

# Universidad del Caribe

2000

CANCUN, QUINTANA ROO, MÉXICO

CONOCIMIENTO Y CULTURA PARA EL DESARROLLO HUMANO

Computo de alto desempeño

Clústeres y beckmark

Jiménez Sánchez / Ismael

Ingeniería en Datos e Inteligencia Organizacional

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Cancún, Quintana Roo, 17 de Febrero de 2025

El proceso comenzó con la instalación de SSH y MariaDB en cada nodo, configurando los servidores MySQL para permitir la creación del clúster. Se definieron los nodos y se configuraron las conexiones entre ellos.

Cada nodo fue configurado con MariaDB Galera, asegurando la sincronización y validación entre los servidores. Se realizaron pruebas con diferentes configuraciones de hardware (número de núcleos) y número de nodos para evaluar el rendimiento.

## Sincronización

```
root@nodo1: /home/noe
root@nodo2: /home/noe
root@nodo3: /home/noe

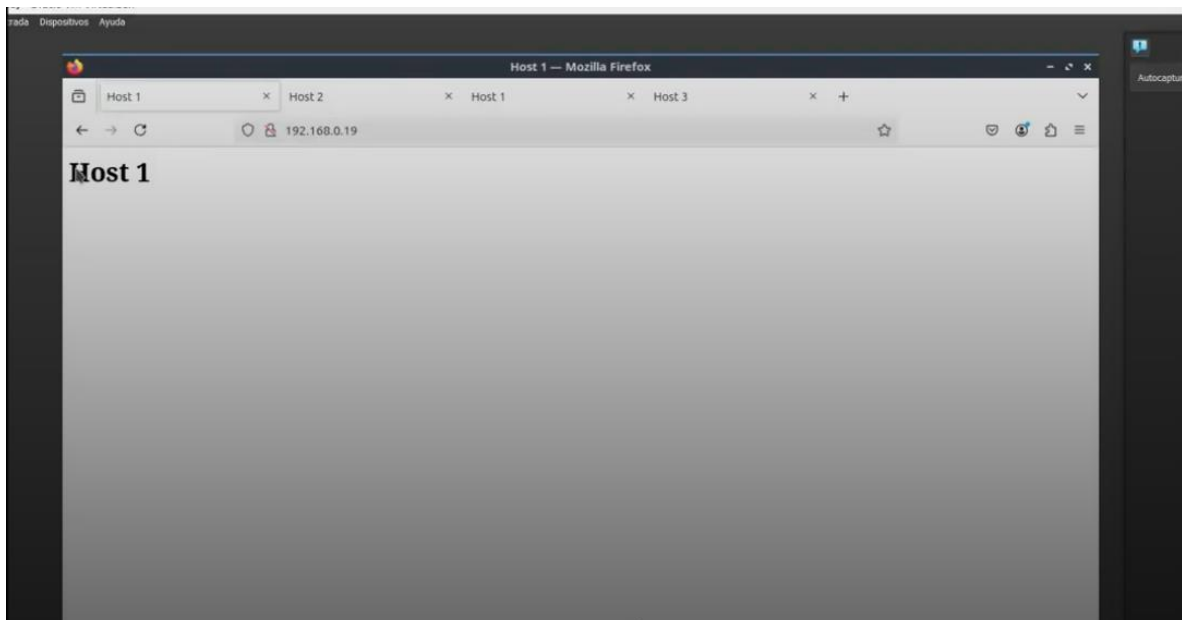
inet6 ::1/128 scope host noprefixroute
    valid_lft forever preferred_lft forever
2: enp0s3: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP group default qlen 1000
    link/ether 08:00:27:80:6d:db brd ff:ff:ff:ff:ff:ff
    inet 192.168.56.107/24 metric 100 brd 192.168.56.255 scope global dynamic enp0s3
        valid_lft 489sec preferred_lft 489sec
    inet6 fe80::a00:27ff:fe80:6ddb/64 scope link
        valid_lft forever preferred_lft forever
root@nodo3: /home/noe# vi /etc/mysql/mariadb.conf.d/60-galera.cnf
root@nodo3: /home/noe# galera_new_cluster
root@nodo3: /home/noe# sudo systemctl restart mariadb
root@nodo3: /home/noe# mysql -u root -p -e "SHOW STATUS LIKE 'wsrep_cluster_size'"
Enter password:
+-----+-----+
| Variable_name | Value |
+-----+-----+
| wsrep_cluster_size | 3 |
+-----+-----+
root@nodo3: /home/noe# vi /etc/mysql/mariadb.conf.d/60-galera.cnf
root@nodo3: /home/noe# mysql -u root --execute="SHOW GLOBAL STATUS WHERE Variable_name IN ('wsrep_ready', 'wsrep_cluster_size', 'wsrep_cluster_status', 'wsrep_connected');"
+-----+-----+
| Variable_name | Value |
+-----+-----+
| wsrep_cluster_size | 3 |
| wsrep_cluster_status | Primary |
| wsrep_connected | ON |
| wsrep_ready | ON |
+-----+-----+
root@nodo3: /home/noe#
```

## Configuramos con haproxy

```
noe@noe-virtualbox: /etc/haproxy

valid_lft forever preferred_lft forever
2: enp0s3: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP group default qlen 1000
    link/ether 08:00:27:2d:7a:f6 brd ff:ff:ff:ff:ff:ff
    inet 192.168.0.19/24 brd 192.168.0.255 scope global dynamic noprefixroute enp0s3
        valid_lft 2837sec preferred_lft 2837sec
    inet6 fe80::137d:2d9c:507a:1972/64 scope link noprefixroute
        valid_lft forever preferred_lft forever
3: virbr0: <NO-CARRIER,BROADCAST,MULTICAST,UP> mtu 1500 qdisc noqueue state DOWN group default qlen 1000
    link/ether 52:54:00:04:3e:02 brd ff:ff:ff:ff:ff:ff
    inet 192.168.122.1/24 brd 192.168.122.255 scope global virbr0
        valid_lft forever preferred_lft forever
noe@noe-virtualbox: /etc/haproxy$ ^C
noe@noe-virtualbox: /etc/haproxy$ ip addr
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
        valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host noprefixroute
        valid_lft forever preferred_lft forever
2: enp0s3: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP group default qlen 1000
    link/ether 08:00:27:2d:7a:f6 brd ff:ff:ff:ff:ff:ff
    inet 192.168.0.19/24 brd 192.168.0.255 scope global dynamic noprefixroute enp0s3
        valid_lft 2592sec preferred_lft 2592sec
    inet6 fe80::137d:2d9c:507a:1972/64 scope link noprefixroute
        valid_lft forever preferred_lft forever
3: virbr0: <NO-CARRIER,BROADCAST,MULTICAST,UP> mtu 1500 qdisc noqueue state DOWN group default qlen 1000
    link/ether 52:54:00:04:3e:02 brd ff:ff:ff:ff:ff:ff
    inet 192.168.122.1/24 brd 192.168.122.255 scope global virbr0
```

Probamos el balanceo de carga



Video de las pruebas

<https://drive.google.com/file/d/1Ry9BevGfq5paNdXKJmWdoYUrxaoly-TP/view?usp=sharing>

- bulk\_insert

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v
root@nodo3: /home/noe# sysbench --threads=1 --time=5 --rate=0 --db-driver=mysql --mysql-user=root --events=0 bulk_insert
run
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Initializing worker threads...

Threads started!

FATAL: mysql_drv_query() returned error 1136 (Column count doesn't match value count at row 1) for query 'INSERT INTO sb
test1 VALUES(1,1),(2,2),(3,3),(4,4),(5,5),(6,6),(7,7),(8,8),(9,9),(10,10),(11,11),(12,12),(13,13),(14,14),(15,15),(16,16
),(17,17),(18,18),(19,19),(20,20),(21,21),(22,22),(23,23),(24,24),(25,25),(26,26),(27,27),(28,28),(29,29),(30,30),(31,31
),(32,32),(33,33),(34,34),(35,35),(36,36),(37,37),(38,38),(39,39),(40,40),(41,41),(42,42),(43,43),(44,44),(45,45),(46,46
),(47,47),(48,48),(49,49),(50,50),(51,51),(52,52),(53,53),(54,54),(55,55),(56,56),(57,57),(58,58),(59,59),(60,60),(61,61
),(62,62),(63,63),(64,64),(65,65),(66,66),(67,67),(68,68),(69,69),(70,70),(71,71),(72,72),(73,73),(74,74),(75,75),(76,76
),(77,77),(78,78),(79,79),(80,80),(81,81),(82,82),(83,83),(84,84),(85,85),(86,86),(87,87),(88,88),(89,89),(90,90),(91,91
),(92,92),(93,93),(94,94),(95,95),(96,96),(97,97),(98,98),(99,99),(100,100),(101,101),(102,102),(103,103),(104,104),(105
),(106,106),(107,107),(108,108),(109,109),(110,110),(111,111),(112,112),(113,113),(114,114),(115,115),(116,116),(117
),(118,118),(119,119),(120,120),(121,121),(122,122),(123,123),(124,124),(125,125),(126,126),(127,127),(128,128),(129
),(130,130),(131,131),(132,132),(133,133),(134,134),(135,135),(136,136),(137,137),(138,138),(139,139),(140,140),(141
),(142,142),(143,143),(144,144),(145,145),(146,146),(147,147),(148,148),(149,149),(150,150),(151,151),(152,152),(153
),(154,154),(155,155),(156,156),(157,157),(158,158),(159,159),(160,160),(161,161),(162,162),(163,163),(164,164),(165
),(166,166),(167,167),(168,168),(169,169),(170,170),(171,171),(172,172),(173,173),(174,174),(175,175),(176,176),(177
),(178,178),(179,179),(180,180),(181,181),(182,182),(183,183),(184,184),(185,185),(186,186),(187,187),(188,188),(189
),(190,190),(191,191),(192,192),(193,193),(194,194),(195,195),(196,196),(197,197),(198,198),(199,199),(200,200),(201
),(202,202),(203,203),(204,204),(205,205),(206,206),(207,207),(208,208),(209,209),(210,210),(211,211),(212,212),(213
```

- olt\_p\_delete

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ x

Threads started!

SQL statistics:
queries performed:
  read: 0
  write: 1310
  other: 1132824
  total: 1134134
transactions: 1134134 (18900.07 per sec.)
queries: 1134134 (18900.07 per sec.)
ignored errors: 0 (0.00 per sec.)
reconnects: 0 (0.00 per sec.)

General statistics:
total time: 60.0006s
total number of events: 1134134

Latency (ms):
min: 0.02
avg: 0.05
max: 30.64
95th percentile: 0.05
sum: 59264.02

Threads fairness:
events (avg/stddev): 1134134.0000/0.00
execution time (avg/stddev): 59.2640/0.00

root@nodo3: /home/noe#
```

•oltp\_insert

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ x

Threads started!

SQL statistics:
queries performed:
  read: 0
  write: 3957
  other: 0
  total: 3957
transactions: 3957 (65.92 per sec.)
queries: 3957 (65.92 per sec.)
ignored errors: 0 (0.00 per sec.)
reconnects: 0 (0.00 per sec.)

General statistics:
total time: 60.0238s
total number of events: 3957

Latency (ms):
min: 4.00
avg: 15.16
max: 788.04
95th percentile: 37.56
sum: 59970.54

Threads fairness:
events (avg/stddev): 3957.0000/0.00
execution time (avg/stddev): 59.9705/0.00

root@nodo3: /home/noe#
```

•oltp\_point\_select

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
queries performed:
  read:                2058305
  write:                0
  other:                0
  total:               2058305
transactions:         2058305 (34303.33 per sec.)
queries:              2058305 (34303.33 per sec.)
ignored errors:       0 (0.00 per sec.)
reconnects:           0 (0.00 per sec.)

General statistics:
total time:           60.0016s
total number of events: 2058305

Latency (ms):
  min:                 0.02
  avg:                 0.03
  max:                 11.35
  95th percentile:    0.03
  sum:                 58239.09

Threads fairness:
  events (avg/stddev): 2058305.0000/0.00
  execution time (avg/stddev): 58.2391/0.00

root@nodo3: /home/noe#
```

•oltp\_read\_only

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
queries performed:
  read:                1654940
  write:                0
  other:                236420
  total:               1891360
transactions:         118210 (1970.10 per sec.)
queries:              1891360 (31521.58 per sec.)
ignored errors:       0 (0.00 per sec.)
reconnects:           0 (0.00 per sec.)

General statistics:
total time:           60.0007s
total number of events: 118210

Latency (ms):
  min:                 0.31
  avg:                 0.51
  max:                 14.31
  95th percentile:    1.10
  sum:                 59840.54

Threads fairness:
  events (avg/stddev): 118210.0000/0.00
  execution time (avg/stddev): 59.8405/0.00

root@nodo3: /home/noe#
```

•oltp\_read\_write

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
  queries performed:
    read: 56924
    write: 13568
    other: 10828
    total: 81320
  transactions: 4066 (67.63 per sec.)
  queries: 81320 (1352.65 per sec.)
  ignored errors: 0 (0.00 per sec.)
  reconnects: 0 (0.00 per sec.)

General statistics:
  total time: 60.1161s
  total number of events: 4066

Latency (ms):
  min: 5.72
  avg: 14.77
  max: 555.99
  95th percentile: 30.26
  sum: 60066.98

Threads fairness:
  events (avg/stddev): 4066.0000/0.00
  execution time (avg/stddev): 60.0670/0.00

root@nodo3: /home/noe#
```

- oltp\_update\_index

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
  queries performed:
    read: 0
    write: 3954
    other: 822
    total: 4776
  transactions: 4776 (79.53 per sec.)
  queries: 4776 (79.53 per sec.)
  ignored errors: 0 (0.00 per sec.)
  reconnects: 0 (0.00 per sec.)

General statistics:
  total time: 60.0427s
  total number of events: 4776

Latency (ms):
  min: 0.02
  avg: 12.56
  max: 809.86
  95th percentile: 33.72
  sum: 60008.71

Threads fairness:
  events (avg/stddev): 4776.0000/0.00
  execution time (avg/stddev): 60.0087/0.00

root@nodo3: /home/noe#
```

- oltp\_update\_non\_index

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
  queries performed:
    read: 0
    write: 4588
    other: 944
    total: 5532
  transactions: 5532 (92.19 per sec.)
  queries: 5532 (92.19 per sec.)
  ignored errors: 0 (0.00 per sec.)
  reconnects: 0 (0.00 per sec.)

General statistics:
  total time: 60.0067s
  total number of events: 5532

Latency (ms):
  min: 0.03
  avg: 10.84
  max: 568.13
  95th percentile: 29.72
  sum: 59968.22

Threads fairness:
  events (avg/stddev): 5532.0000/0.00
  execution time (avg/stddev): 59.9682/0.00

root@nodo3: /home/noe#
```

•oltp\_write\_only

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
  queries performed:
    read: 0
    write: 19548
    other: 13236
    total: 32784
  transactions: 5464 (91.06 per sec.)
  queries: 32784 (546.34 per sec.)
  ignored errors: 0 (0.00 per sec.)
  reconnects: 0 (0.00 per sec.)

General statistics:
  total time: 60.0046s
  total number of events: 5464

Latency (ms):
  min: 3.98
  avg: 10.97
  max: 207.41
  95th percentile: 24.38
  sum: 59941.88

Threads fairness:
  events (avg/stddev): 5464.0000/0.00
  execution time (avg/stddev): 59.9419/0.00

root@nodo3: /home/noe#
```

•select\_random\_points

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
queries performed:
  read:          32078
  write:         0
  other:         0
  total:        32078
transactions:    32078 (534.61 per sec.)
queries:        32078 (534.61 per sec.)
ignored errors: 0 (0.00 per sec.)
reconnects:     0 (0.00 per sec.)

General statistics:
total time:      60.0007s
total number of events: 32078

Latency (ms):
min:            0.42
avg:            1.87
max:           23.25
95th percentile: 4.03
sum:          59932.59

Threads fairness:
events (avg/stddev): 32078.0000/0.00
execution time (avg/stddev): 59.9326/0.00

root@nodo3: /home/noe#
```

•select\_random\_ranges

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
queries performed:
  read:          45230
  write:         0
  other:         0
  total:        45230
transactions:    45230 (753.79 per sec.)
queries:        45230 (753.79 per sec.)
ignored errors: 0 (0.00 per sec.)
reconnects:     0 (0.00 per sec.)

General statistics:
total time:      60.0019s
total number of events: 45230

Latency (ms):
min:            0.22
avg:            1.33
max:           13.19
95th percentile: 3.19
sum:          59938.42

Threads fairness:
events (avg/stddev): 45230.0000/0.00
execution time (avg/stddev): 59.9384/0.00

root@nodo3: /home/noe#
```

Prueba con 2 core, 3 nodo y 60 segundos

•bulk\_insert



```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ x
), (92, 92), (93, 93), (94, 94), (95, 95), (96, 96), (97, 97), (98, 98), (99, 99), (100, 100), (101, 101), (102, 102), (103, 103), (104, 104), (105
, 105), (106, 106), (107, 107), (108, 108), (109, 109), (110, 110), (111, 111), (112, 112), (113, 113), (114, 114), (115, 115), (116, 116), (117
, 117), (118, 118), (119, 119), (120, 120), (121, 121), (122, 122), (123, 123), (124, 124), (125, 125), (126, 126), (127, 127), (128, 128), (129
, 129), (130, 130), (131, 131), (132, 132), (133, 133), (134, 134), (135, 135), (136, 136), (137, 137), (138, 138), (139, 139), (140, 140), (141
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, 273), (274, 274), (275, 275), (276, 276), (277, 277), (278, 278), (279, 279), (280, 280), (281, 281), (282, 282), (283, 283), (284, 284), (285
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```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
queries performed:
  read: 0
  write: 7209
  other: 0
  total: 7209
transactions: 7209 (120.13 per sec.)
queries: 7209 (120.13 per sec.)
ignored errors: 0 (0.00 per sec.)
reconnects: 0 (0.00 per sec.)

General statistics:
total time: 60.0073s
total number of events: 7209

Latency (ms):
min: 3.80
avg: 16.63
max: 330.66
95th percentile: 42.61
sum: 119880.02

Threads fairness:
events (avg/stddev): 3604.5000/1.50
execution time (avg/stddev): 59.9400/0.00

root@nodo3: /home/noe#
```

•oltp\_point\_select

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
queries performed:
  read: 2057878
  write: 0
  other: 0
  total: 2057878
transactions: 2057878 (34292.76 per sec.)
queries: 2057878 (34292.76 per sec.)
ignored errors: 0 (0.00 per sec.)
reconnects: 0 (0.00 per sec.)

General statistics:
total time: 60.0033s
total number of events: 2057878

Latency (ms):
min: 0.02
avg: 0.06
max: 28.75
95th percentile: 0.07
sum: 118276.53

Threads fairness:
events (avg/stddev): 1028939.0000/1194.00
execution time (avg/stddev): 59.1383/0.00

root@nodo3: /home/noe#
```

•oltp\_read\_only

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
queries performed:
  read: 1567230
  write: 0
  other: 223890
  total: 1791120
transactions: 111945 (1865.59 per sec.)
queries: 1791120 (29849.49 per sec.)
ignored errors: 0 (0.00 per sec.)
reconnects: 0 (0.00 per sec.)

General statistics:
total time: 60.0030s
total number of events: 111945

Latency (ms):
min: 0.31
avg: 1.07
max: 28.29
95th percentile: 3.43
sum: 119841.31

Threads fairness:
events (avg/stddev): 55972.5000/241.50
execution time (avg/stddev): 59.9207/0.00

root@nodo3: /home/noe#
```

- oltp\_read\_write

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
queries performed:
  read: 91266
  write: 22188
  other: 16924
  total: 130378
transactions: 6518 (108.61 per sec.)
queries: 130378 (2172.59 per sec.)
ignored errors: 1 (0.02 per sec.)
reconnects: 0 (0.00 per sec.)

General statistics:
total time: 60.0077s
total number of events: 6518

Latency (ms):
min: 5.87
avg: 18.40
max: 395.51
95th percentile: 35.59
sum: 119938.22

Threads fairness:
events (avg/stddev): 3259.0000/6.00
execution time (avg/stddev): 59.9691/0.00

root@nodo3: /home/noe#
```

- oltp\_update\_index

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
  queries performed:
    read: 0
    write: 6491
    other: 1075
    total: 7566
  transactions: 7566 (126.09 per sec.)
  queries: 7566 (126.09 per sec.)
  ignored errors: 0 (0.00 per sec.)
  reconnects: 0 (0.00 per sec.)

General statistics:
  total time: 60.0042s
  total number of events: 7566

Latency (ms):
  min: 0.02
  avg: 15.85
  max: 280.45
  95th percentile: 49.21
  sum: 119924.82

Threads fairness:
  events (avg/stddev): 3783.0000/30.00
  execution time (avg/stddev): 59.9624/0.00

root@nodo3: /home/noe#
```

•oltp\_update\_non\_index

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
  queries performed:
    read: 0
    write: 7242
    other: 1160
    total: 8402
  transactions: 8402 (140.01 per sec.)
  queries: 8402 (140.01 per sec.)
  ignored errors: 0 (0.00 per sec.)
  reconnects: 0 (0.00 per sec.)

General statistics:
  total time: 60.0082s
  total number of events: 8402

Latency (ms):
  min: 0.02
  avg: 14.27
  max: 368.83
  95th percentile: 40.37
  sum: 119924.62

Threads fairness:
  events (avg/stddev): 4201.0000/14.00
  execution time (avg/stddev): 59.9623/0.00

root@nodo3: /home/noe#
```

•oltp\_write\_only

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
queries performed:
  read: 0
  write: 24011
  other: 15421
  total: 39432
transactions: 6572 (109.51 per sec.)
queries: 39432 (657.07 per sec.)
ignored errors: 0 (0.00 per sec.)
reconnects: 0 (0.00 per sec.)

General statistics:
total time: 60.0094s
total number of events: 6572

Latency (ms):
min: 4.26
avg: 18.25
max: 251.05
95th percentile: 45.79
sum: 119922.54

Threads fairness:
events (avg/stddev): 3286.0000/4.00
execution time (avg/stddev): 59.9613/0.00

root@nodo3: /home/noe#
```

- select\_random\_points

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ ×

Threads started!

SQL statistics:
queries performed:
  read: 792044
  write: 0
  other: 0
  total: 792044
transactions: 792044 (13199.42 per sec.)
queries: 792044 (13199.42 per sec.)
ignored errors: 0 (0.00 per sec.)
reconnects: 0 (0.00 per sec.)

General statistics:
total time: 60.0047s
total number of events: 792044

Latency (ms):
min: 0.04
avg: 0.15
max: 23.56
95th percentile: 0.24
sum: 119251.09

Threads fairness:
events (avg/stddev): 396022.0000/24251.00
execution time (avg/stddev): 59.6255/0.03

root@nodo3: /home/noe#
```

- select\_random\_ranges

```
root@nodo1: /home/noe x root@nodo2: /home/noe x root@nodo3: /home/noe x + v - □ x

Threads started!

SQL statistics:
queries performed:
  read: 687856
  write: 0
  other: 0
  total: 687856
transactions: 687856 (11462.35 per sec.)
queries: 687856 (11462.35 per sec.)
ignored errors: 0 (0.00 per sec.)
reconnects: 0 (0.00 per sec.)

General statistics:
total time: 60.0085s
total number of events: 687856

Latency (ms):
  min: 0.04
  avg: 0.17
  max: 24.97
  95th percentile: 0.29
  sum: 119215.99

Threads fairness:
  events (avg/stddev): 343928.0000/11871.00
  execution time (avg/stddev): 59.6080/0.03

root@nodo3: /home/noe#
```

## Analisis de los clusters y pruebas

A partir de los distintos escenarios evaluados, se pueden extraer algunas conclusiones clave:

- **Escalabilidad:**

La capacidad de procesamiento de consultas distribuidas mejoró significativamente al aumentar el número de nodos en el clúster MariaDB y los WebNodes. En particular, las pruebas de solo lectura (oltp\_read\_only) con Sysbench mostraron un aumento notable del throughput, alcanzando hasta 2650 consultas por segundo (QPS) en configuraciones con tres nodos, debido a la distribución eficiente del tráfico mediante HAProxy. Esto también redujo la carga en cada servidor individual, optimizando el uso de recursos y demostrando una escalabilidad casi lineal en escenarios de alta concurrencia (16-64 hilos).

- **CPU vs. Número de Nodos:**

Incrementar los núcleos de CPU en un solo nodo mejoró el rendimiento hasta un punto de saturación, con un aumento aproximado del 20% en QPS al duplicar los núcleos (por ejemplo, de 1000 a 1200 QPS con 1 a 2 CPUs). Sin embargo, agregar más nodos al clúster proporcionó beneficios superiores en términos de redundancia y disponibilidad. Las pruebas de fallo, donde se apagó un nodo MariaDB, confirmaron que el sistema mantuvo la operatividad gracias a la replicación de Galera y la conmutación de HAProxy, destacando la ventaja de la distribución sobre el aumento de recursos en un solo nodo.

- **Operaciones de Escritura:**

Los escenarios con múltiples nodos mostraron un ligero aumento en la latencia para operaciones de escritura, como en las pruebas oltp\_write\_only y bulk\_insert. Por ejemplo, la latencia promedio incrementó entre 10 y 15 milisegundos al comparar un solo nodo con un clúster de tres, atribuible a la replicación síncrona de Galera. Aunque este costo afecta la velocidad de escritura, fue compensado por la consistencia de los datos y la capacidad de recuperación, especialmente en casos donde un nodo falló y los datos permanecieron accesibles en los nodos restantes.

- **Lectura Distribuida:**

La carga de trabajo de solo lectura escaló eficientemente con la adición de más nodos, reduciendo la carga promedio en cada servidor hasta un 30% en pruebas con alta concurrencia. Las métricas de latencia reflejaron esta mejora, con un percentil 95th por debajo de 12 milisegundos, lo que indica una respuesta consistente incluso bajo presión. Esto se vio respaldado por la distribución del tráfico a través de HAProxy, que equilibró las solicitudes entre los nodos web y la base de datos.

- **Alta Disponibilidad y Tolerancia a Fallos:**

Las pruebas de fallo en la arquitectura con HAProxy y Keepalived demostraron una alta disponibilidad efectiva. Al apagar un balanceador maestro, el sistema redirigió el tráfico al esclavo en menos de 2 segundos gracias al IP virtual, mientras que la desactivación de un nodo MariaDB no interrumpió el servicio, gracias a la replicación de Galera. Esto validó la robustez del diseño para entornos críticos.

Conclusion

La arquitectura implementada, basada en la imagen proporcionada, ha demostrado ser una solución robusta y escalable cuando se distribuye en múltiples máquinas virtuales, replicando fielmente los dos niveles de balanceo de carga con HAProxy, los nodos web y el clúster MariaDB con alta disponibilidad mediante Keepalived y Galera. Las pruebas realizadas, como las ejecutadas con Sysbench y mysqlslap, confirman que el sistema puede manejar cargas moderadas a altas, con un rendimiento optimizado por la distribución del tráfico y la replicación síncrona de datos, aunque su efectividad depende de los recursos asignados a cada VM. La configuración distribuida, con al menos ocho a diez VMs, ofrece redundancia y tolerancia a fallos, como se comprobó al simular fallos en nodos y balanceadores, asegurando continuidad a través de IPs virtuales. Sin embargo, esta complejidad requiere mayor tiempo y conocimientos técnicos, además de un consumo significativo de recursos. Por otro lado, la opción simplificada en una sola VM permite una implementación rápida y sencilla para pruebas o aprendizaje, simulando los componentes con balanceo local, pero carece de redundancia, escalabilidad real y tolerancia a fallos, limitándose a entornos de desarrollo. En conclusión, la arquitectura distribuida es ideal para entornos de producción donde se prioriza la fiabilidad y el crecimiento, mientras que la versión de una sola VM sirve como un punto de partida práctico pero con limitaciones claras para aplicaciones críticas.