ALTIMETRIK

Scale with **Redis Cluster - Caching**

Author/Architect

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White Paper

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Executive Summary

Redis is an open-source, in-memory data structure store that can be used for caching, databases, and message brokering. As an in-memory store, it delivers significantly higher performance compared to traditional databases. Redis supports a wide range of use cases, including message brokering, key-value storage, caching, databases, Pub/Sub messaging, clustering, and ensuring high availability of data.

In this case study, we will focus on caching, one of the most common use cases of Redis. Redis offers high availability through replication, and its performance can be further enhanced by leveraging its clustering features.

Introduction
Redis Clustering

Redis clustering enables scaling by distributing data across multiple Redis instances, allowing the system to handle larger datasets while increasing read and write throughput. Built-in fault tolerance is achieved by replicating data to secondary nodes, and data is partitioned based on hash slots.

Redis scales effectively through clustering, with the application managing redistribution in the event of node failures or additions. Redis also includes Sentinel, a built-in service that handles clustering management. Additionally, Redis clusters can be monitored using Redis Sentinel or various third-party tools.

Industry **Trends**

Redis is widely regarded as one of the most popular key-value stores in the IT industry, known for its robustness, scalability, and high availability. As the world becomes more competitive with advances in internet speed and technological upgrades, Redis supports high-speed client communication through its in-memory architecture.

Redis clustering has become a critical component of modern infrastructure, especially for real-time data processing in industries such as e-commerce, gaming, analytics, and finance. Organizations are increasingly adopting Redis clusters due to their scalability, performance, and resilience. Industry trends indicate a growing interest in Redis, as reflected in the increasing number of Docker image downloads and widespread adoption of Redis software.

Key Statistics Regarding Interest in **Redis Clusters**

The Bitnami/Redis-cluster images have been downloaded over 100 million times, reflecting the strong interest and widespread usability of Redis clusters in the software industry.

A significant number of downloads have been recorded for Redis-related APIs and programming package managers.

Redis is among the most downloaded images on Docker Hub.

Understanding the **Redis Cluster**

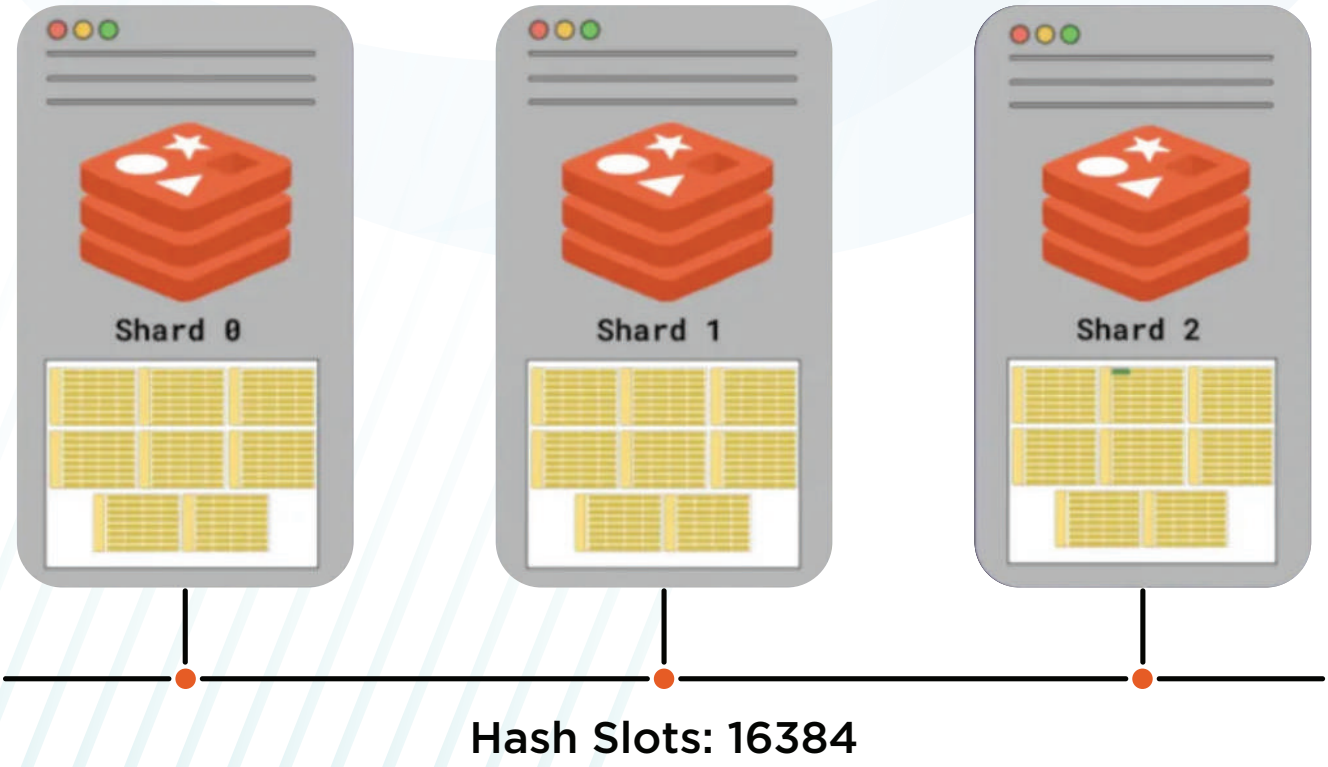
What is Redis Cluster

Redis Cluster is a distributed implementation of Redis that splits data storage across multiple Redis nodes, enabling horizontal scaling and ensuring high availability through automatic failover.

Benefits of Redis Cluster

Redis Cluster provides substantial benefits, including horizontal scaling, high availability, automatic failover, and data sharding. By distributing data and workloads across multiple nodes, it ensures continuous service through replicas and optimizes resource utilization through sharding. Redis Cluster delivers a best-in-class solution for modern, data-intensive applications.

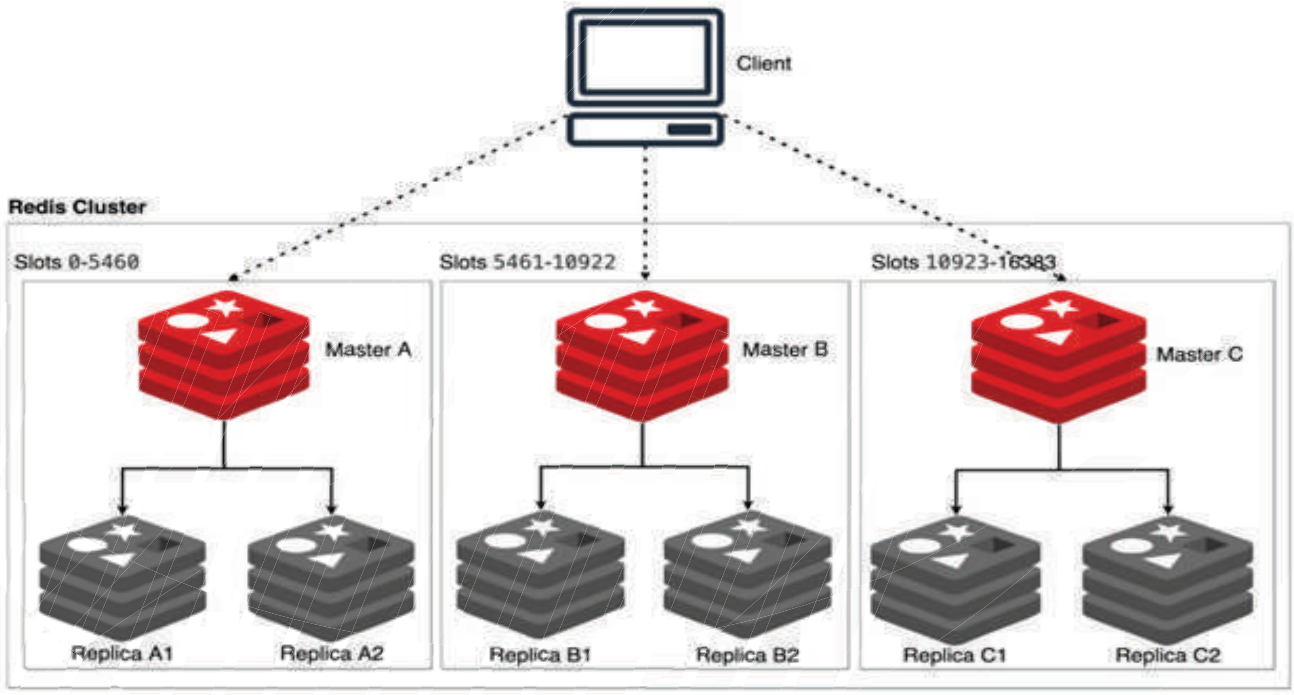
These features make Redis Cluster an excellent choice for applications requiring high performance, scalability, and resilience, particularly when handling large datasets with multiple write points.



Horizontal Scaling

Horizontal scaling architecture enables systems to expand by adding more nodes as needed to accommodate increased workloads and data volumes. By distributing data across multiple nodes, read and write operations are spread out, reducing the load on any single node and improving overall performance—especially in high-traffic enterprise systems, such as e-commerce or financial platforms that require real-time data access.

Nodes and data storage can be added without significant changes to the application architecture, allowing the system to easily scale up or down based on demand. This makes horizontal scaling both cost-effective and efficient for managing fluctuating workloads.

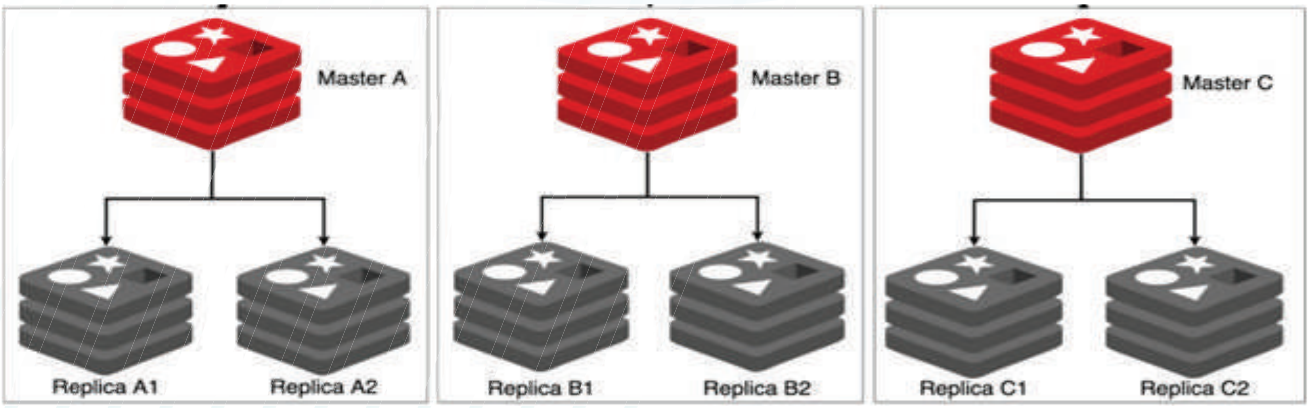


High Availability

Redis is built with replication capabilities, allowing additional instances to be added to ensure failover. Redis Cluster guarantees high availability by maintaining multiple replica nodes for each master node. These replicas serve as backups and can quickly take over if a master node fails. Redis provides synchronization mechanisms to keep replicas up to date, using either full or partial sync depending on data integrity needs.

In the event of a master node failure, replicas are promoted to master, ensuring uninterrupted service with minimal downtime.

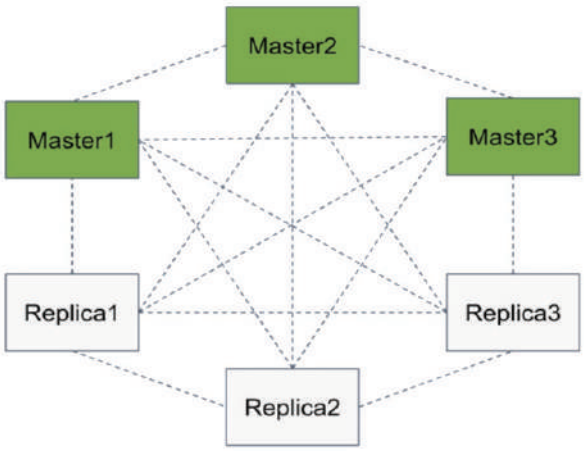
Replicas consistently synchronize with the master node, protecting against data loss and maintaining data consistency. This architecture also handles node failures and network partitions, offering robust fault tolerance.



Automatic Failover nodes

Redis Cluster includes an automatic failover mechanism that promotes a replica (slave) to master if the current master node fails. This process occurs automatically, without requiring human intervention, ensuring minimal downtime and maintaining service responsiveness even during node failures.

By eliminating the risk of human error in failover situations, Redis Cluster significantly improves operational efficiency. Automatic failover enhances the reliability of applications by ensuring continuous data access and smooth operation during failures.

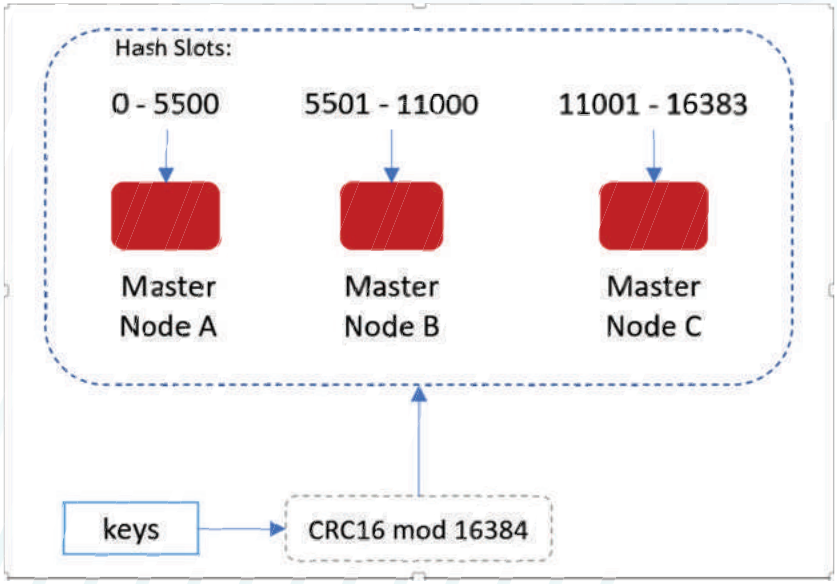


Data Sharding

Sharding involves distributing data across multiple nodes using consistent hashing, which partitions the data into smaller, more manageable chunks spread across the cluster. Redis Cluster employs hash slot-based partitioning, automatically handling sharding or resharding when nodes are added or removed.

By distributing data evenly across multiple nodes, Redis Cluster ensures no single node becomes overloaded, optimizing resource utilization.

Data sharding enables parallel processing of operations within the same application across different nodes, improving overall throughput and reducing latency. As data grows, the cluster can be expanded by adding more nodes, with each node managing a portion of the data, allowing the system to handle larger datasets effortlessly.



Setting Up Redis Cluster

Pre-Requisites

- Multiple instances or multiple nodes or multiple virtual machines.
- Redis should be installed in all machines which will be part of cluster.
- Network configuration to have the communication between nodes.

Installation

Install the same version of Redis sever into the nodes. This can be done by installing using binary download from the Redis releases.

This can be done in various ways. Manual install, Docker install, or the helm install.

Configure nodes

By default, Redis configuration for single instance application. To make it Redis cluster we need to modify to enable Redis cluster.

Minimally we need to make these config changes on the custom redis.conf file.

```
port 6379
cluster-enabled yes
cluster-config-file redis.conf
cluster-node-timeout 5000
appendonly yes
```

Start the Instances

Stat the Redis instance with parameterised the conf file updated with Redis cluster configuration.

Use the redis.conf file to start the redis instance in each node of the cluster.

```
redis-server /path/to/redis.conf
```

Create Cluster

Once you have all the nodes up and running, (with Redis server) create cluster in master server.

Create helm install the repo

```
aannamalai@aannamalais-MacBook-Pro:~ $ helm repo list
NAME            URL
mybitnami       https://charts.bitnami.com/bitnami
datadog         https://helm.datadoghq.com
myairflow       https://airflow.apache.org
aannamalai@aannamalais-MacBook-Pro:~ $
```

Using the helm install the Redis-cluster.

```
(venv) aannamalai@aannamalais-MacBook-Pro:~/Desktop/workspace/sco.redis.cluster $ helm install redis-cluster mybitnami/redis-cluster -n redis
NAME: redis-cluster
LAST DEPLOYED: Mon Jun  3 12:01:38 2024
NAMESPACE: redis
STATUS: deployed
REVISION: 1
TEST SUITE: None
NOTES:
CHART NAME: redis-cluster
CHART VERSION: 10.8.2
APP VERSION: 7.2.4** Please be patient while the chart is being deployed **

To get your password run:
    export REDIS_PASSWORD=$(kubectl get secret --namespace "redis" redis-cluster -o jsonpath="{.data.redis-password}" | base64 -d)

You have deployed a Redis(R) Cluster accessible only from within you Kubernetes Cluster.INFO: The Job to create the cluster will be created.To connect to
your Redis(R) cluster:

1. Run a Redis(R) pod that you can use as a client:
kubectl run --namespace redis redis-cluster-client --rm --tty -i --restart='Never' \
 --env REDIS_PASSWORD=$REDIS_PASSWORD \
--image docker.io/bitnami/redis-cluster:7.2.4-debian-12-r12 -- bash

2. Connect using the Redis(R) CLI:

redis-cli -c -h redis-cluster -a $REDIS_PASSWORD


WARNING: There are "resources" sections in the chart not set. Using "resourcesPreset" is not recommended for production. For production installations, pleas
e set the following values according to your workload needs:
  - redis.resources
  - updateJob.resources
+info https://kubernetes.io/docs/concepts/configuration/manage-resources-containers/
```

Verify Cluster

Verify the cluster using the cluster commands.

redis-cli -c cluster nodes

```
(venv) nonnnenioi@sannoouleis-Noesodk-Pro:~/Oesktep/morksepsce/sre.redis.eluster $ ko oeec -it redis-cluetor-olient -n rodis -- /bin/bosh
Detaulted conteiner "rodis-clustor-client" out of: rodis-cluetor-cliont, datadog-lib-ruby-init (init), datedog-lib-docnot-init (init), dacadog-lib-python-in
it (init), datadog-lib-js-init (init), datedog-lib-java-init (init)
I bave no hanej@redis-plueter-client:/S pe -eeT
UID        PID  PPID  C STIME TTY          TIME CMD
1001         1     0  0 00:33 pts/0    00:00:00 baen
1001        13     0  0 00:34 pte/1    00:00:00 /bin/bssh
1001        16    13 99 00:34 pte/1    00:00:00 oe -ooT
I navo no nenelereais-clueter-client:/S redis-cli -c -h redis-cluster -a SREOIS_PASSNORD
Warning: Using a noosuord with '-a' or '-u' option on the command line interfaco noy not be aofe.
redis-cluster:63799 clueter nodes
733eao579ra0782c560822198377fe0oa6sed75o 10.42.0.100:6379@16379 slave 8009oo890357fa1f98a868001264a50124fe2001 0 1717396497152 2 connected
0009400903357ra1r98a00S0012640080124fc7001 10.42.0.100:6379@16379 myeelr,mastor - 0 1717396496000 2 connected 5461-10922
70121c9co8ed2880366r97c985eeba082a14a120 10.42.0.107:6379@16379 master - 0 1737596496144 1 connected B-5408
0915509a000ceaede0ccacao010460048eee0894 10.42.0.192:6379@16379 slave to121c9ca00d2008364f92c90996b4ob2e14o12c 0 1717396490135 1 connected
30288d177oa04332985a00027abc93832480322e 10.42.0.193:6379@16379 slave 0f0ac97a06bed6cdea6c02e9f2af0227989780039 0 1717396497006 3 connected
p764c97ebebedacdeo5s0239f2ar022798970039 10.42.0.109:6379@16379 mastor - 0 1717396498158 3 connected 10923-15393
```

Scaling the Redis Cluster

Here is the cluster with **6** replicas and each of the **3** masters to have one slave.

```
(venv) aannandinl@vannmmalais-MacDook-Pro:~/Boektep/onchnoooo/ero.rodis.cluster $ kubectl got oll -n zodio
NAME                        READY   STATUS    RESTARTS   AGE
pod/redis-cluster-5         1/1     Running   0          10m
pod/radis-clunter-4         1/1     Running   0          1em
pod/rodis-cluetes-0         1/1     Running   6          10m
pod/reais-6luetes-1         1/1     Running   0          10n
pod/redis-eluotes-2         1/1     Running   0          10m
pod/rodis-eluotor-3         1/1     Running   0          10m
pod/redis-eluster-client    1/3     Running   0          10n

NAME                              TYPE        CLUSTER-IP      EXTERNAL-IP   PORT(S)              AGE
soresee/radis-eiueter-paodiess    ClueterIP   None            <none>        6379/TCP,16379/TCP   10m
servtee/radis-oluster             ClueterIP   10.66.149.112   <none>        6379/TCP             10m

NAME                              READY   AGE
teeeTulset-sapp/redis-caasser     6/6     308
(venv) aannnmelol@vannmmlals-matonok-Pro:~/Boektep/onchncaoo/ero.rodie.cluster $
```

Adding the Nodes

Replicas can be scaled out based on requirement. Or HPA can be created to scale up or scale down.

```
I have no name!@redis-cluster-client:/$ redis-cli -c -h redis-cluster -a $REDIS_PASSWORD cluster meet 10.47.0.200 6379
Warning: Using a password with '-a' or '-u' option on the command line interface may not be safe.
OK
I have no name!@redis-cluster-client:/$ redis-cli -c -h redis-cluster -a $REDIS_PASSWORD cluster meet 10.42.0.201 6379
Warning: Using a password with '-a' or '-u' option on the command line interface may not be safe.
OK
I have no name!@redis-cluster-client:/$ redis-cli -c -h redis-clustor -a $REDIS_PASSWORD clustor meet 10.42.0.202 6379
Warning: Using a password with '-a' or '-u' option on the command line interface may not be safe.
OK
```

After adding additional nodes up and running. Introduce the additional nodes using the cluster meet commands.

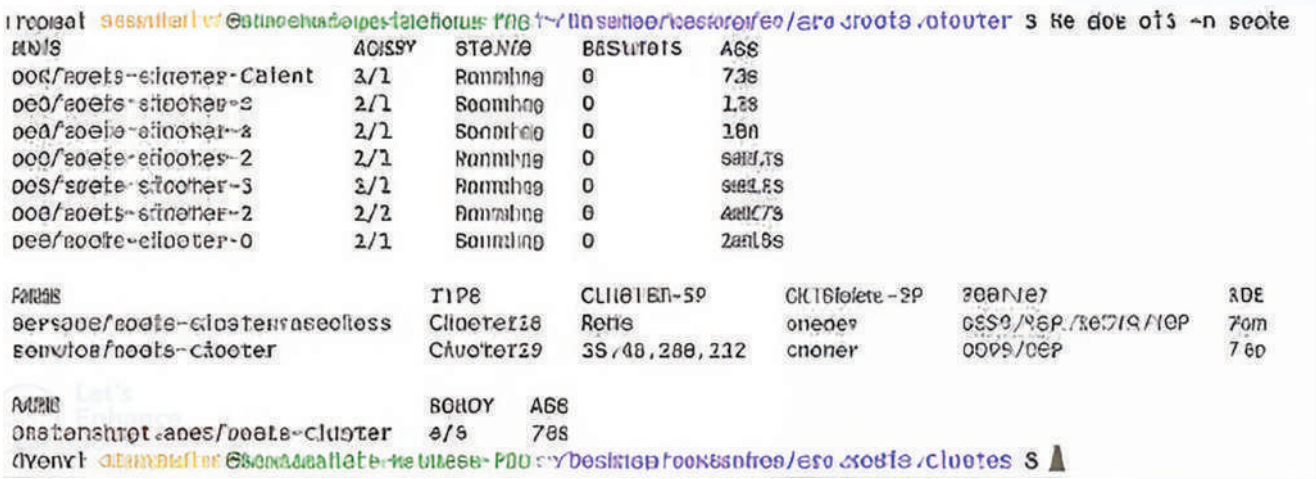
```
I have no name!@redis-cluster-client:/$ redis-cli -a $REDIS_PASSWORD -h redis-cluster cluster nodes
Warning: Using a password with '-a' or '-u' option on the command line interface may not be safe.
80d94a0090357fa1f98a0d5001264e60124fc2d01 10.42.0.188:6379@16379 myself,master - 0 1717399671000 2 connected 5461-10922
dc169bb87f1cabc3af2c7d1519ocd0f316af97eh 10.42.0.200:6379@16379 master - 0 1717399670109 0 connected
fb121c9ca8dd28a0564f92e9055eb4d02a14a12c 10.42.0.387:6379@16379 master - 0 1717399660000 1 connected 0-5460
7ec61ae772fe7ba07d5daeddf6d0f67o6000712c 10.42.0.201:6379@16379 master - 0 1717399670000 7 connected
301e0d1776a543a2986edo027abc916124ac322e 10.42.0.191:6379@16379 slave df66e97ab6oad6cdea5c02e9f2af02279b970b89 0 1717399672126 3 connected
736aed579feb782c540822f96377fabde43ed75c 10.42.0.203:6379@16379 slave 80d94a090855fe1f98a0d5001264e80124fc2001 0 1717399660894 2 connected
89155b9ao0boe6adobecacadb1664dad8cedo69c 10.42.0.192:6379@16379 elave,fail fb121c9ca06d28a0564f92e90566b4db2a16a12c 1717399609429 1717399602000 1 con
df64e97aeóbadócdea8c02a972af82279b970b39 10.42.0.189:6379@16379 master - 0 1717399669000 3 connected 10923-16383
84dc06762fe220a6be24ed1c05e6d1dc012e18c0 10.42.0.202:6379@16379 master - 0 1717399671000 8 connected
I have no name!@redis-cluster-client:/$
```

Removing the Nodes

To remove the nodes, reshard and reduce the stateful set replica count.

```
(venv) nanebrelat@1abimmlmis-MacBook-Pro:~/Booktab/oaghepana/ere_redis-cluster $ heim oogrede redis-cluster mgestnemi/rodis-cinecer --ser cloater.aodoons -n Todie --sor pesedocd=$REDIS_PASSWORD
Retehee "redis-cluster" hes boes eopeeded. Reaby heInsng!
NAME: eoets-sinecer
LAST DEPLOYED: Mon Jdh  3 13:07:13 2014
NAMESPACE: roels
STATUS: deployed
REVISION: 3
TEST SUITE: None
NOTES:
CHART NAME: redis-cauoter
CHART VERSION: 10-8.3
APP VERSION: 7.2.0** Pleane co puttent knile rhe chost is oesng deptoyes ss


To got your peeenere cun:
    enport REDIS_PASSWORD=$(kubectl get Boeret --nomnopboe "radis" rodis-cluster -o jsonpath="{.ooto.rodis-passaord}" | boooeA -d)

You heve deoloved a RedisaTeg: Cluster accersioto onSy tron within you Konarnpces Cluster.INFO: The Job to creets the clvster will bo craetod.To coaneer to your RedioSrop: siusror:

3. Non a Rediserogi pod that you con Ere se a ellent:
aelvots ren --Rohpesece soess redis-cllustet-cilent --rn --tty -> --restacts'Nevet' \
 --eov REDIS_PASSWORD=$REDIS_PASSWORD \
--Image docker.io/bitnami/redis-clusters7.3.4-debian-12-r12 -- oaen

2. Conneet veing the RedioBrap: CLI:

redis-cli -o -h redisoraloeter -o $REDIS_PASSWORD


WARNING: Thead ooe "resources" soorione in the onort bot oet. Using "resourcesPreset" io net reoomreodoe for prosuecion. Per predoetion inotelloliens, plebeo set the telloving seluse ooeoceding to re
eod neeos:
  - sod19.iosanrees
  - upeobetob.reoburnes
+Sore netpe://oadeonetes.io/docs/eoncepts/contigucatten/menage-resources-oentainers/
(venv) nanebrelat@1abimmlmis-MacBook-Pro:~/Booktab/oaesapdna/eee-redis-cluster/ $
```

After reducing the nodes, go back to original configurations



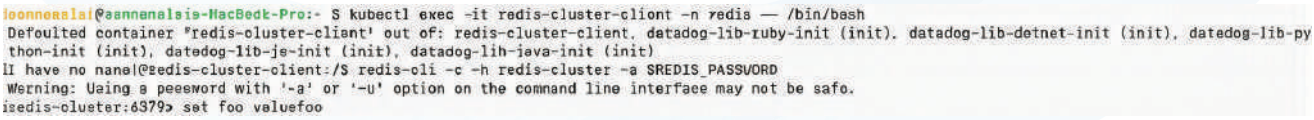
Access the Redis Cluster

Here is the command client implementation of accessing the Redis cluster through CLI interface.

Create the Cluster Client.

We can create redis-cluster client to access the cluster in cmd line. Even we can expose the deployment so it can be accessed through external Api clients.

**kubectl run --namespace redis redis-cluster-client --rm --tty -i --restart='Never' **
**--env REDIS_PASSWORD=$REDIS_PASSWORD **
--image docker.io/bitnami/redis-cluster:7.2.4-debian-12-r12 – bash



Set the keys

Based on the keys hash value, keys are redirected to relevant slots.

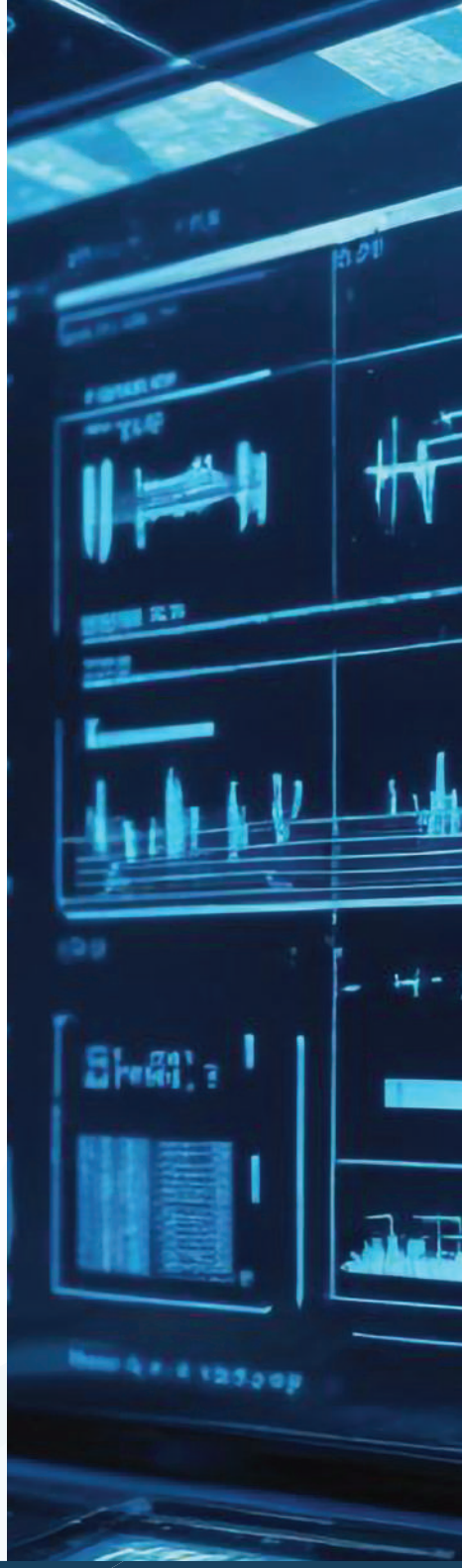
```
10.42.0.189:6379> set bar bar
-> Redirected to slot [6861] located at 10.42.0.187:6379
OK
10.42.0.187:6379> set car bmw
-> Redirected to slot [9461] located at 10.42.0.188:6379
OK
10.42.0.188:6379> set foo foo
-> Redirected to slot [12182] located at 10.42.0.189:6379
OK
10.42.0.189:6379>
```

Access the keys

Keys are retrieved from the relevant slots.

```
10.42.0.189:6379> get foo
"foo"
10.42.0.189:6379> get bar
-> Redirected to slot [5061] located at 10.42.0.187:6379
"bar"
10.42.0.187:6379> get car
-> Redirected to slot [9461] located at 10.42.0.188:6379
"bmw"
10.42.0.188:6379>
```

Keys are retrieved from the relevant slots.



Best **Practices**

Redis is a high-performance application with sub-millisecond response times. Due to its performance capabilities, careful consideration is required when configuring it for production. It's essential to implement consistent algorithms for data sharding, maintain real-time observability to monitor patterns, establish a proper backup strategy to ensure data integrity, and secure access to the application.

Data Sharding

- Design Redis keys to distribute data evenly across all shards.
- Use consistent hashing to minimize data movement when adding or removing nodes.
- Utilize hash tags (delimited by “{}”) in keys so that related keys are stored on the same shard.

Monitoring

Monitoring is critical for maintaining the health and performance of a Redis Cluster. With proper monitoring, issues can be detected early on.

- Use Redis Sentinel, a high-availability component, to automate monitoring and manage the failover process.
- Configure exporters and integrate Redis with external monitoring systems like Prometheus, Grafana, or Datadog to track key metrics such as CPU usage, memory consumption, cache hit/miss ratios, and latency.
- Implement alerting for critical events such as node failures, high memory usage, and increased latency to proactively address potential issues

Backup

Redis is an in-memory data store, where application data is stored in RAM. However, Redis provides file-based backup options.

- Leverage Redis snapshots to create point-in-time copies of the dataset. You canadjust the configuration to trigger backups based on time intervals or the number of writes.
- Utilize the Append Only File (AOF) to log every write operation, ensuring durability and offering a complete recovery mechanism.
- Define Recovery Time Objectives (RTO) and Recovery Point Objectives (RPO), and regularly test your backup and recovery processes.

Security

Protecting Redis instances from unauthorized access, data breaches, and security threats is crucial.

- Apply firewall restrictions at the port level and allow only trusted IP addresses and networks to connect to Redis.
- Implement role-based access control to define user roles and permissions, restricting sensitive commands based on user roles.
- Keep Redis software up to date with the latest security patches and updates, following Redis documentation and release notes.
- Enable authentication for Redis instances to safeguard against unauthorized access.

Limitations

- Redis clustering only supports db0, compared to the default Redis instance, which supports db0 to db15, providing 16 databases in total.
- Redis Cluster does not support Pub/Sub due to potential issues with hashing patterns. It's not recommended to use Pub/Sub commands on cluster instances.
- Multi-key operations are restricted in Redis Cluster.

Use Cases

E-commerce Application

One use case involves an e-commerce client with a large product catalog featuring multiple SKUs and product add-ons. E-commerce traffic is often driven by events, marketing campaigns, and product launches, leading to fluctuating demand. The client can scale the service by adding more nodes to handle increased traffic. If the web server uses load balancing, it funnels parallel requests to caching, databases, or external APIs.

Typically, web servers and databases respond within 1 to 100 milliseconds, while in-memory caching provides response times as fast as 1 to 100 nanoseconds. During high-traffic conditions, when multiple users access various products simultaneously, requests are queued, and caching helps reduce the load on databases. With a caching system backed by clustering, data reads are distributed across multiple nodes, utilizing different CPU cores and data storage, instead of relying on a single instance.

After implementing Redis Cluster, the client's system was upgraded to handle more traffic during peak demand, redefining application scalability.

Key Takeaways

Redis Cluster provides high availability and horizontal scalability to accommodate growing data and traffic. By implementing Redis Cluster for caching, frequently accessed data is stored in-memory and distributed, reducing database load and improving response times. Additionally, Redis manages replication and high availability, making it an ideal solution for modern IT applications.

Conclusion

Redis Cluster offers a robust solution for scalable and resilient caching. By distributing data across multiple nodes, it enhances performance and ensures high availability. For optimal results, it is essential to follow best practices and implement strong security measures. Enabling Redis Cluster can significantly boost application performance and reliability.

References

- Redis Documentation: redis.io/documentation
- Redis Cluster Tutorial: redis.io/topics/cluster-tutorial
- Redis GitHub Repository: github.com/redis/redis

This whitepaper will help as guide for Analysing and implementation of the Redis cluster for scalable caching solutions, providing detailed steps and best practices to ensure a successful deployment.

About Altimetrik

Altimetrik is a pure play digital business company focused on delivering business outcomes with an agile, product-oriented approach. Our digital business methodology provides a blueprint to develop, scale, and launch new products to market faster. Our team of 5,000+ employees with software, data, cloud engineering skills help create a culture of innovation and agility that optimizes team performance, modernizes technology, and builds new business models. As a strategic partner and catalyst, Altimetrik quickly delivers results without disruption to the business.

Our unique Digital Business Methodology centers on business led ownership aligned to company goals. It is comprised of three pillars: experienced team of practitioners, an incremental approach, and an end-to-end self-service digital business platform. These combine to facilitate collaboration and agility between business and engineering teams to co-create products and solutions faster without disruption to the business. This is powered by a single source of truth and a culture of innovation that brings unlimited growth within reach.

We cater to companies of all sizes from Fortune 100 to digital disruptors and start-ups. We are a people-centric organization and talent is one of the central pillars of our business model and success. Employee engagement, diversity & inclusion, well-being and empowerment are central themes to our ethos. This project has been instrumental in taking our digital culture to the next level and brings our globally spread employee base on a unified platform.