НАСТРОЙКА РЕПЛИКАЦИИ

В качестве БД – ***Postgres 14.*** Нагрузочное тестирование - **Jmeter 5.5**

Бекенд - **github.com/jackc/pgx/v5/pgxpool**

Будем делать master - slave асинхронную репликацию. Один мастер и два слейва, для удобства балансировки (50/50 между слейвами), восстановления при потере мастера и интеграции будем использовать **pgpool.**

Воспользуемся образами от bitnami т.к. это позволит удобно разворачивать систему. Отличная документация https://hub.docker.com/r/bitnami/pgpool

Ниже представлен фрагмент docker-compose с конфигурацией.

```
pg-0:
  image: bitnami/postgresql-repmgr:14
  ports:
    - 5432
  volumes:
    - pg_0_data:/bitnami/postgresql
  environment:
    - POSTGRESQL_POSTGRES_PASSWORD=adminpassword
    - POSTGRESQL_USERNAME=customuser
    - POSTGRESQL_PASSWORD=custompassword
    - POSTGRESQL_DATABASE=default-db
    - REPMGR_PASSWORD=repmgrpassword
    - REPMGR_PRIMARY_HOST=pg-0
    - REPMGR_PARTNER_NODES=pg-0,pg-1,pg-2
    - REPMGR_NODE_NAME=pg-0
    - REPMGR_NODE_NETWORK_NAME=pg-0
  healthcheck:
    test: [ "CMD-SHELL", "pg_isready -U postgres -d default-db" ]
    interval: 10s
    timeout: 5s
    retries: 5
    start_period: 10s
pg-1:
  image: bitnami/postgresql-repmgr:14
  ports:
    - 5432
  volumes:
    - pg_1_data:/bitnami/postgresql
  environment:
    - POSTGRESQL_POSTGRES_PASSWORD=adminpassword
    - POSTGRESQL_USERNAME=customuser
    - POSTGRESQL_PASSWORD=custompassword
    - POSTGRESQL_DATABASE=default-db
    - REPMGR_PASSWORD=repmgrpassword
    - REPMGR_PRIMARY_HOST=pg-0
    - REPMGR_PARTNER_NODES=pg-0,pg-1,pg-2
    - REPMGR_NODE_NAME=pg-1
    - REPMGR_NODE_NETWORK_NAME=pg-1
  healthcheck:
    test: [ "CMD-SHELL", "pg_isready -U postgres -d default-db" ]
    interval: 10s
```

```
    timeout: 5s
    retries: 5
    start_period: 10s
pg-2:
  image: bitnami/postgresql-repmgr:14
  ports:
    - 5432
  volumes:
    - pg_2_data:/bitnami/postgresql
  environment:
    - POSTGRESQL_POSTGRES_PASSWORD=adminpassword
    - POSTGRESQL_USERNAME=customuser
    - POSTGRESQL_PASSWORD=custompassword
    - POSTGRESQL_DATABASE=default-db
    - REPMGR_PASSWORD=repmgrpassword
    - REPMGR_PRIMARY_HOST=pg-0
    - REPMGR_PARTNER_NODES=pg-0,pg-1,pg-2
    - REPMGR_NODE_NAME=pg-2
    - REPMGR_NODE_NETWORK_NAME=pg-2
  healthcheck:
    test: [ "CMD-SHELL", "pg_isready -U postgres -d default-db" ]
    interval: 10s
    timeout: 5s
    retries: 5
    start_period: 10s
pgpool:
  image: bitnami/pgpool:latest
  ports:
    - 5432:5432
  environment:
    - PGPOOL_BACKEND_NODES=0:pg-0:5432:0:pg-
0:ALWAYS_PRIMARY|DISALLOW_TO_FAILOVER,1:pg-1:5432:1:pg-
1:DISALLOW_TO_FAILOVER,2:pg-2:5432:1:pg-2:DISALLOW_TO_FAILOVER
    - PGPOOL_SR_CHECK_USER=customuser
    - PGPOOL_SR_CHECK_PASSWORD=custompassword
    - PGPOOL_ENABLE_LDAP=no
    - PGPOOL_POSTGRES_USERNAME=postgres
    - PGPOOL_POSTGRES_PASSWORD=adminpassword
    - PGPOOL_ADMIN_USERNAME=admin
    - PGPOOL_ADMIN_PASSWORD=adminpassword
  depends_on:
    pg-0:
      condition: service_healthy
    pg-1:
      condition: service_healthy
    pg-2:
      condition: service_healthy
  healthcheck:
    test: ["CMD", "/opt/bitnami/scripts/pgpool/healthcheck.sh"]
    interval: 10s
    timeout: 5s
    retries: 5
```

Берем именно postgresql-repmgr тк хотим использовать стратегию failover из коробки. Будем делать потоковую репликацию(Streaming Replication), по-умолчанию она асинхронная.

Рассмотрим флаги для нод:

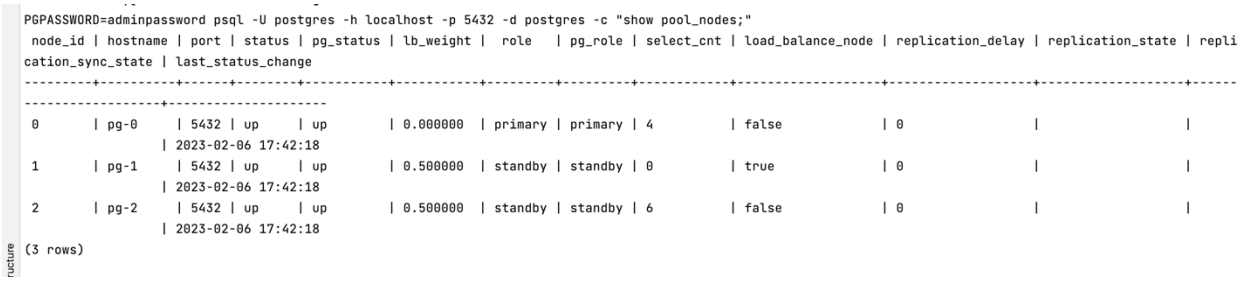
1) ALWAYS_PRIMARY – флаг означает, что данная нода(БД) является постоянным мастером.

2) DISALLOW_TO_FAILOVER – флаг означает, что аварийное(failover) переключение не доступно для ноды

3) ALLOW_TO_FAILOVER – флаг означает, что аварийное переключение доступно

С помощью этих флагов будем управлять поведением системы при потере мастера.

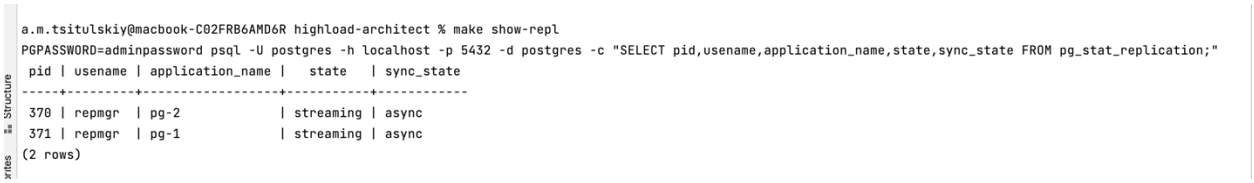
Смотрим статус нод: `show pool_nodes;`



```
PGPASSWORD=adminpassword psql -U postgres -h localhost -p 5432 -d postgres -c "show pool_nodes;"
 node_id | hostname | port | status | pg_status | lb_weight |  role   | pg_role | select_cnt | load_balance_node | replication_delay | replication_state | repli
cation_sync_state | last_status_change
---------+----------+------+--------+-----------+-----------+---------+---------+------------+-------------------+-------------------+-------------------+------
------------------+---------------------
 0       | pg-0     | 5432 | up     | up        | 0.000000  | primary | primary | 4          | false             | 0                 |                   |
                  | 2023-02-06 17:42:18
 1       | pg-1     | 5432 | up     | up        | 0.500000  | standby | standby | 0          | true              | 0                 |                   |
                  | 2023-02-06 17:42:18
 2       | pg-2     | 5432 | up     | up        | 0.500000  | standby | standby | 6          | false             | 0                 |                   |
                  | 2023-02-06 17:42:18
(3 rows)
```

Смотрим тип репликации слейвов

```
SELECT pid,usename,application_name,state,sync_state FROM pg_stat_replication;
```



```
a.m.tsitulskiy@macbook-C02FRB6AMD6R highload-architect % make show-repl
PGPASSWORD=adminpassword psql -U postgres -h localhost -p 5432 -d postgres -c "SELECT pid,usename,application_name,state,sync_state FROM pg_stat_replication;"
 pid | usename | application_name |   state   | sync_state
-----+---------+------------------+-----------+------------
 370 | repmgr  | pg-2             | streaming | async
 371 | repmgr  | pg-1             | streaming | async
(2 rows)
```

Рассмотрим потерю мастера при асинхронной и синхронной репликации, стратегию failover – включим, тк без нее очевидно будет потеря данных.

ЗАПИСЬ НА СЛЕЙВЫ

Запустим скрипт для сбора docker stats, что бы потом визуализировать

Запустим нагрузочный тест для чтения из прошлого ДЗ

```
a.m.tsitulskiy@macbook-C02FRB6AMD6R highload-architect % make run-jmeter
jmeter -n -t ./HTTP_Request_1.jmx -l ./results.csv -e -o ./report
WARNING: package sun.awt.X11 not in java.desktop
Creating summariser <summary>
Created the tree successfully using ./HTTP_Request_1.jmx
Starting standalone test @ 2023 Feb 6 21:02:13 MSK (1675706533325)
Waiting for possible Shutdown/StopTestNow/HeapDump/ThreadDump message on port 4445
summary +    556 in 00:00:17 =   33.5/s Avg:    29 Min:     3 Max:  1144 Err:     0 (0.00%) Active: 1 Started: 1 Finished: 0
summary +   2421 in 00:00:30 =   80.7/s Avg:    12 Min:     3 Max:   351 Err:     0 (0.00%) Active: 1 Started: 1 Finished: 0
summary =   2977 in 00:00:47 =   63.9/s Avg:    15 Min:     3 Max:  1144 Err:     0 (0.00%)
summary +   3356 in 00:00:30 =  111.9/s Avg:    51 Min:     3 Max:  3506 Err:     0 (0.00%) Active: 10 Started: 11 Finished: 1
summary =   6333 in 00:01:17 =   82.7/s Avg:    34 Min:     3 Max:  3506 Err:     0 (0.00%)
summary +   3582 in 00:00:30 =  119.3/s Avg:    83 Min:     6 Max:  3289 Err:     0 (0.00%) Active: 10 Started: 11 Finished: 1
summary =   9915 in 00:01:47 =   93.0/s Avg:    52 Min:     3 Max:  3506 Err:     0 (0.00%)
summary +   4044 in 00:00:30 =  134.8/s Avg:   422 Min:     8 Max:  1912 Err:     0 (0.00%) Active: 100 Started: 111 Finished: 11
summary =  13959 in 00:02:17 =  102.2/s Avg:   159 Min:     3 Max:  3506 Err:     0 (0.00%)
summary +   3392 in 00:00:30 =  113.0/s Avg:   827 Min:   357 Max:  4660 Err:     0 (0.00%) Active: 100 Started: 111 Finished: 11
summary =  17351 in 00:02:47 =  104.1/s Avg:   290 Min:     3 Max:  4660 Err:     0 (0.00%)
summary +   1799 in 00:00:34 =   52.2/s Avg:   920 Min:   310 Max: 21760 Err:     0 (0.00%) Active: 1085 Started: 1111 Finished: 26
summary =  19150 in 00:03:21 =   95.2/s Avg:   349 Min:     3 Max: 21760 Err:     0 (0.00%)
^Cmake: *** [run-jmeter] Error 130
```

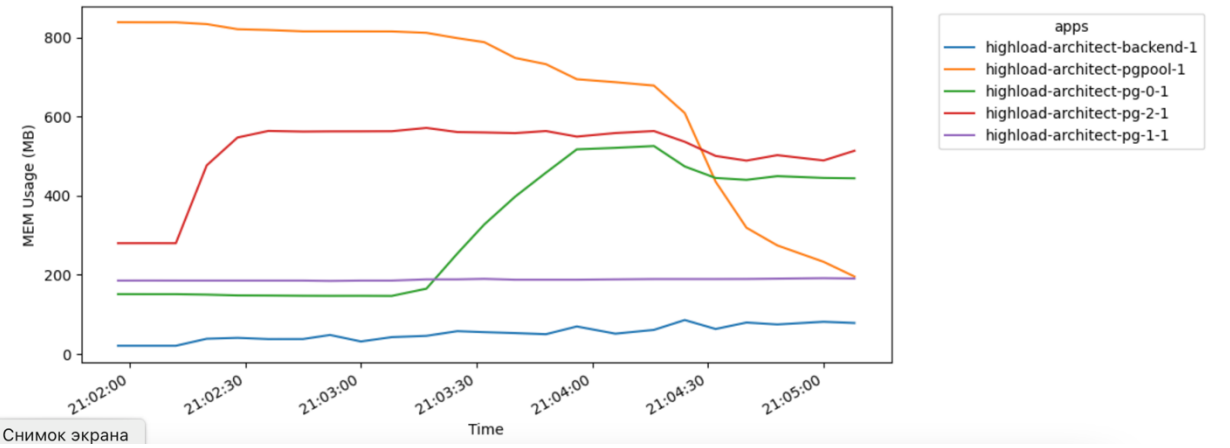
Видим, что запросы шли на слейвы

```
(END)...skipping...
 node_id | hostname | port | status | pg_status | lb_weight |  role   | pg_role | select_cnt | load_balance_node | replication_delay | replication_state | r
eplication_sync_state | last_status_change
---------+----------+------+--------+-----------+-----------+---------+---------+------------+-------------------+-------------------+-------------------+--
----------------------+---------------------
 0       | pg-0     | 5432 | up     | up        | 0.000000  | primary | primary | 80         | false             | 0                 |                   |
                      | 2023-02-06 17:42:18
 1       | pg-1     | 5432 | up     | up        | 0.500000  | standby | standby | 2607       | false             | 0                 |                   |
                      | 2023-02-06 17:42:18
 2       | pg-2     | 5432 | up     | up        | 0.500000  | standby | standby | 16730      | true              | 0                 |                   |
                      | 2023-02-06 17:42:18
(3 rows)

~
~
~
~
```

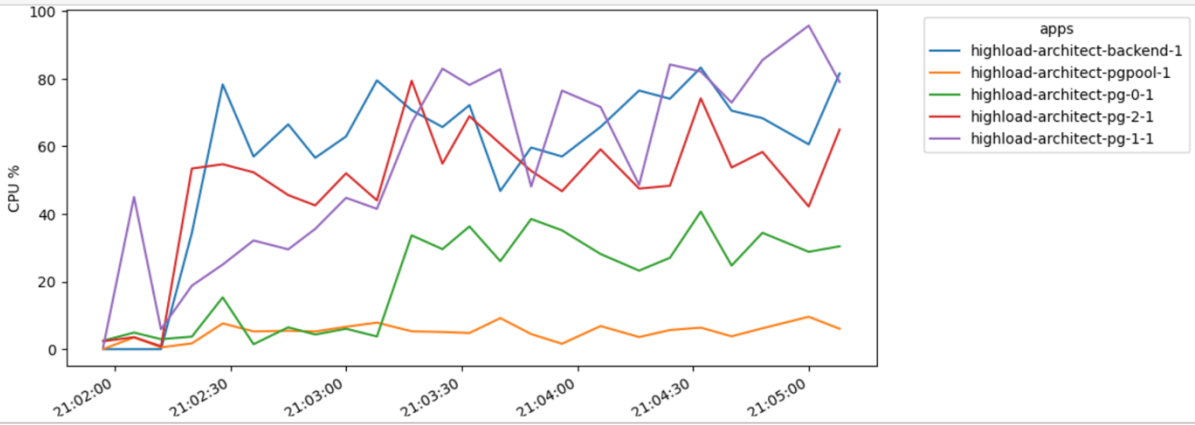
В среднем такое потребление ресурсов было во время нагрузки на чтение

NAME	CPU %	MEM %	MEM Usage	PID	NET INPUT	NET OUTPUT	BLOCK INPUT	BLOCK OUTPUT
highload-architect-backend-1	57.83	1.29	50.97	11.50	404.17	393.43	2.08	0.00
highload-architect-pg-0-1	5.10	17.20	676.91	17.92	791.58	1860.00	34.96	3230.00
highload-architect-pg-1-1	20.35	7.76	305.57	11.88	876.88	45.49	176.34	3389.58
highload-architect-pg-2-1	48.47	12.89	507.53	11.92	897.67	364.57	205.71	3477.92
highload-architect-pgpool-1	55.59	4.75	186.85	38.21	1042.38	1354.71	2.21	1.67



Снимок экрана

[5]:
```
ds.plot_category_all()
```



ПОТЕРЯ МАСТЕРА ПРИ АСИНХРОННОЙ РЕПЛИКАЦИИ

Запустим скрипт для сбора docker stats, что бы потом визуализировать.

Запустим нагрузку на запись, остановим pg-0 и посмотрим % ошибок

```
a.m.tsitulskiy@macbook-C02FRB6AMD6R highload-architect % make run-jmeter-w
jmeter -n -t ./HTTP_write.jmx -l ./results-w.csv -e -o ./report-w
WARNING: package sun.awt.X11 not in java.desktop
Creating summariser <summary>
Created the tree successfully using ./HTTP_write.jmx
Starting standalone test @ 2023 Feb 6 21:35:37 MSK (1675708537793)
Waiting for possible Shutdown/StopTestNow/HeapDump/ThreadDump message on port 4445
summary +    284 in 00:00:22 =   12.8/s Avg:    77 Min:    60 Max:   336 Err:     0 (0.00%) Active: 1 Started: 1 Finished: 0
summary +    464 in 00:00:30 =   15.5/s Avg:    64 Min:    60 Max:    93 Err:     0 (0.00%) Active: 1 Started: 1 Finished: 0
summary =    748 in 00:00:52 =   14.3/s Avg:    69 Min:    60 Max:   336 Err:     0 (0.00%)
summary +     66 in 00:00:31 =    2.2/s Avg:  3055 Min:    61 Max:  6512 Err:    44 (66.67%) Active: 11 Started: 11 Finished: 0
summary =    814 in 00:01:23 =    9.8/s Avg:   311 Min:    60 Max:  6512 Err:    44 (5.41%)
summary +     72 in 00:00:30 =    2.4/s Avg:  4211 Min:  3333 Max:  5182 Err:    72 (100.00%) Active: 11 Started: 11 Finished: 0
summary =    886 in 00:01:53 =    7.9/s Avg:   628 Min:    60 Max:  6512 Err:   116 (13.09%)
summary +   1137 in 00:00:30 =   38.4/s Avg:  1949 Min:    99 Max: 62792 Err:    12 (1.06%) Active: 100 Started: 111 Finished: 11
summary =   2023 in 00:02:22 =   14.2/s Avg:  1371 Min:    60 Max: 62792 Err:   128 (6.33%)
summary +   1648 in 00:00:30 =   55.0/s Avg:  1828 Min:  1575 Max:  2248 Err:     0 (0.00%) Active: 100 Started: 111 Finished: 11
summary =   3671 in 00:02:52 =   21.3/s Avg:  1576 Min:    60 Max: 62792 Err:   128 (3.49%)
summary +    473 in 00:00:30 =   15.7/s Avg:  2371 Min:  1568 Max: 22230 Err:     1 (0.21%) Active: 1065 Started: 1111 Finished: 46
summary =   4144 in 00:03:22 =   20.5/s Avg:  1667 Min:    60 Max: 62792 Err:   129 (3.11%)
^Cmake: *** [run-jmeter-w] Error 130
```

Видим, что failover отработал

```
(END)...skipping...
 node_id | hostname | port | status | pg_status | lb_weight |  role   | pg_role | select_cnt | load_balance_node | replication_delay
cation_sync_state | last_status_change
---------+----------+------+--------+-----------+-----------+---------+---------+------------+-------------------+------------------
------------------+---------------------
 0       | pg-0     | 5432 | down   | down      | 0.000000  | standby | unknown | 4          | false             | 0
                  | 2023-02-06 18:37:32
 1       | pg-1     | 5432 | up     | up        | 0.500000  | primary | primary | 5          | true              | 0
                  | 2023-02-06 18:37:32
 2       | pg-2     | 5432 | up     | up        | 0.500000  | standby | standby | 1          | false             | 0
                  | 2023-02-06 18:33:07
(3 rows)
```

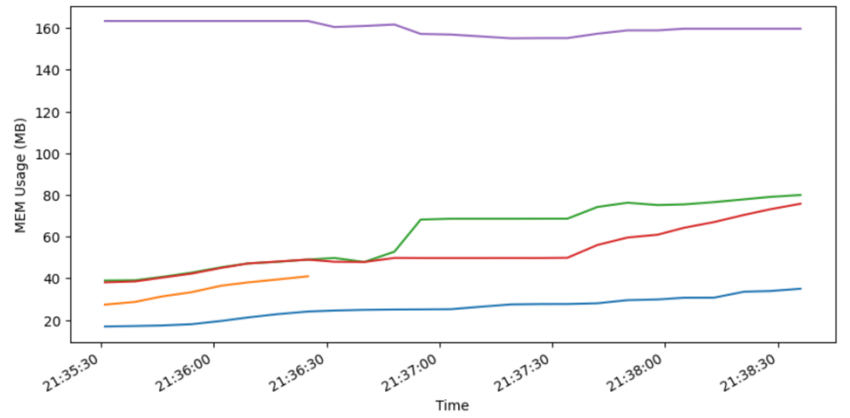
Среднее потребление ресурсов

```
[4]: ds.mean_for_apps()
```

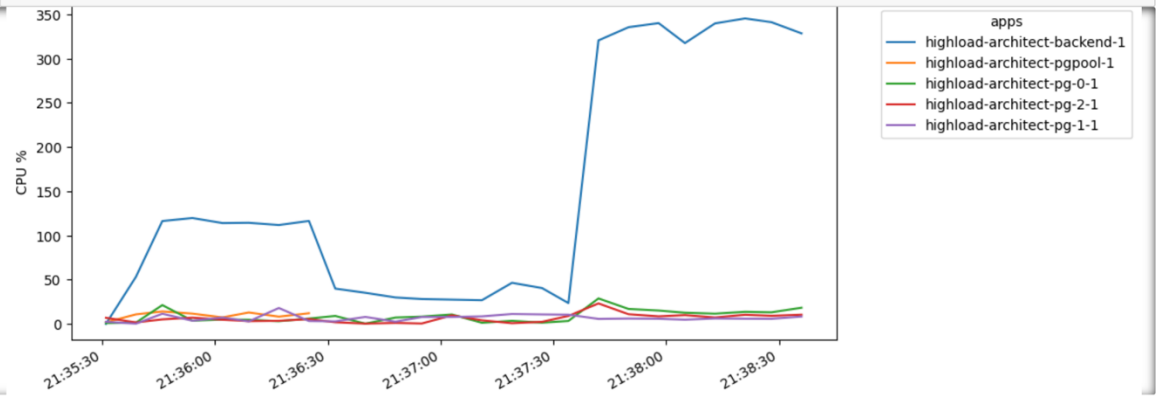
:[4]:

NAME	CPU %	MEM %	MEM Usage	PID	NET INPUT	NET OUTPUT	BLOCK INPUT	BLOCK OUTPUT
highload-architect-backend-1	148.50	0.65	25.73	9.16	0.84	0.98	1.11	0.00
highload-architect-pg-0-1	9.87	0.88	34.48	16.00	2.38	1157.50	0.05	58.06
highload-architect-pg-1-1	8.86	1.55	61.09	13.64	583.48	18.77	0.93	252.28
highload-architect-pg-2-1	6.29	1.34	52.80	10.60	600.64	1.60	0.71	255.00
highload-architect-pgpool-1	6.71	4.06	159.98	38.08	1.22	1.57	0.95	1.67

```
[5]: ds.plot_category('MEM Usage')
```




```
[6]: ds.plot_category_all()
```



Если просто убить мастера и не восстанавливать, то

На pg-0 мастер, которого потеряли: 1000810 записей

На pg-1 слейв, ставший мастером: 1004123 записей

На pg-2 слейв: 1000810 записей

В случае если мастер просто умер(docker-compose stop), а потом восстановился(docker-compose start)

На pg-0 мастер, которого потеряли: 1004123 записей

На pg-1 слейв, ставший мастером: 1004123 записей

На pg-2 слейв: 1004123 записей

ПОТЕРЯ МАСТЕРА ПРИ СИНХРОННОЙ РЕПЛИКАЦИИ

Устанавливаем синхронную репликацию на pg-0

- POSTGRESQL_SYNCHRONOUS_COMMIT_MODE=on
- POSTGRESQL_NUM_SYNCHRONOUS_REPLICAS=2

```
a.m.tsitulskiy@macbook-C02FRB6AMD6R highload-architect % make show-repl
PGPASSWORD=adminpassword psql -U postgres -h localhost -p 5432 -d postgres -c "SELECT pid,usename,application_name,sta
 pid | usename | application_name |   state   | sync_state
-----+---------+------------------+-----------+------------
 375 | repmgr  | pg-2             | streaming | sync
 376 | repmgr  | pg-1             | streaming | sync
(2 rows)
```

Действуем аналогично

```
a.m.tsitulskiy@macbook-C02FRB6AMD6R highload-architect % make run-jmeter-w
jmeter -n -t ./HTTP_write.jmx -l ./results-w.csv -e -o ./report-w
WARNING: package sun.awt.X11 not in java.desktop
Creating summariser <summary>
Created the tree successfully using ./HTTP_write.jmx
Starting standalone test @ 2023 Feb 6 22:53:24 MSK (1675713204825)
Waiting for possible Shutdown/StopTestNow/HeapDump/ThreadDump message on port 4445
summary +     42 in 00:00:05 =    8.0/s Avg:   121 Min:    63 Max:   847 Err:     0 (0.00%) Active: 1 Started: 1 Finished: 0
summary +    389 in 00:00:30 =   13.0/s Avg:    76 Min:    61 Max:   424 Err:     0 (0.00%) Active: 1 Started: 1 Finished: 0
summary =    431 in 00:00:35 =   12.3/s Avg:    80 Min:    61 Max:   847 Err:     0 (0.00%)
summary +    183 in 00:00:31 =    6.0/s Avg:   163 Min:    62 Max:  5404 Err:     6 (3.28%) Active: 11 Started: 11 Finished: 0
summary =    614 in 00:01:06 =    9.3/s Avg:   105 Min:    61 Max:  5404 Err:     6 (0.98%)
summary +     70 in 00:00:30 =    2.3/s Avg:  4504 Min:  3330 Max:  8078 Err:    70 (100.00%) Active: 11 Started: 11 Finished: 0
summary =    684 in 00:01:36 =    7.1/s Avg:   555 Min:    61 Max:  8078 Err:    76 (11.11%)
summary +   1336 in 00:00:29 =   45.4/s Avg:   490 Min:    89 Max: 51788 Err:    12 (0.90%) Active: 100 Started: 111 Finished: 11
summary =   2020 in 00:02:05 =   16.1/s Avg:   512 Min:    61 Max: 51788 Err:    88 (4.36%)
summary +   1473 in 00:00:30 =   49.1/s Avg:  2052 Min:  1570 Max:  4543 Err:     0 (0.00%) Active: 100 Started: 111 Finished: 11
summary =   3493 in 00:02:35 =   22.5/s Avg:  1161 Min:    61 Max: 51788 Err:    88 (2.52%)
summary +   1307 in 00:00:30 =   43.3/s Avg:  1953 Min:  1548 Max:  6716 Err:     0 (0.00%) Active: 1087 Started: 1111 Finished: 24
summary =   4800 in 00:03:05 =   25.9/s Avg:  1377 Min:    61 Max: 51788 Err:    88 (1.83%)
^Cmake: *** [run-jmeter-w] Error 130
```

Failover – отработал

```
a.m.tsitulskiy@macbook-C02FRB6AMD6R highload-architect % make show-nodes
PGPASSWORD=adminpassword psql -U postgres -h localhost -p 5432 -d postgres -c "show pool_nodes;"
 node_id | hostname | port | status | pg_status | lb_weight |  role   | pg_role | select_cnt | load_balance_node | replication_delay | re
cation_sync_state | last_status_change
---------+----------+------+--------+-----------+-----------+---------+---------+------------+-------------------+-------------------+---
-----------------+---------------------
 0       | pg-0     | 5432 | down   | down      | 0.000000  | standby | unknown | 82         | false             | 0                 |
                  | 2023-02-06 19:55:01
 1       | pg-1     | 5432 | up     | up        | 0.500000  | primary | primary | 5          | true              | 0                 |
                  | 2023-02-06 19:55:01
 2       | pg-2     | 5432 | up     | up        | 0.500000  | standby | standby | 15         | false             | 0                 |
                  | 2023-02-06 19:38:27
(3 rows)

(END)
```

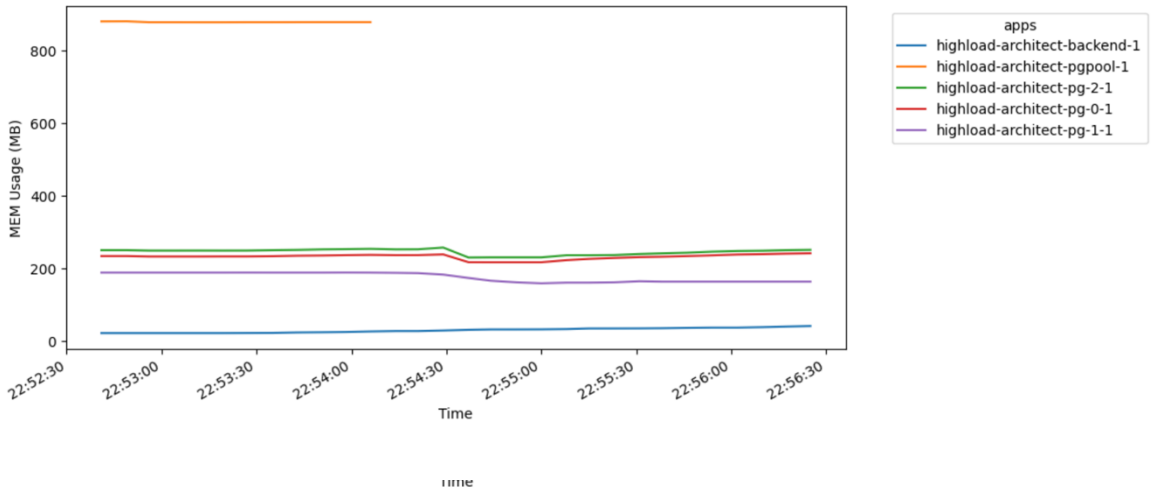
Потребление ресурсов

```
In [4]: ds.mean_for_apps()
```

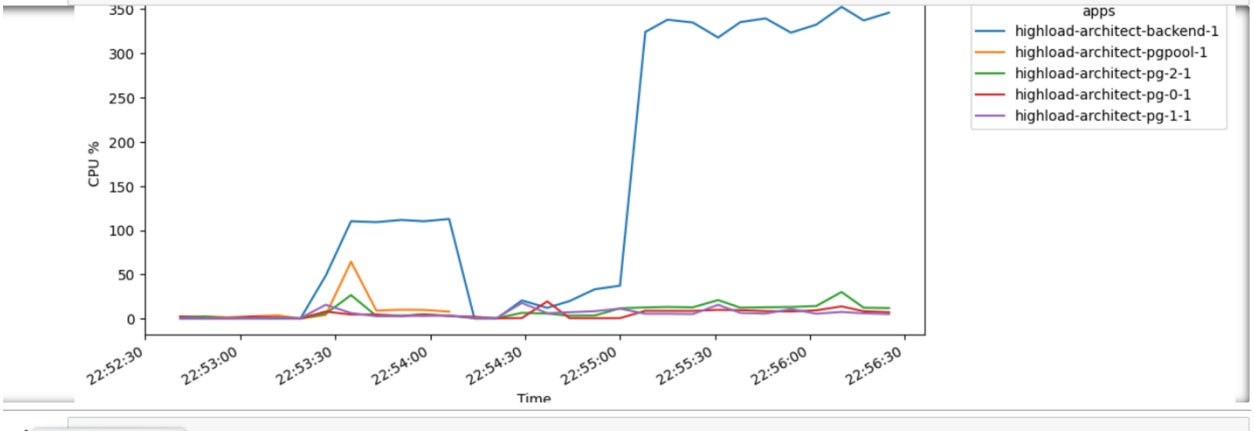
Out[4]:

NAME	CPU %	MEM %	MEM Usage	PID	NET INPUT	NET OUTPUT	BLOCK INPUT	BLOCK OUTPUT
highload-architect-backend-1	146.86	0.74	29.19	10.20	0.84	0.97	8.71	0.00
highload-architect-pg-0-1	9.75	22.32	878.50	16.17	781.42	1834.17	21.40	3085.00
highload-architect-pg-1-1	8.38	6.23	245.31	13.67	860.80	16.58	21.63	3144.00
highload-architect-pg-2-1	5.34	5.89	231.74	11.03	891.60	4.61	23.93	3203.67
highload-architect-pgpool-1	5.63	4.46	175.44	38.33	648.63	939.43	4.67	1.67

```
In [5]: ds.plot_category('MEM Usage')
```




```
n [6]: ds.plot_category_all()
```



Если мастер умер, а потом восстановился, то

На pg-0 мастер, которого потеряли: 1004801 записей

На pg-1 слейв, ставший мастером: 1004801 записей

На pg-2 слейв: 1004801 записей

ВЫВОД

Благодаря failover и pgpool, в случае временной потери мастера, данные в любом случае засинкаются, когда мастер восстановится.

Если сначала умрет мастер, потом умрет весь кластер, то данные будут рассинхронизированы.

По latency видно, что синхронная репликация немного дольше, чем асинхронная.