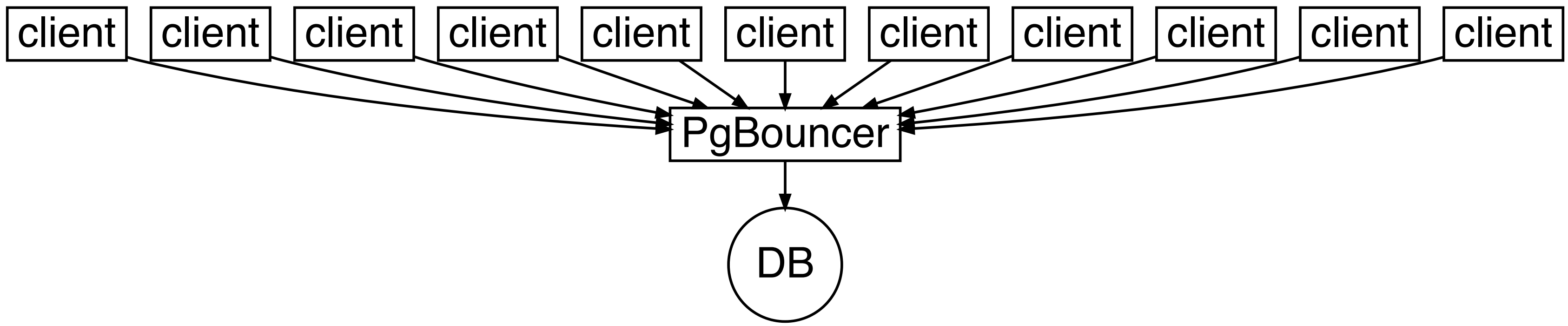
Some more benchmarking

server: AWS EC2 m5d.2xlarge (8 core, 32 GiB, 300 GB)
pgbench: same

database exceeds RAM: `pgbench -i -s 8192` = 136 GB

```
pgbench -T 60 -j32 -c48
latency average = 4.822 ms
tps = 9953.933322 (including connections establishing)
tps = 9956.487118 (excluding connections establishing)
```

What to do with the rest?



PgBouncer configuration

```
[databases]
myapp = host=elsewhere port=5432 dbname=myapp

[pgbouncer]
;listen_port = 6432
;pool_mode = session
default_pool_size = 32
max_client_conn = 10000
```

About pool modes

- `pool_mode = session`
- `pool_mode = transaction`
- `pool_mode = statement`

Deterministic queueing ex.

pool size = 1

transaction time = 10 ms = 100 tps

---

arrival rate = every 25 ms :-)

arrival rate = every 10 ms :-/

arrival rate = every 8 ms :-(

Deterministic queueing ex.

pool size = 10

transaction time = 10 ms = 100 tps

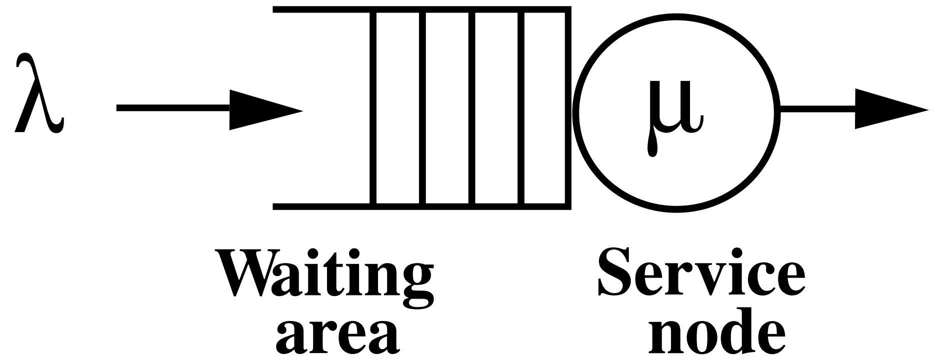
---

arrival rate = every 2.5 ms :-)

arrival rate = every 1.0 ms :-/

arrival rate = every 0.8 ms :-(

Queueing nodes



λ: arrival rate
μ: departure rate

Kendall's notation

A/S/c

A = arrival process
S = service time distribution
c = number of servers

Kendall's notation examples

D/D/1
D/D/k
M/D/1
M/M/1
M/M/k
M/G/1
…

Little's law

$$L = \lambda W$$

L: average number of jobs in system (load)
λ: average arrival rate
W: average time spent in system

M/M/1 queue

arrival rate λ
service rate μ
server utilization $\rho = \lambda/\mu$

must: $\rho<1$

$\pi_i = \big(1 - \rho\big)\rho^i$

$\pi_0 = (1 - \rho)$
$\pi_1 = (1 - \rho)\rho$

avg. nr. jobs $L = \rho/(1 - \rho)$

M/M/1 queue example

arrival rate $\lambda = 1/25\mathrm{ms} = 40/\mathrm{s}$
service rate $\mu = 1/10\mathrm{ms} = 100/\mathrm{s}$

server utilization $\rho = \lambda/\mu = 40/100 = 0.4$

$\pi_0 = (1 - \rho) = 0.6$
$\pi_1 = (1 - \rho)\rho = 0.24$

avg. nr. jobs $L = \rho/(1 - \rho) = 0.67$

M/M/1 queue response time

$W = L/\lambda = \ldots = 1/(\mu - \lambda)$

Example:

$W = 1/(100 - 40) = 0.0167\,\mathrm{s}$

M/M/c queue

arrival rate λ
service rate μ

server utilization $\rho = \lambda/(c\mu)$

must: $\rho < 1$

M/M/c queue analysis

probability of having to wait:

$$P = \mathrm{ErlangC}(\lambda/\mu, c)$$

avg. nr. jobs in system:

$$L = \frac{\rho}{1-\rho}\,\mathrm{ErlangC}\Big(\lambda/\mu, c\Big) + c\rho$$

response time:

$$W = \frac{\mathrm{ErlangC}(\lambda/\mu, c)}{c\mu - \lambda} + \frac{1}{\mu}$$

Erlang C formula

```
def ErlangC(A, N):
    L = (A**N / factorial(N)) * (N / (N - A))
    sum_ = 0
    for i in range(N):
        sum_ += (A**i) / factorial(i)
    return (L / (sum_ + L))
```

M/M/c queue examples

$\lambda = 1/25\text{ms} = 40/\text{s}$
$\mu = 1/10\text{ms} = 100/\text{s}$

$c = 1$

$P = 0.4 \quad L = 0.67 \quad W = 0.0167\text{ s}$

$c = 2$

$P = 0.067 \quad L = 0.41 \quad W = 0.0104\text{ s}$

$c = 3$

$P = 0.008 \quad L = 0.40 \quad W = 0.010\text{ s}$

A final example

10000 tps
pool_size = 48

so

$c = 48$
$\mu = 10000/48 = 208$

$\lambda = 1000 \quad P \approx 0 \quad L = 4.8 \quad W = 0.0048$
$\lambda = 2000 \quad P \approx 0 \quad L = 9.6 \quad W = 0.0048$
$\lambda = 4000 \quad P \approx 0 \quad L = 19.2 \quad W = 0.0048$
$\lambda = 6000 \quad P = 0.0007 \quad L = 28.8 \quad W = 0.0048$
$\lambda = 8000 \quad P = 0.09 \quad L = 38.8 \quad W = 0.0049$
$\lambda = 9000 \quad P = 0.37 \quad L = 46.7 \quad W = 0.0051$

Summary

- arrival rate (measure, calculate)
- service rate (measure, benchmark)
- server count/pool size (benchmark)
- load (measure)
- response time (measure, calculate)
- waiting probability
- Little’s law
- M/M/c queue
- Erlang-C