http://arnaud-nauwynck.github.io

Big Data

Principles of Distributed Computing
Failures and Resiliency

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MTBF

M.T.B.F = Mean Team Between Failure

For HDD ~ 500 000 hours

≥ 50 years

May looks good at home, to save your data

(Mean = average.. may be smaller/longer)

MTBF « at Scale »

In DataCenter with 10 000 servers x 4 disks

=> 1 failure every 1h 15mn

= 19 failures per day

becomes a recurrent task / job

When Failure(s) Happens ?

=> Program fails ?

=> System fails ?

=> need relaunch manually ?

=> diagnostic hardware/software ?

=> interrupt all, repair ?

Studying « When Failure » 1/5

=> Program fails ?

=> System fails ?

=> need relaunch manually ?

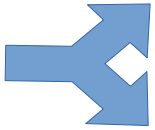
=> diagnostic hardware/software ?

=> interrupt all, repair ?

When Failure..

=> Program fails ?

Individual Component : Obviously FAIL



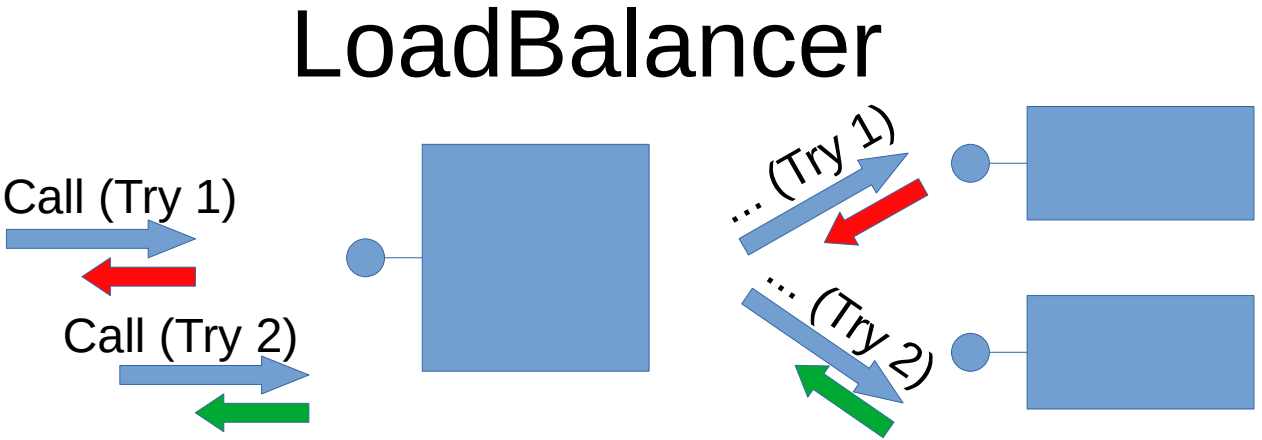
Distributed Architecture : RESILIENT

resist (hopefully) to (some) failure

Failure is not « Exceptional »
.. is a « normal » path
consider it everywhere in code

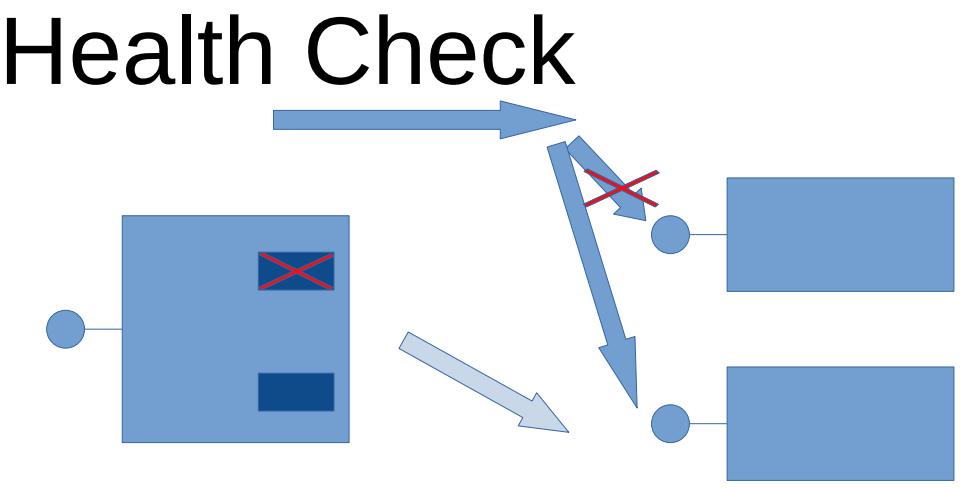
```java
public void doSomething() throws Exception {
    int maxRetry = 5;
    for(int retry = 0; retry < maxRetry; retry++) {
        try {
            anyTreatmentCanFail();
            break; // success!
        } catch(Exception ex) {
            log.warn("Failed .. retry " + retry + "/" + maxRetry, ex);
            sleep(100 * Math.pow(2, maxRetry)); // wait a little
        }
    }
}
```

Retrying with a LoadBalancer .. might just work

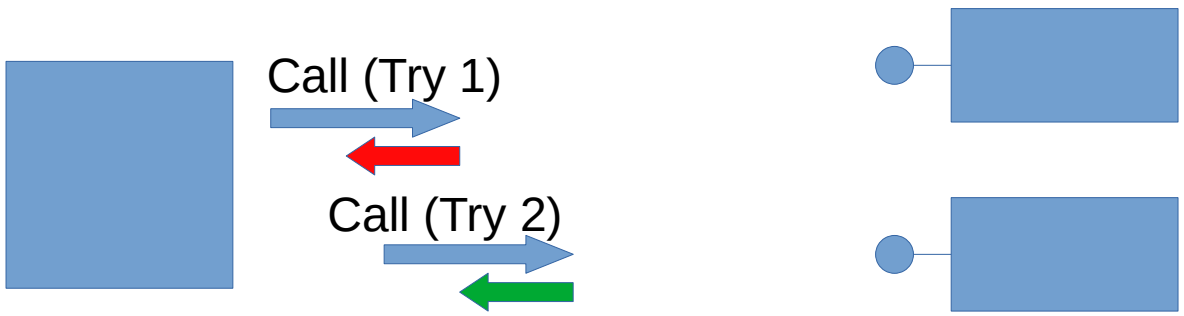


Dispatch to underlying servers
Using Round-Robin

Server Health Check
Temporary evict
from RoundRobin Pool



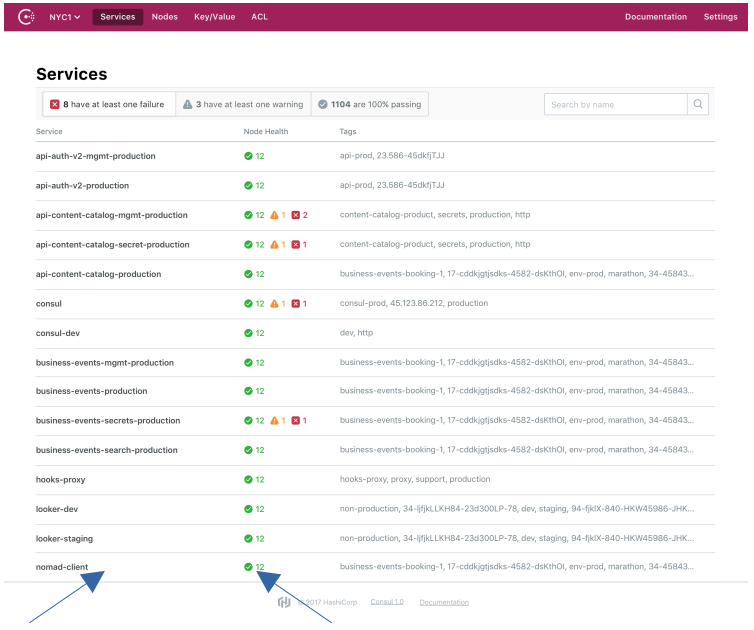
Client-Side « LB »



NO « LB »
Need discovery mecanism on client

Service >= Nodes
Examples of Service Discovery

DNS, ServiceMesh,
Zookeeper, Consul.io,
HAProxy, Kubernetes, ..



Consul.io Services

Nodes

Studying « When Failure » 2/5

=> Program fails ?

=> System fails ?

=> need relaunch manually ?

=> diagnostic hardware/software ?

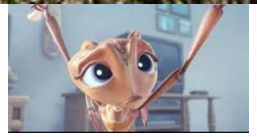
=> interrupt all, repair ?

System = Union of independent components

Each component can be killed
… The system must survive each failure

Be Confident in « System »

Walk on a « Ant » ...



… « Anthill » not in danger

How to Check System does not « Fail » ?

Very difficult to « prove » system correctness

Easy to test : « kill and see »
Not an exhaustive test… Repeat + Changes

Test Kill with Chaos Engineering

Initiated by Netflix

Goal : Randomly kill Process / VM / Datacenter

SLA : 99.99 Up-time ?

= Daily: 8s
Weekly: 1m 0s
Monthly: 4m 22s
Quarterly: 13m 8s
Yearly: 52m 35s

3 nines : 99.999 = Yearly : 5mn15s

4 nines : 99.9999 = Yearly : 31s

Studying « When Failure » 3/5

=> Program fails ?

=> System fails ?

=> need relaunch manually ?

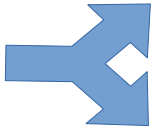
=> diagnostic hardware/software ?

=> interrupt all, repair ?

When Failure ...

=> need relaunch manually ?

Hard-Coded Launch to specific server.. fail



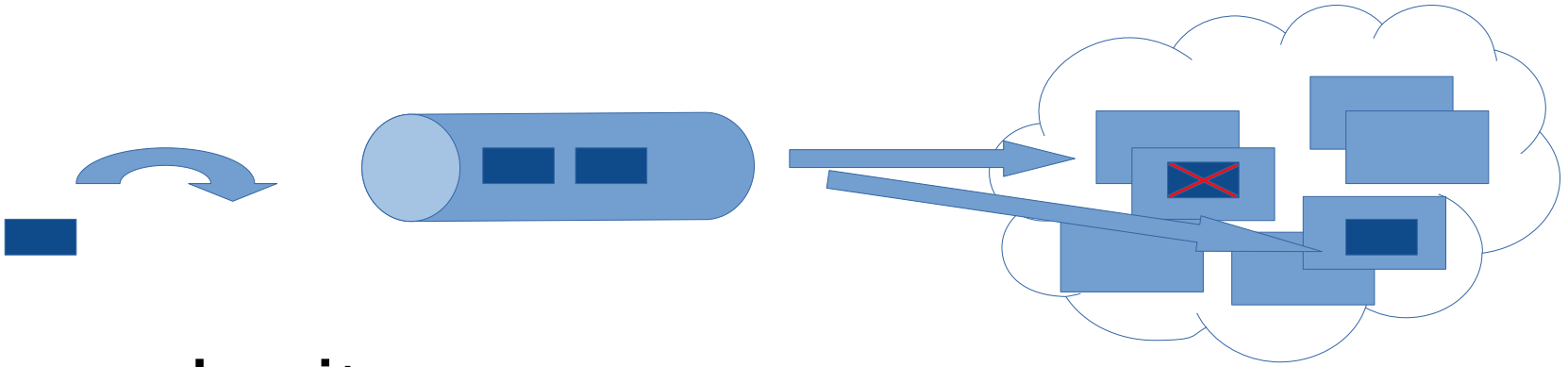
Auto Distributed: RESILIENT
don’t launch manually on a specific server
Let the system select one

Pet vs Cattle

Pet have id=name
You take extra care of it

Cattle >= 1000 : anonymous
Id=Number, interchangeable

Launching => Scheduling on Allocated Resource



You submit
Something to run

You don’t run yourself

Maybe wait for resource
Allocate resource
Try launch
retry

Studying « When Failure » 4/5

=> Program fails ?

=> System fails ?

=> need relaunch manually ?

=> diagnostic hardware/software ?

=> interrupt all, repair ?

When Failure ...

=> diagnostic hardware/software ?

NO ? … difficult anyway
Bugs may exist
BUT failure is « not » a bug

Studying « When Failure » 5/5

=> Program fails ?

=> System fails ?

=> need relaunch manually ?

=> diagnostic hardware/software ?

=> interrupt all, repair ?

When Failure ...

=> interrupt all, repair ?

NO …
Immutable-Infrastructure
Do not edit infra once created
Drop and re-create new VMs

When Failure ...

Hardware HOT-PLUG :
unplug old disk, and plug new one
Without interruption

When Failure ...

Idem for Software :
add/remove servers to cluster
(no hard-coded topology/confs)

Duplicate Failable Component for Fewer System Failure

If a component has 0.01 chance to Fail today

Adding another (independent) component…
=> Probability that 2 fail today = 0.01*0.01 = 0.0001

=> Probability that 3 fail today = 0.01^3 = 0.000001 = 1e-6

« If » your system still works with 1 working components out of 2 … better

System ≥ Component
If No Correlated / Dispatch / No Spof

Electric power : when fail … all fails (correlated failures)

Need reliable network + dispatching to working components (retry/detect failed ones)

Everything between the components can be a « SPOF »
Network may be a « Single Point Of Failure »
as all forgotten components not redundant

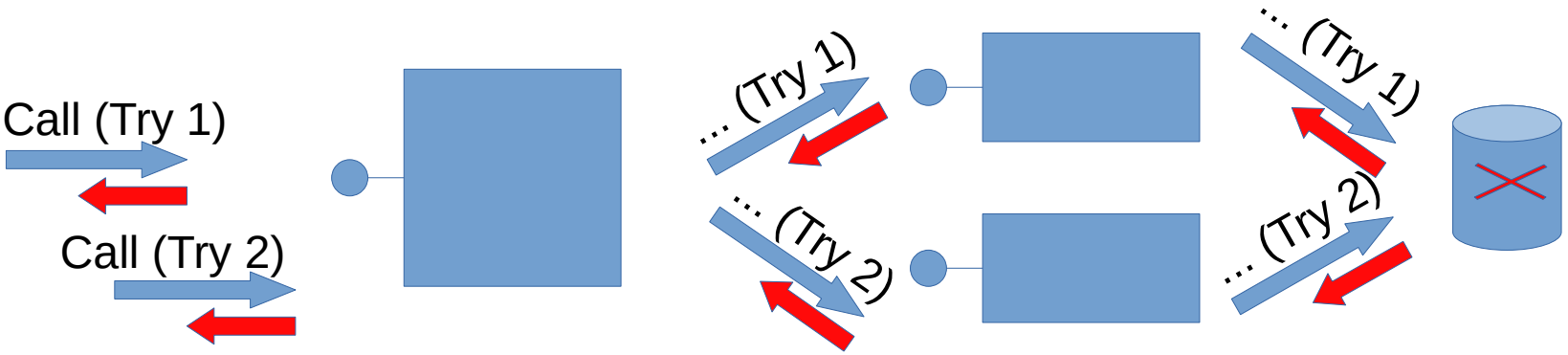
Story of Arianne 501
Duplicated / « Correlated » Errors...

Flight computation performed twice in parallel on 2 isolated hardwares

But using same program…
Both programs throw same «overflow exception » at exact same millis

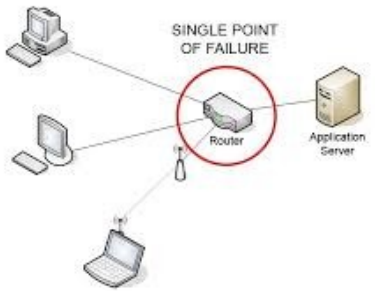
=> Lessons learned : use 2 hardwares + 2 independent softwares + ..

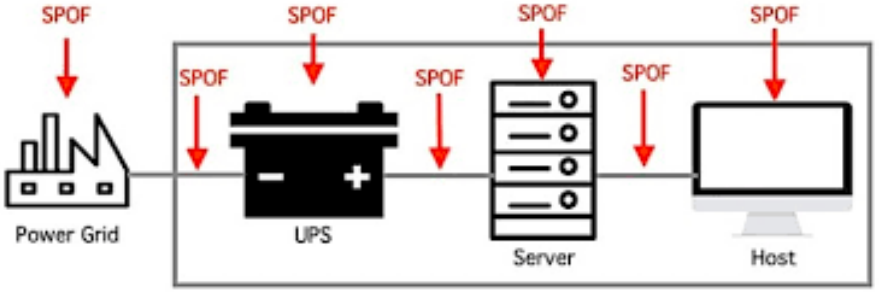
Single Point Of Failure ?

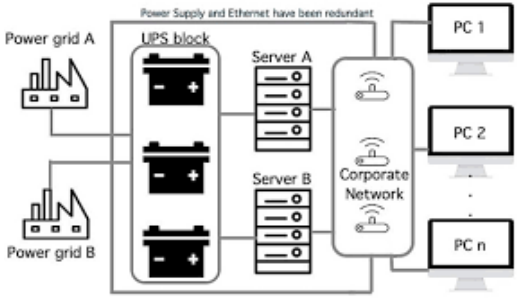


High Availability Servers…
But Shared State / Database .. SPOF

Examples of SPOF





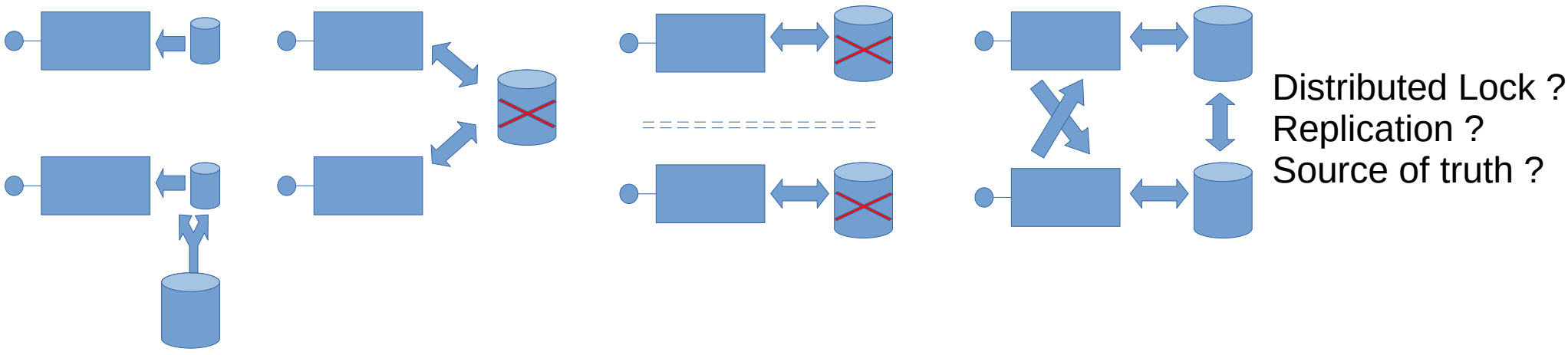


NO SPOF : Duplicate Everything

But how to duplicate a single Source of Truth « Data » ?

Copy => stale data / replication / distributed lock ?

Stateless, Spof, Sharded (easy) vs Statefull (difficult)



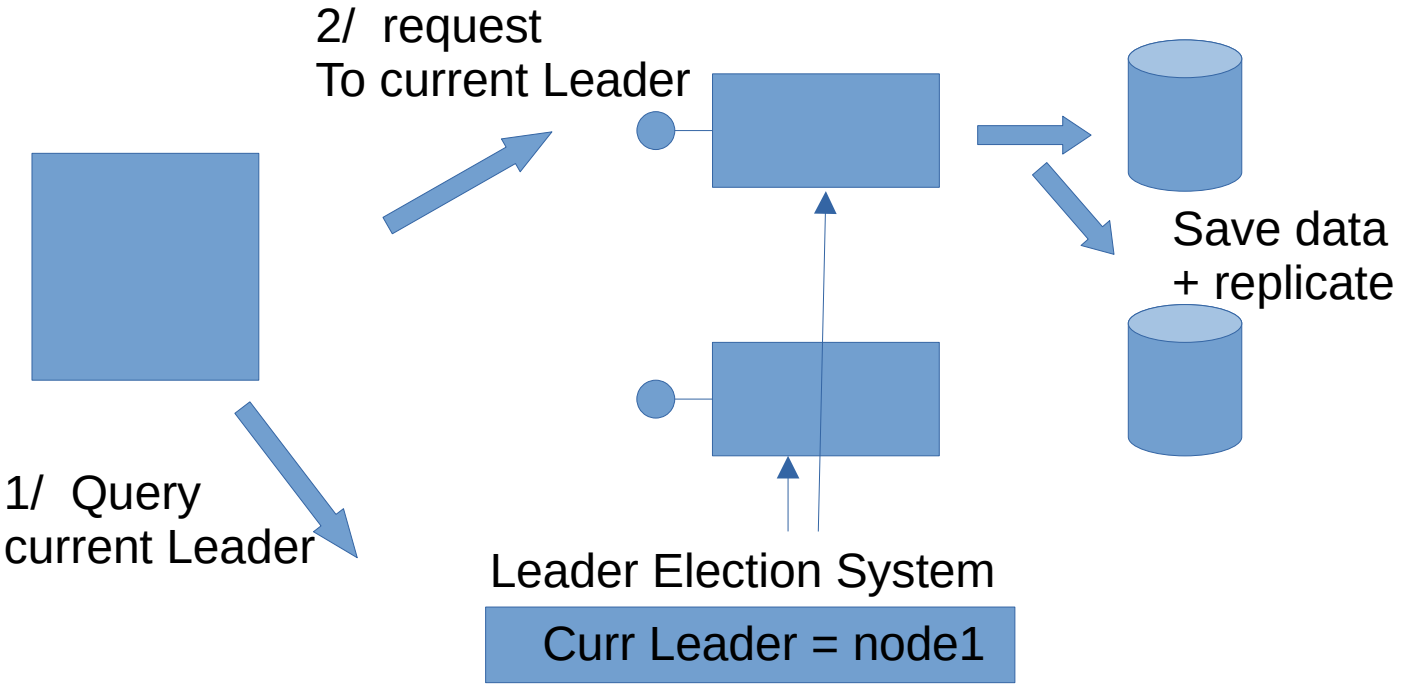
Stateless
(or stale Read-Only
cached data)

Spof

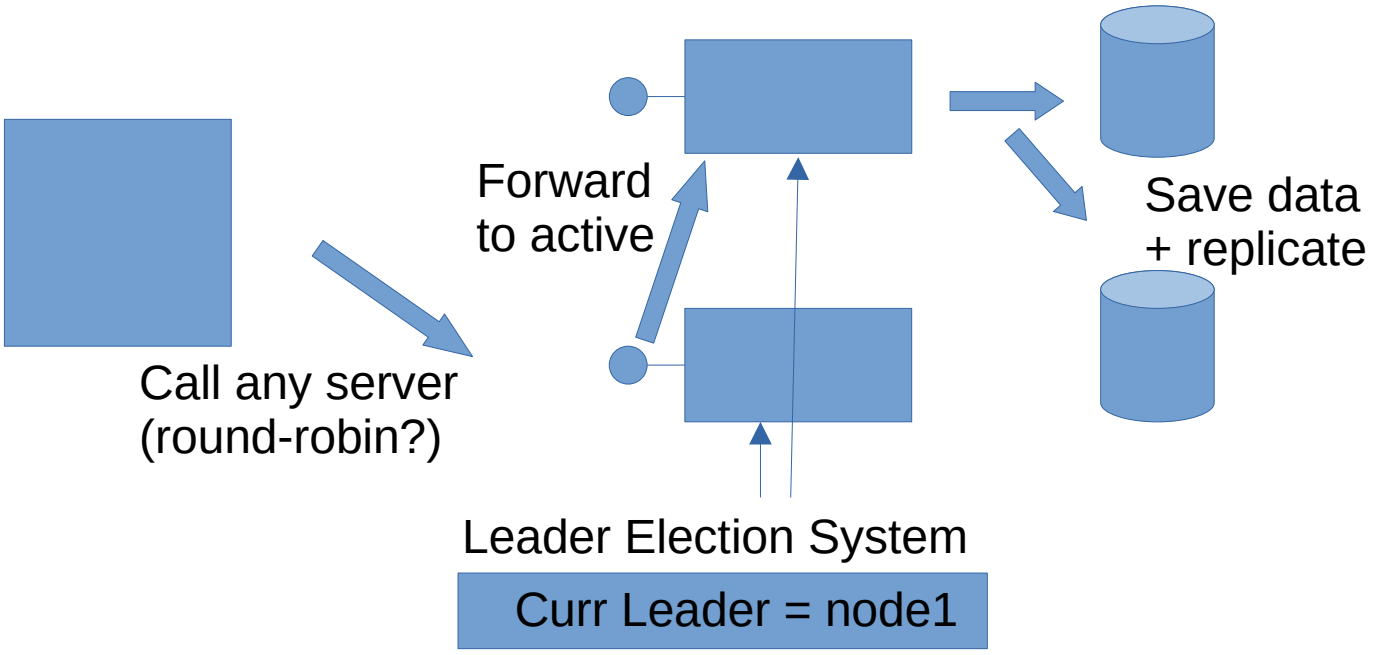
Sharded… 2 spofs
(ex : id modulo 2)
Horizontal scale : OK
But not replicated

Statefull
Concurrent Distributed Data

« HA » High Availability
Active – Standby + Replication



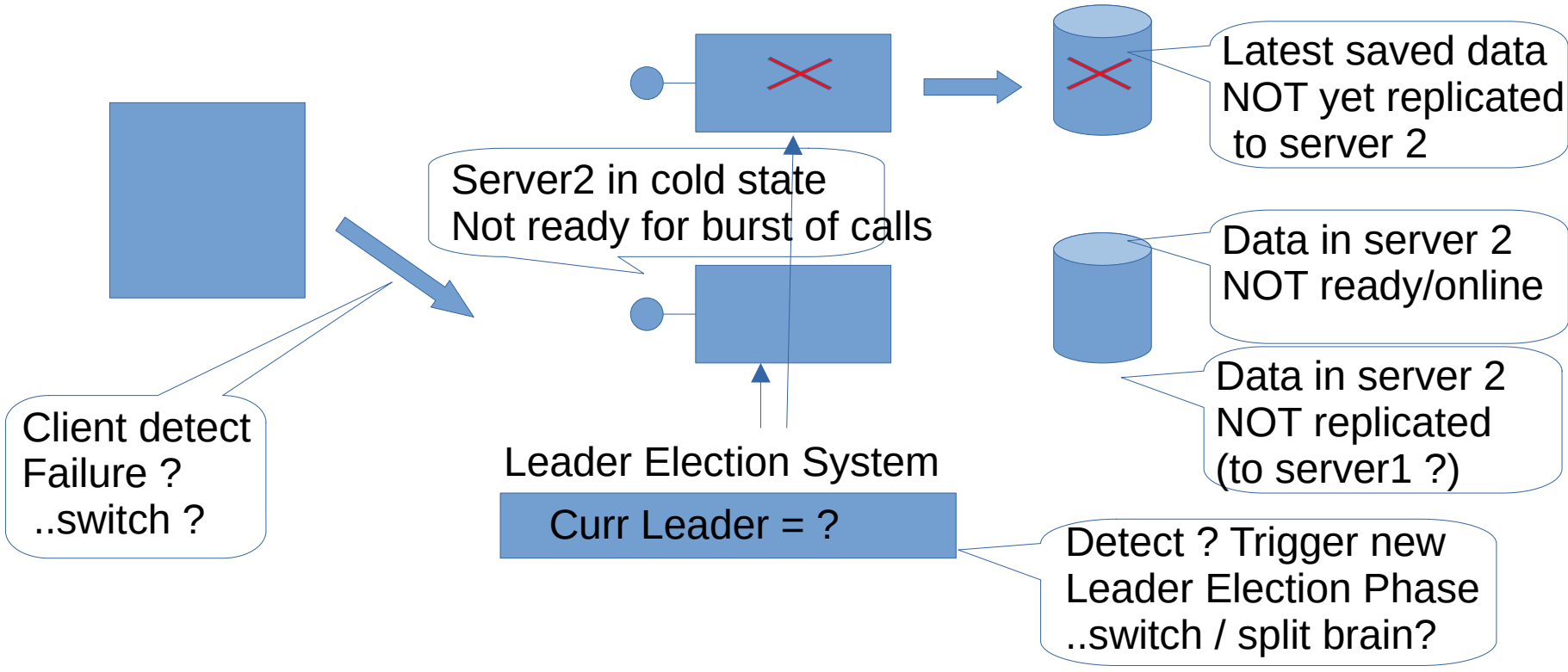
Transparent Delegate to Active



Synonym Terms...

Master – Slaves (not polically correct)
Leader – Followers
Active – StandBys
Primary – Secondaries
Main – Replica
MainSite - Disaster Recovery
MainDisk - BackupDisk

Switching from Active to StandBy



Problem with Leaders same as in Political

works only when there is exactly 1 leader

≥ 2 leaders … conflicts / Split-Brains / Network Partitioning

0 Leader … nothing works

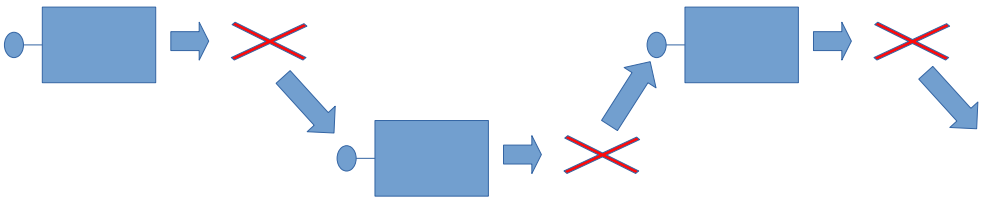
Imposters pretend to be Leader
Leader staying leader too long after new election

Slow to organize election
Trust the result of election ?
Who can organize if there is no leader?

Can’t decide election in 50 % / 50 % equality … need an odd number : 3, 5, 7..
There must be at least 50 % participation (no Abstention)
Otherwise both candidates pretend to majority (not absolute majority) with 50 %

Leader fail to « Start Lead » … re-electing too Often ?

Example of Catastrophic scenario :



1/ Server « N » become Leader

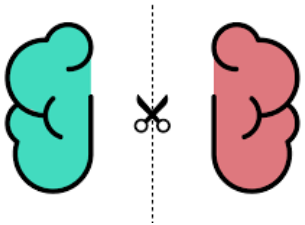
2/ It needs huge memory to serve requests
There are too many requests (burst of waiting requests)

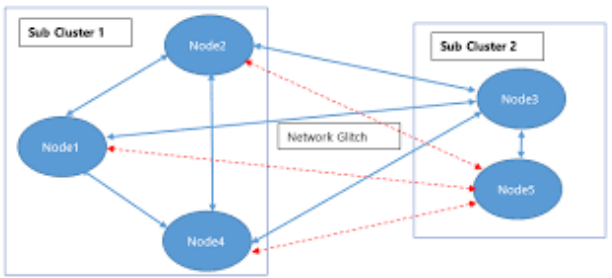
3/ « Full GC » occurs, take >=30s , and « stop-the-world »
30s is the default Timeout for socket connection / read response

… During this time, Leader fails to answer to « Health check »
4/ Leader is considered not healthy => not leader any more

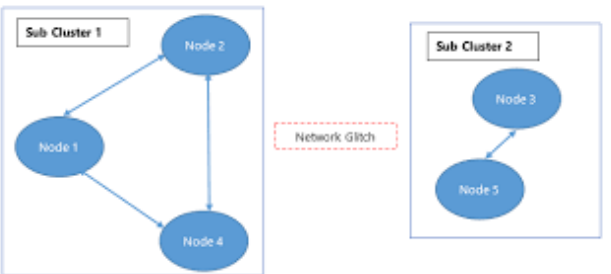
=> 5/ Electing another Leader « N+1 » => back to beginning 1/

Split Brain / Network Partitionning





1 cluster, 1 master
status=OK
… but network partition happens



2 clusters fully isolated each
Each have 1 master
Each have status=OK
… data diverge, will discover conflict on merge

Quorum of 50 %

Quorum of >50 % reachs => elect candidate1

NO Quorum of 50 % reachs
=> re-organize new election
(proba=0.5 that 2 of 3 vote for same)

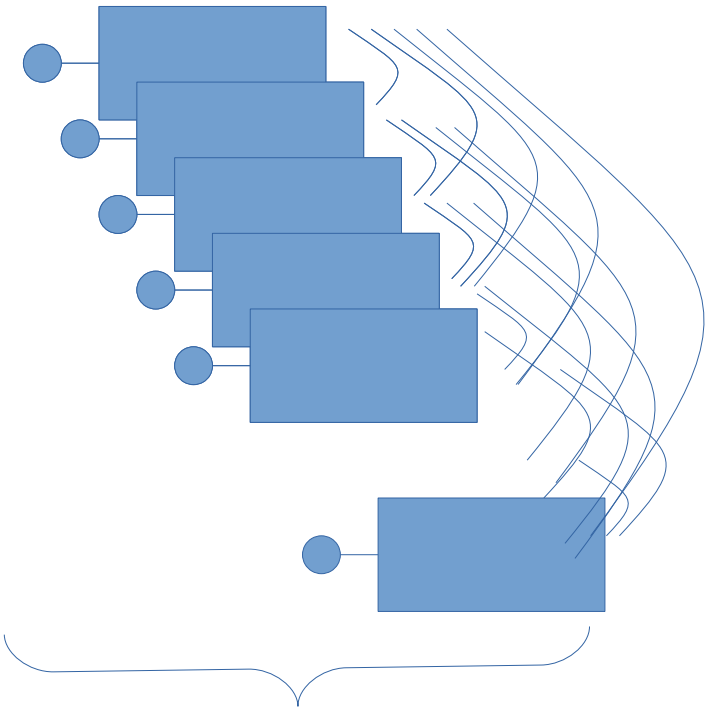
Majority but NO Quorum
… high risk of Split-Brain
(all others may vote and you are not aware)
=> wait enough voters (re-organize / accept vote)

Waiting Quorum
= system « Not Available »

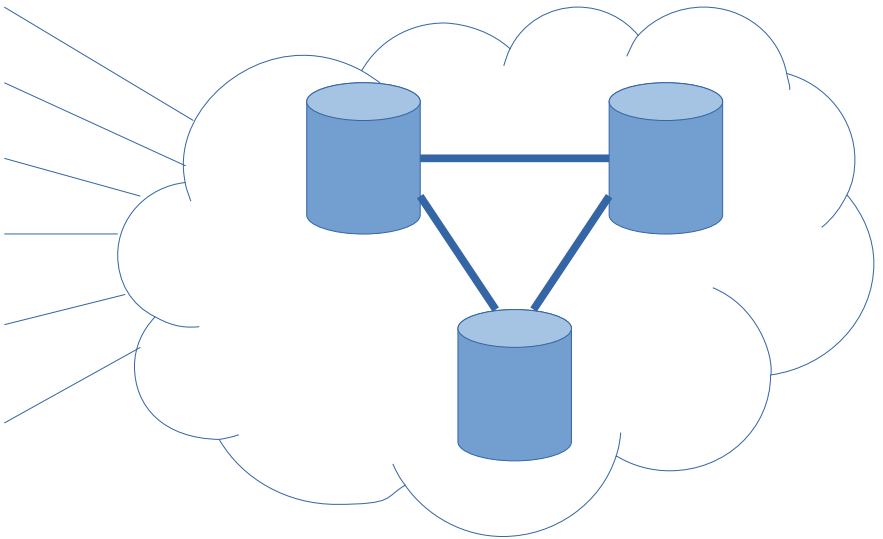
Waiting Quorum

<= 50 %
… means cluster 0 % working

Distributed Coordination Server(s)



Difficult to synchronize data on N servers
N servers => 1/2 * N * (N-1) connections .. too many
Slow to organize election

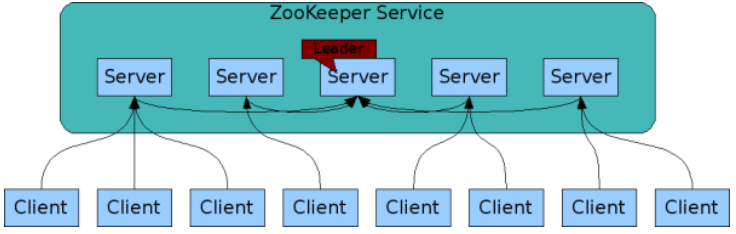


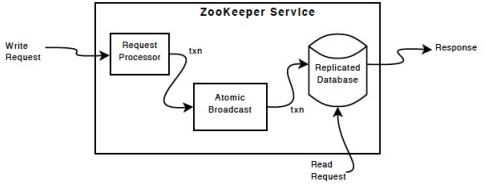
Small subsystem (3,5,7 nodes)
for quorum / election
Storing coordination data
N servers => N+3 connections

ZooKeeper

Because Coordinating Distributed Systems is a Zoo

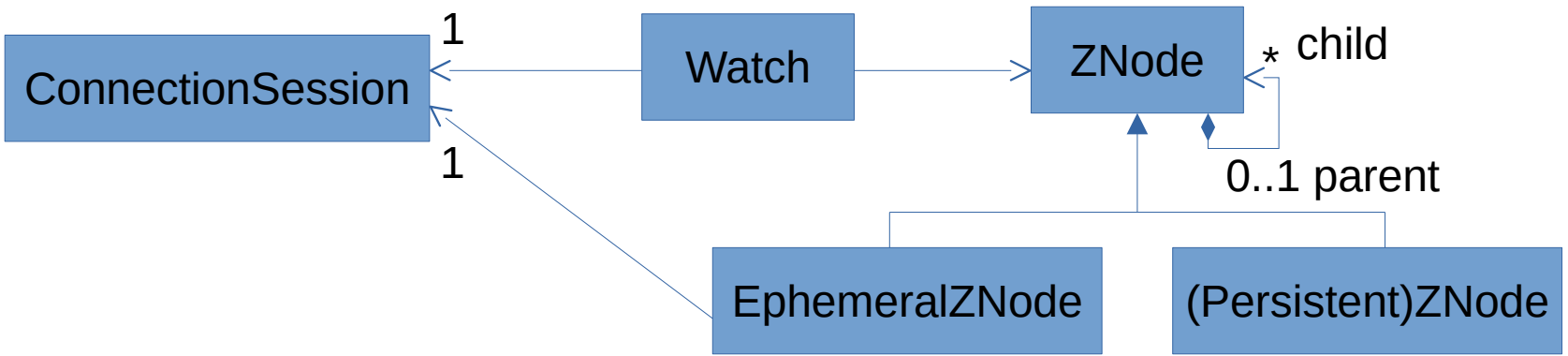
Zookeeper is **CP** (Consistent and Partition Tolerant)
Not **A** (Available)





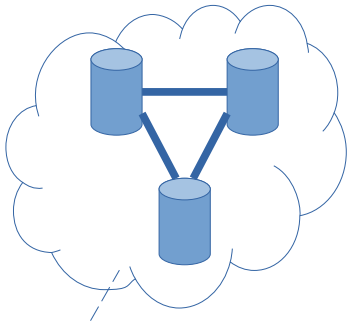
All writes are serialized to Leader
(exclusive lock)
+ replicated to quorum for committing

ZooKeeper Features



Zookeeper kernel : « key=value » database, with atomic features
Organized as directories hierarchy, called Znode
With Listening capabilities
And Ephemeral Znode for connections

ZooKeeper



Znode « / »

Znode « /data »

« /prop » = value

Znode « /servers »

EphemeralZNode « /node1 »

EphemeralZNode « /node2»

EphemeralZNode « /node3»

Get key..
Set key=value
List key/*
Listen Key

Example for service discovery :
Listen « */servers*/* »

ZooKeeper : for Master Election
+ Persist Topology/Metadata Infos

1 Master for All => does not scale

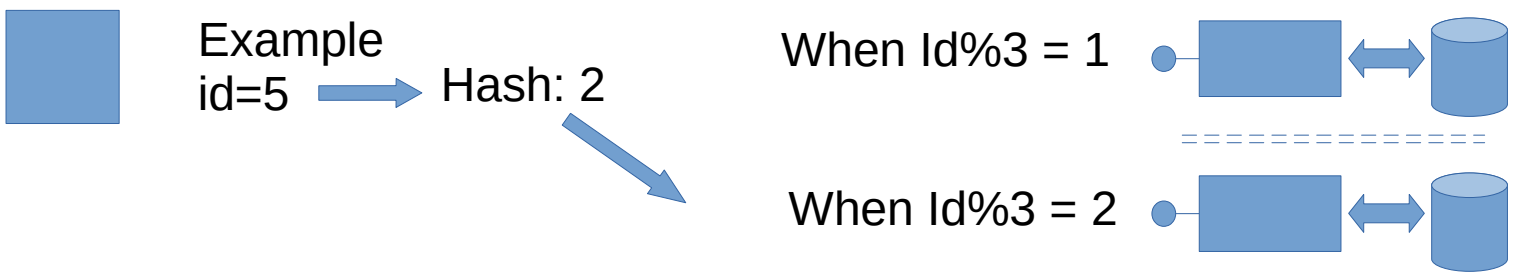
Master treat
all requests

Followers in StandBy Mode
(waste of cpu)

Sharding for Horyzontal Scaling

Sharding = choose responsible server from data Id
(shared rule for clients and servers)

ServerId = Id modulo 3



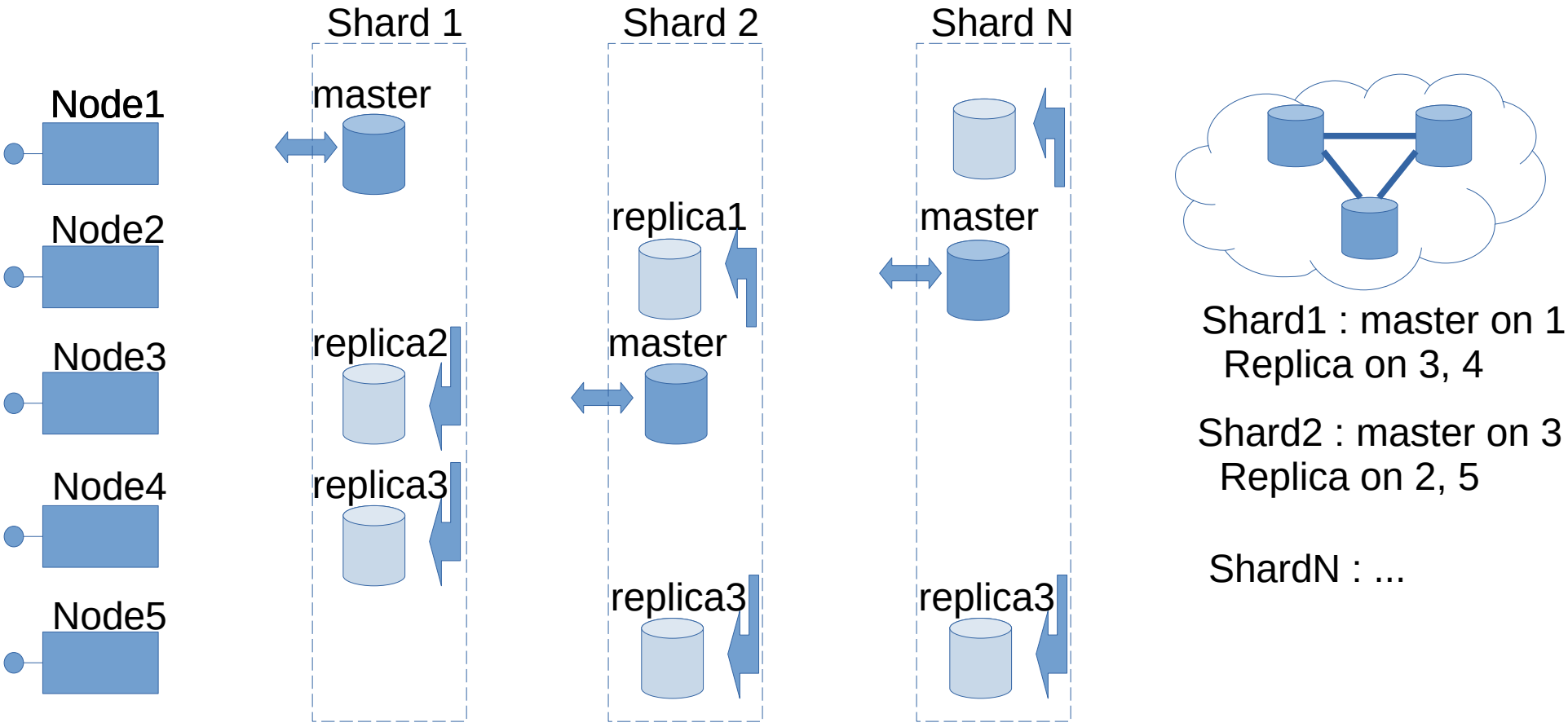
Sharding .. Pros/Cons

Scale very well « linearly » with number of servers

ONLY for request with known « ID »
(not for search / full scan)

Difficult to redimension « N » at runtime… need re-shuffle all data !

1 Master per Shard



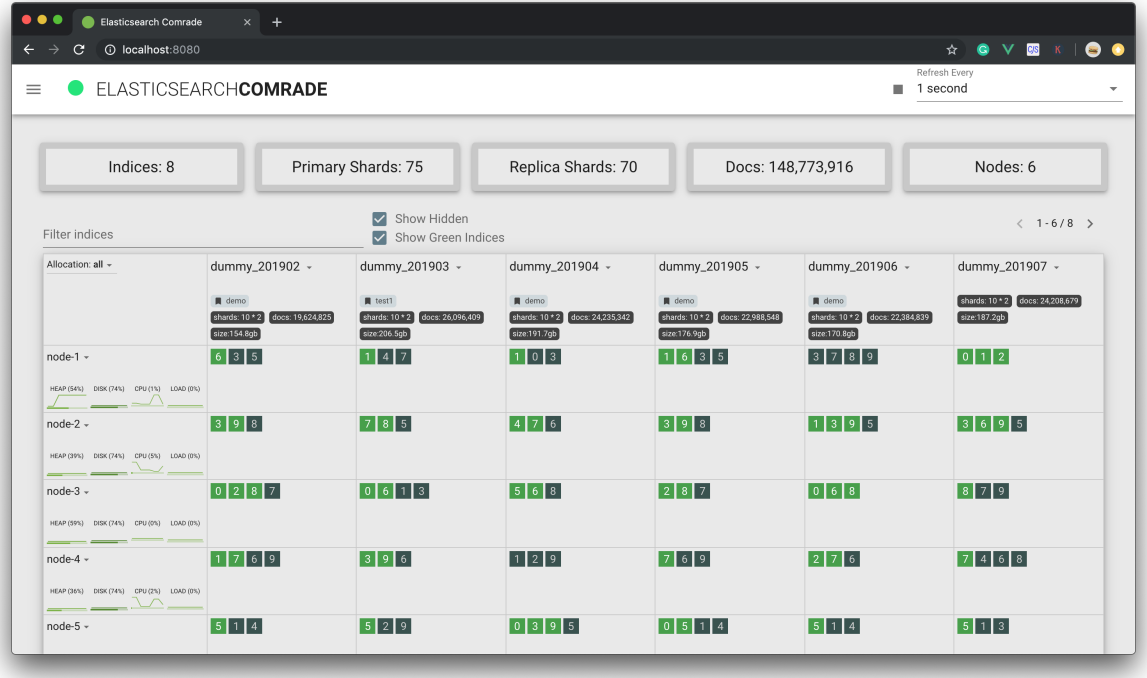
Shard1 : master on 1
Replica on 3, 4

Shard2 : master on 3
Replica on 2, 5

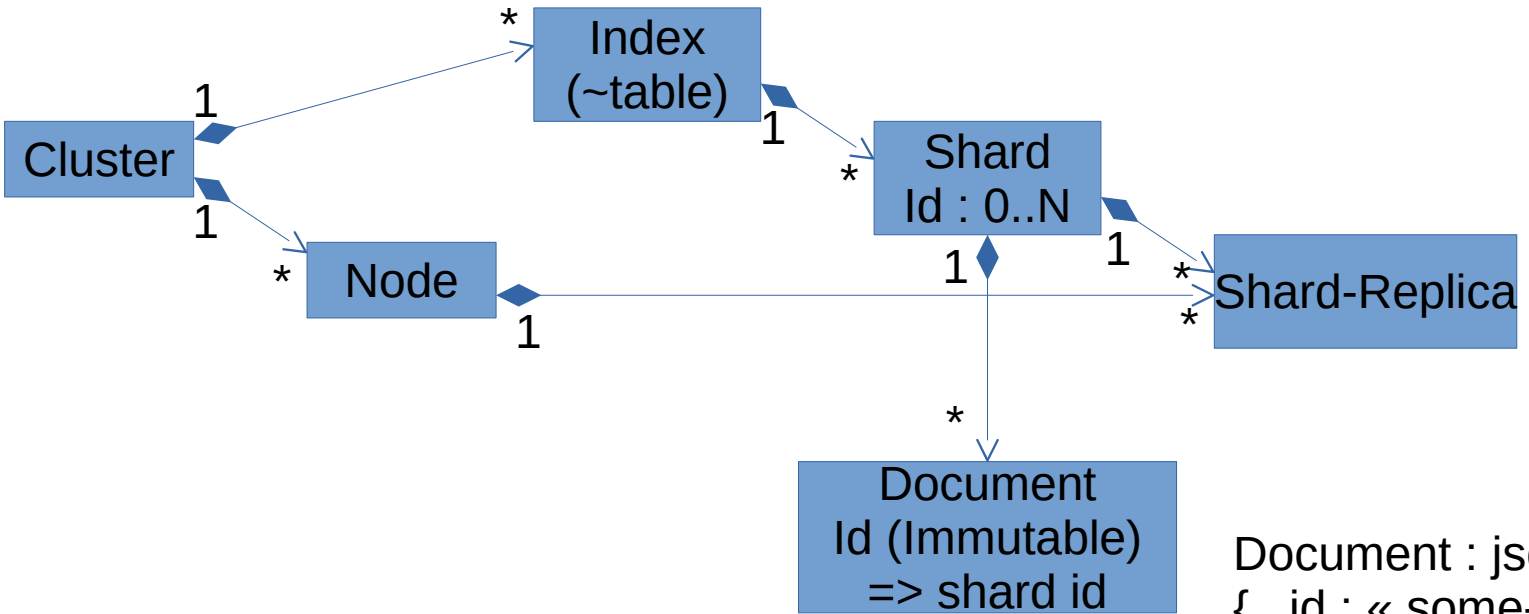
ShardN : ...

3 Examples & Comparisons for Sharding + Master/Replica

Example 1/3 : ElasticSearch

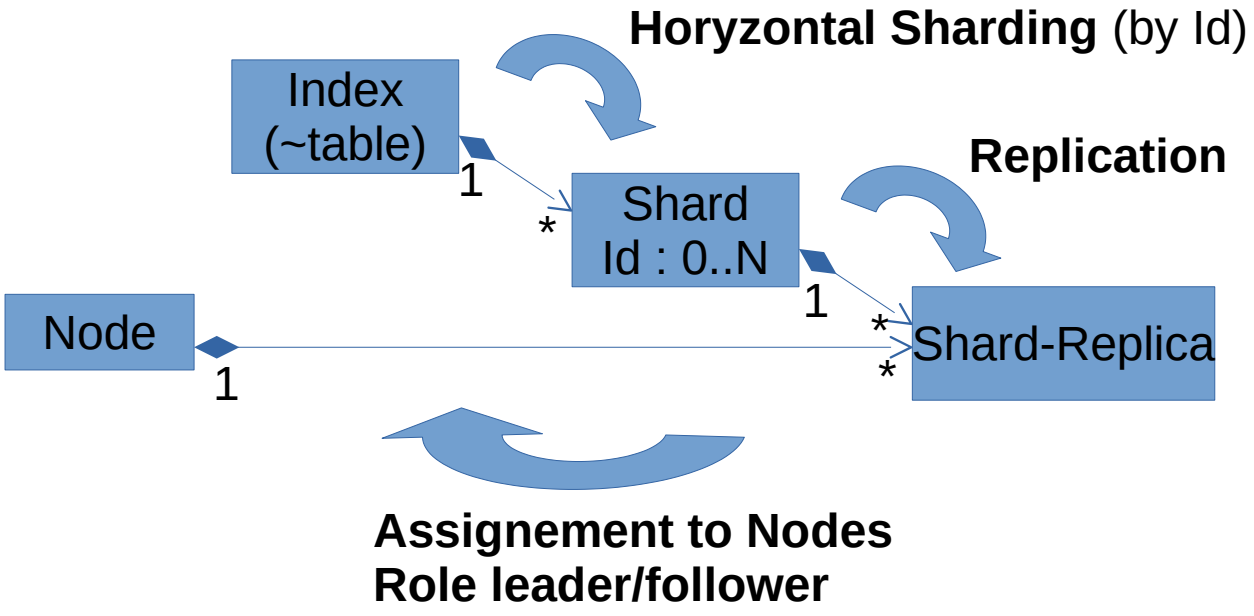


ElasticSearch … UML model

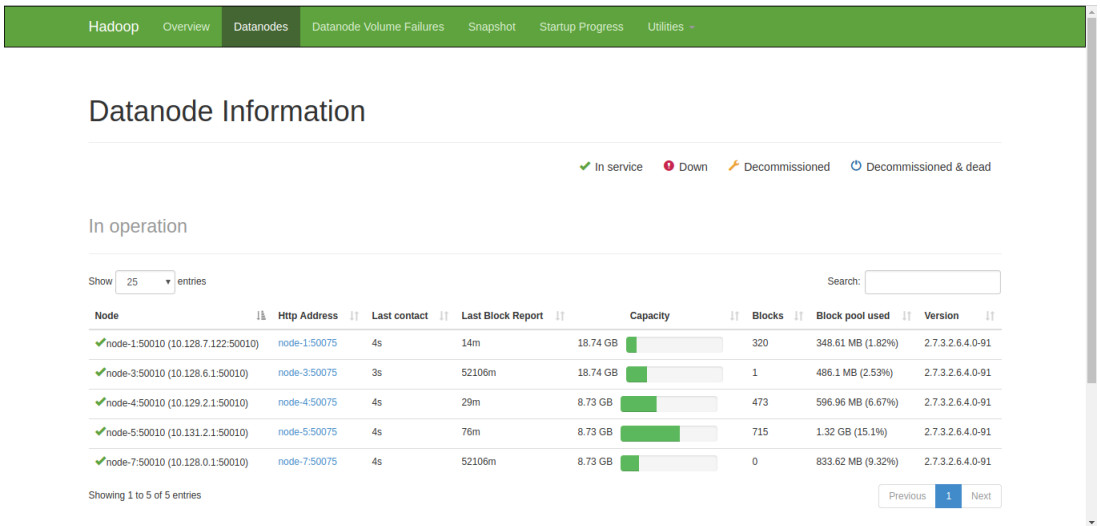


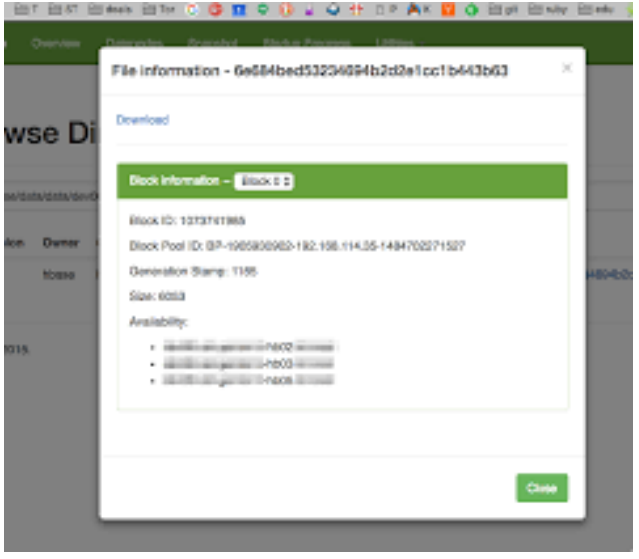
Document : json text
{ _id : « some-id1 »,
  field1 : 123,
  field2 : { subField : [« a »] }
}

ElasticSearch …
Zooming Relations

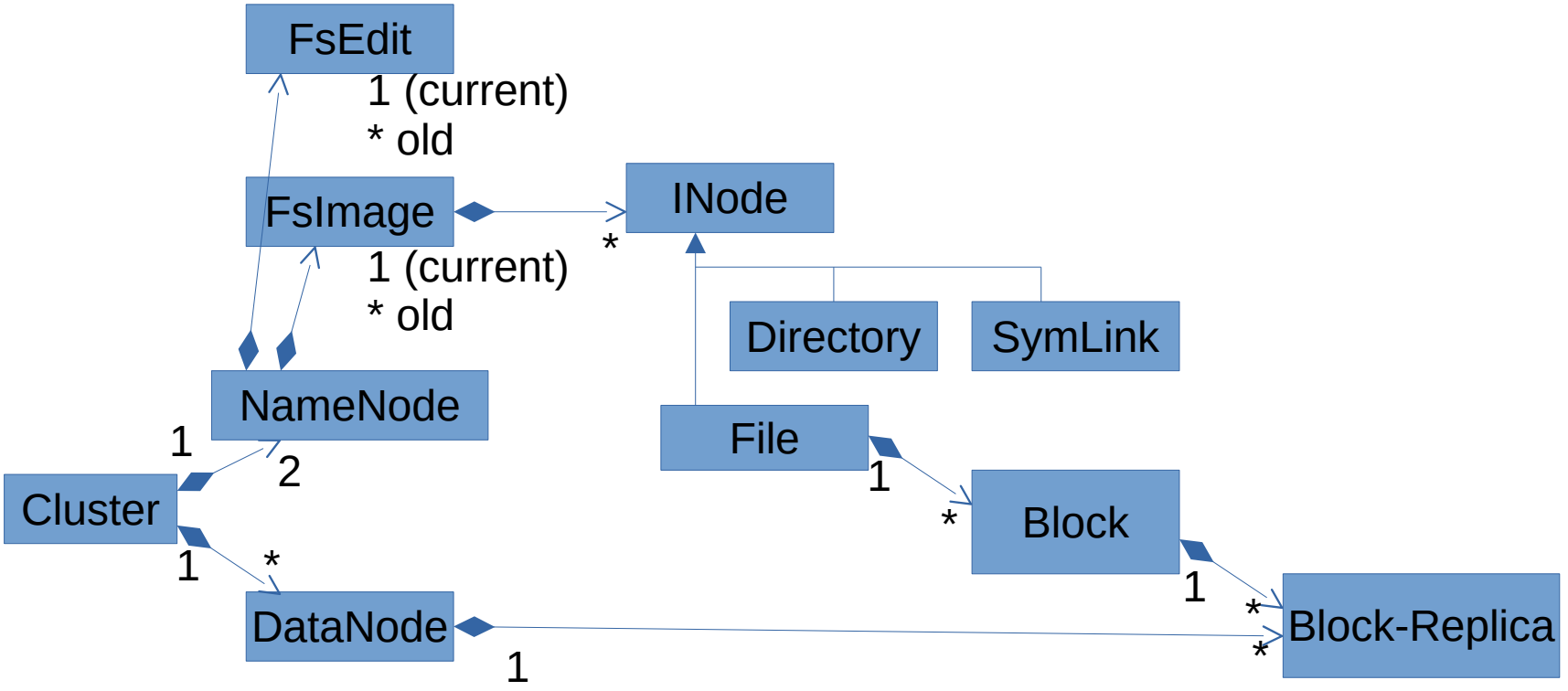


HDFS


Hadoop
Overview
Datanodes
Datanode Volume Failures
Snapshot
Startup Progress
Utilities
Datanode Information
In service
Down
Decommissioned
Decommissioned & dead
In operation
Show 25 entries
Search:
Node
Http Address
Last contact
Last Block Report
Capacity
Blocks
Block pool used
Version
node-1:50010 (10.128.7.122:50010) node-1:50075 4s 14m 18.74 GB 320 348.61 MB (1.82%) 2.7.3.2.6.4.0-91
node-3:50010 (10.128.6.1:50010) node-3:50075 3s 52106m 18.74 GB 1 486.1 MB (2.53%) 2.7.3.2.6.4.0-91
node-4:50010 (10.129.2.1:50010) node-4:50075 4s 29m 8.73 GB 473 596.96 MB (6.67%) 2.7.3.2.6.4.0-91
node-5:50010 (10.131.2.1:50010) node-5:50075 4s 76m 8.73 GB 715 1.32 GB (15.1%) 2.7.3.2.6.4.0-91
node-7:50010 (10.128.0.1:50010) node-7:50075 4s 52106m 8.73 GB 0 833.62 MB (9.32%) 2.7.3.2.6.4.0-91
Showing 1 to 5 of 5 entries
Previous
1
Next

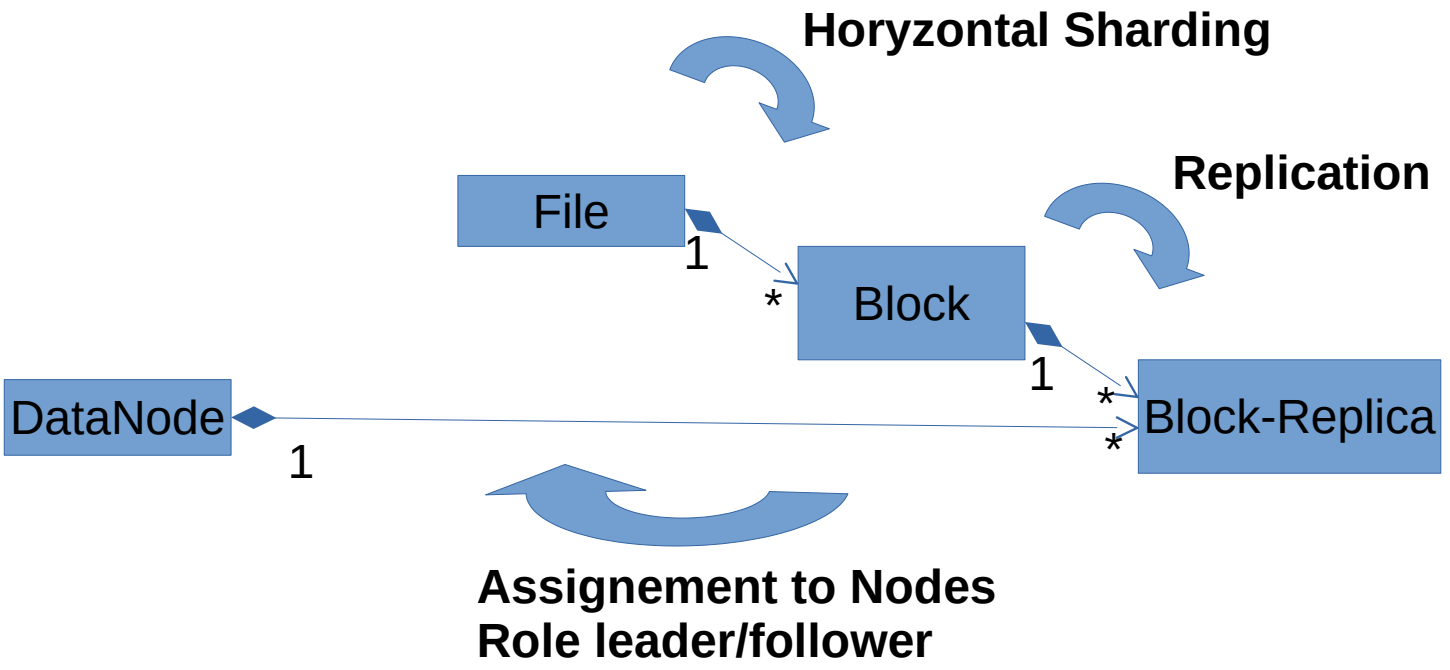

File information
Download
Block information
Close

HDFS … UML Model

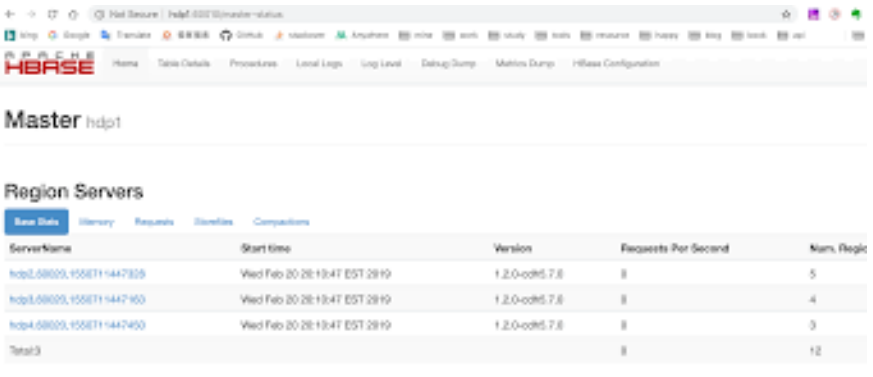


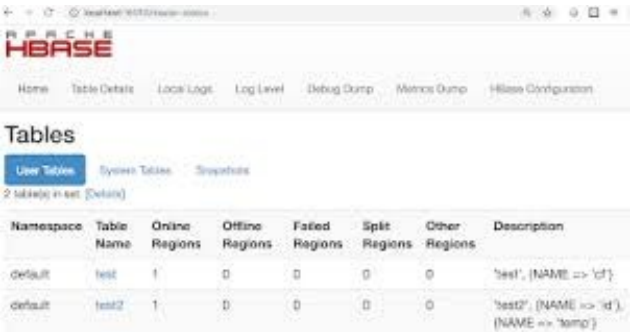
File: binary large object « blob »
= metadata
(owner, group, chmod, acl, ..)
+ list of blocks

HDFS … Zoomin Relations



HBase


Master hdp1
Region Servers


Tables
Namespace
Table Name
Online Regions
Offline Regions
Failed Regions
Split Regions
Other Regions
Description

HBase … UML Model

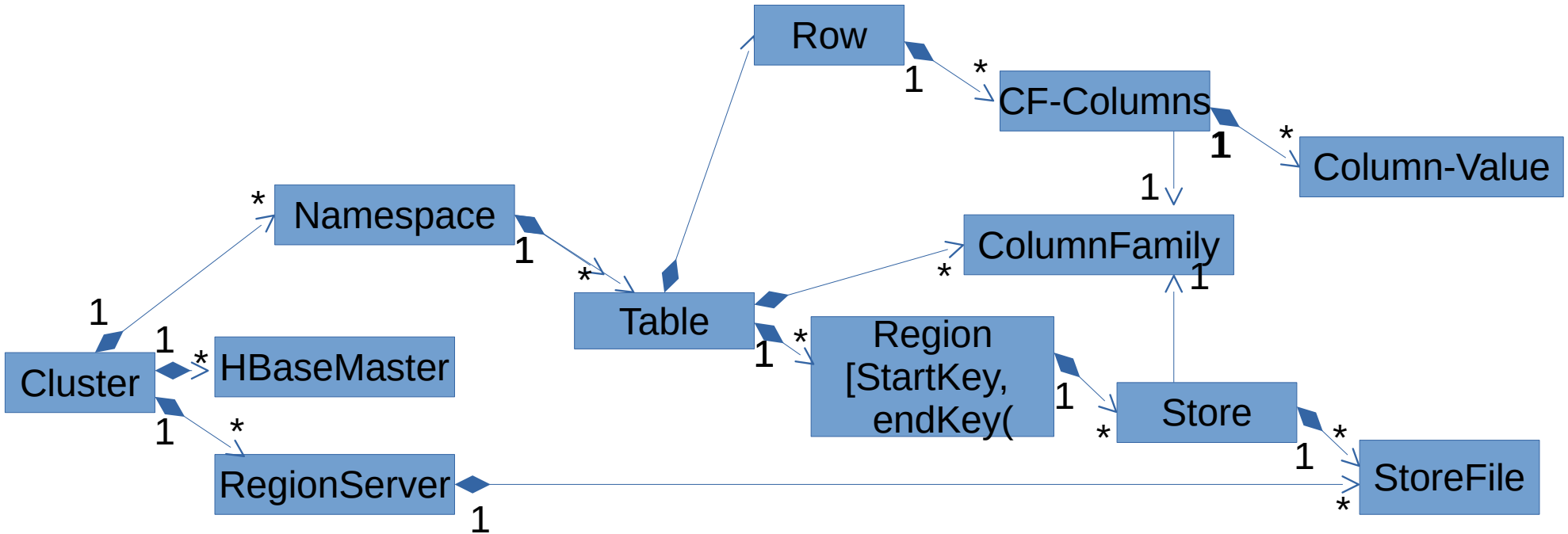


Table = Map<byte[],Map<byte[],byte[]>>

RowKey ColumnFamily:Column BlobValue

HBase … Zooming Relations