Introduction To YARN, NameNode HA and HDFS Federation

Adam Kawa, Spotify

4/27/13

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About Me

Data Engineer at Spotify, Sweden

Hadoop Instructor at Compendium (Cloudera Training Partner)

+2.5 year of experience in Hadoop

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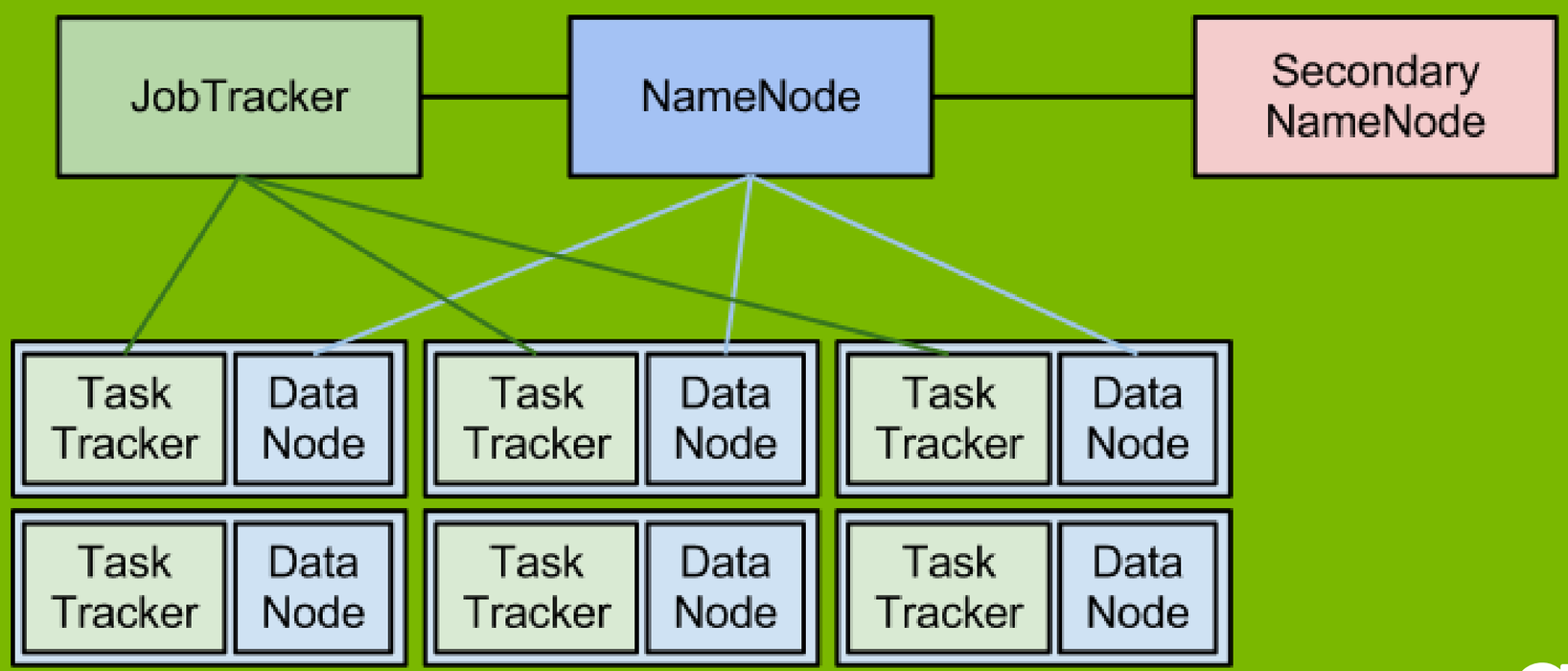
“Classical” Apache Hadoop Cluster

Can consist of one, five, hundred or 4000 nodes



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Hadoop Golden Era

One of the most exciting open-source projects on the planet

Becomes the standard for large-scale processing

Successfully deployed by hundreds/thousands of companies

Like a salutary virus

... But it has some little drawbacks

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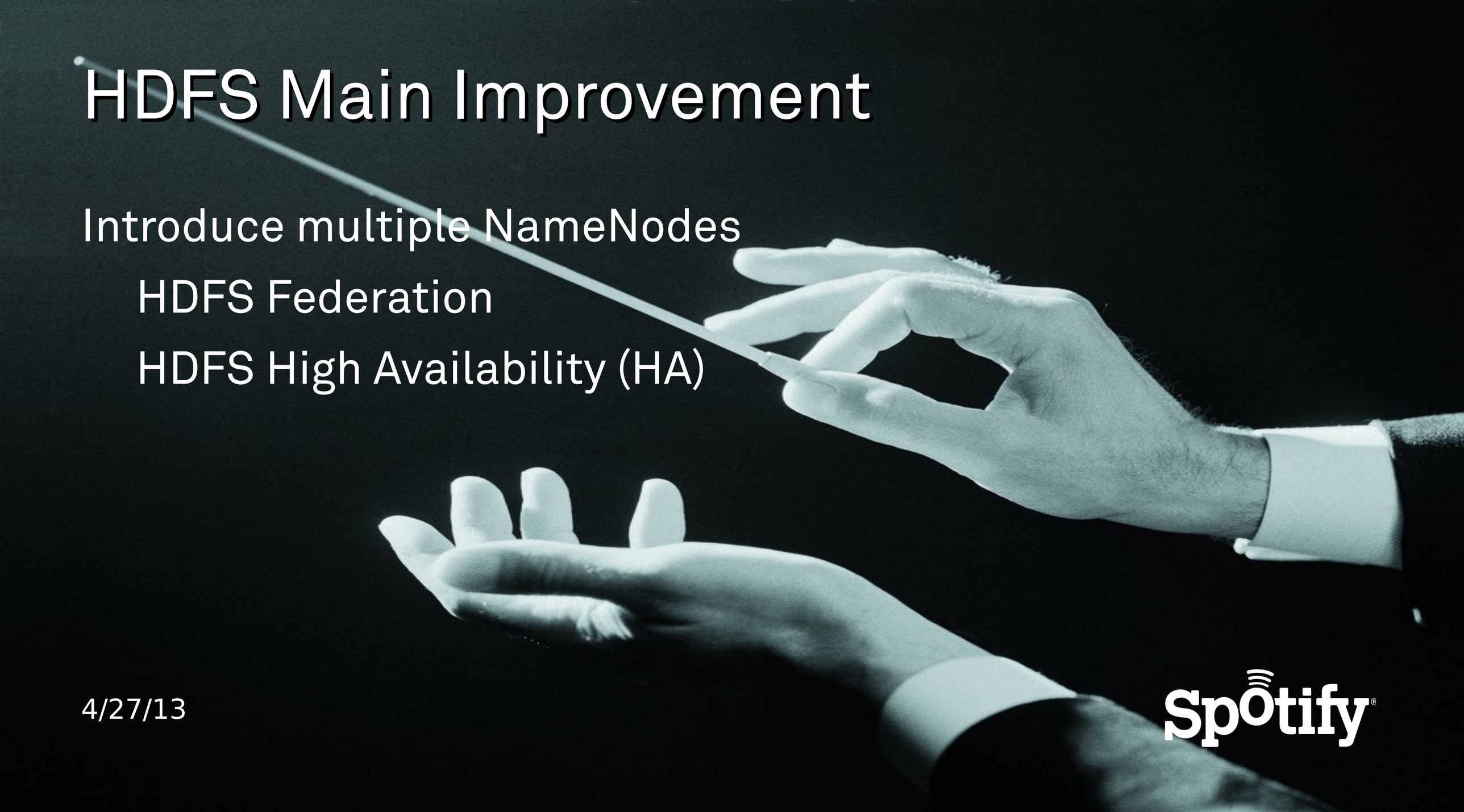
HDFS Main Limitations

Single NameNode that

- keeps all metadata in RAM
- performs all metadata operations
- becomes a single point of failure (SPOF)

HDFS Main Improvement



Introduce multiple NameNodes

- HDFS Federation
- HDFS High Availability (HA)

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Motivation for HDFS Federation

Limited namespace scalability

Decreased metadata operations performance

Lack of isolation

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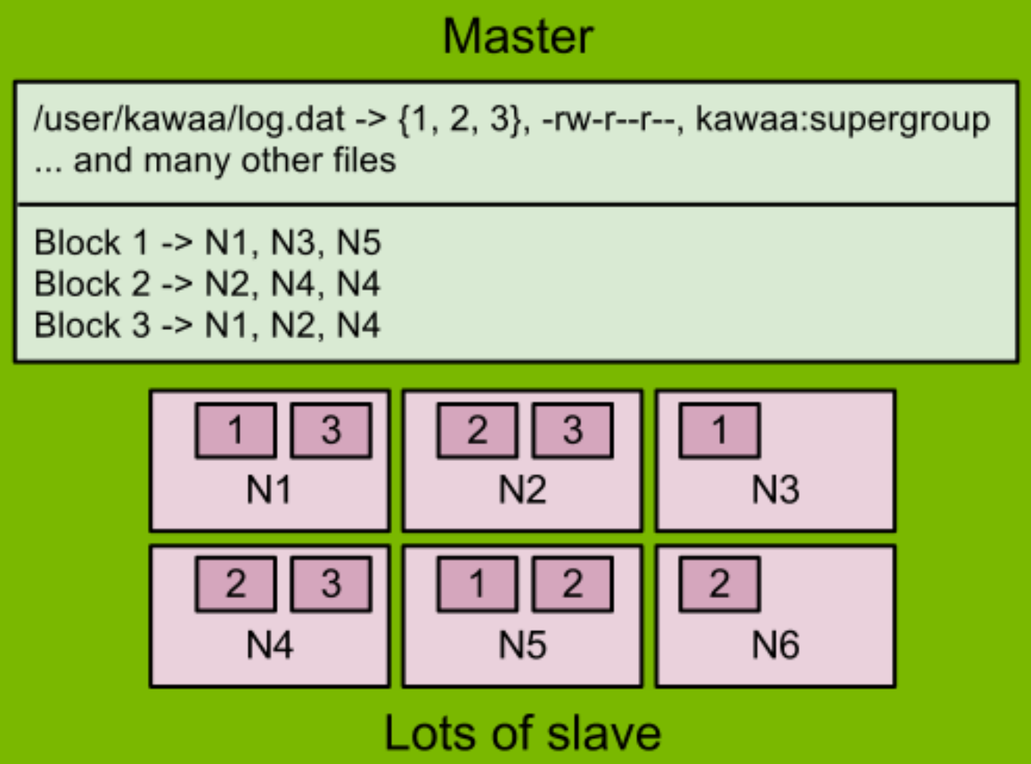
HDFS – master and slaves

Master (NameNode) manages all metadata information

Slaves (DataNodes) store blocks of data and serve them to the client



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HDFS NameNode (NN)

Supports all the namespace-related file system operations

Keeps information in RAM for fast lookup

- The filesystem tree
- Metadata for all files/directories (e.g. ownerships, permissions)
- Names and locations of blocks

Metadata (not all) is additionally stored on disk(s)

- Filesystem snapshot (`fsimage`) + editlog (`edits`) files

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HDFS DataNode (DN)

Stores and retrieves blocks

- A block is stored as a regular files on local disk
  - e.g. blk_-9923913549105616 45
- A block itself does not know which file it belongs to

Sends the block report to NN periodically

Sends the heartbeat signals to NN to say that it is alive

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NameNode scalability issues

Number of files limited by the amount of RAM of one machine

More RAM means also heavier GC

Stats based on Y! Clusters

- An average file ≈ 1.5 blocks (block size = 128 MB)
- An average file ≈ 600 bytes of metadata (1 file and 2 blocks objects)
- 100M files ≈ 60 GB of metadata
- 1 GB of metadata ≈ 1 PB physical storage (but usually less)

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NameNode performance

Read/write operations throughput limited by one machine

- ~120K read ops/sec, ~6K write ops/sec
- MapReduce tasks are also HDFS clients

Internal load increases as the cluster grows

- Block reports and heartbeats from DataNodes
- Bigger snapshots transferred from/to Secondary NameNode

NNBench - benchmark that stresses the NameNode

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Lack of isolation

Experimental applications

- (can) overload the NN and slow down production jobs

Production applications with different requirements

- (can) benefit from “own” NameNode
- e.g. HBase requires extremely fast responses

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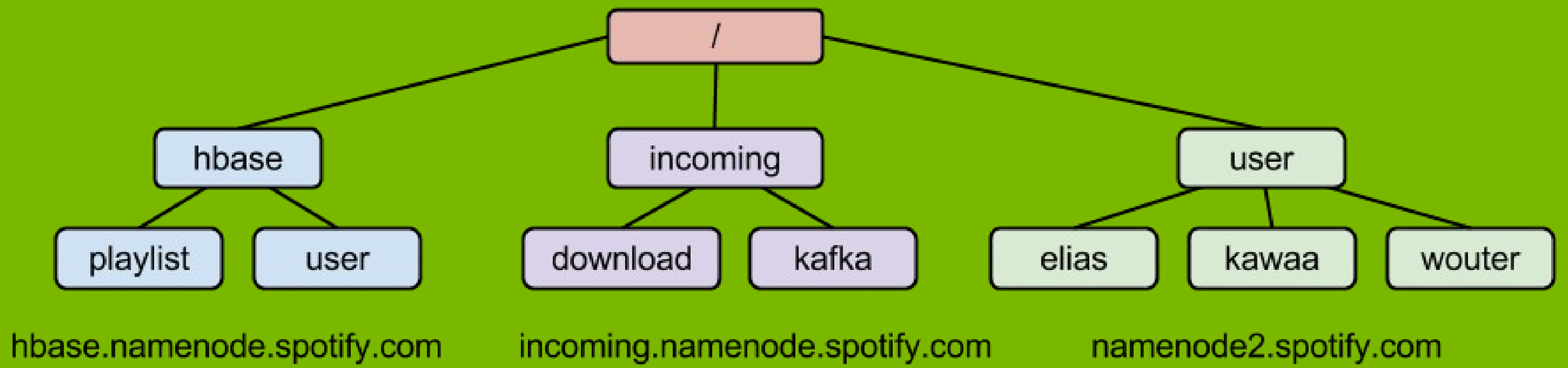
HDFS Federation

Partition the filesystem namespace over multiple separated NameNodes



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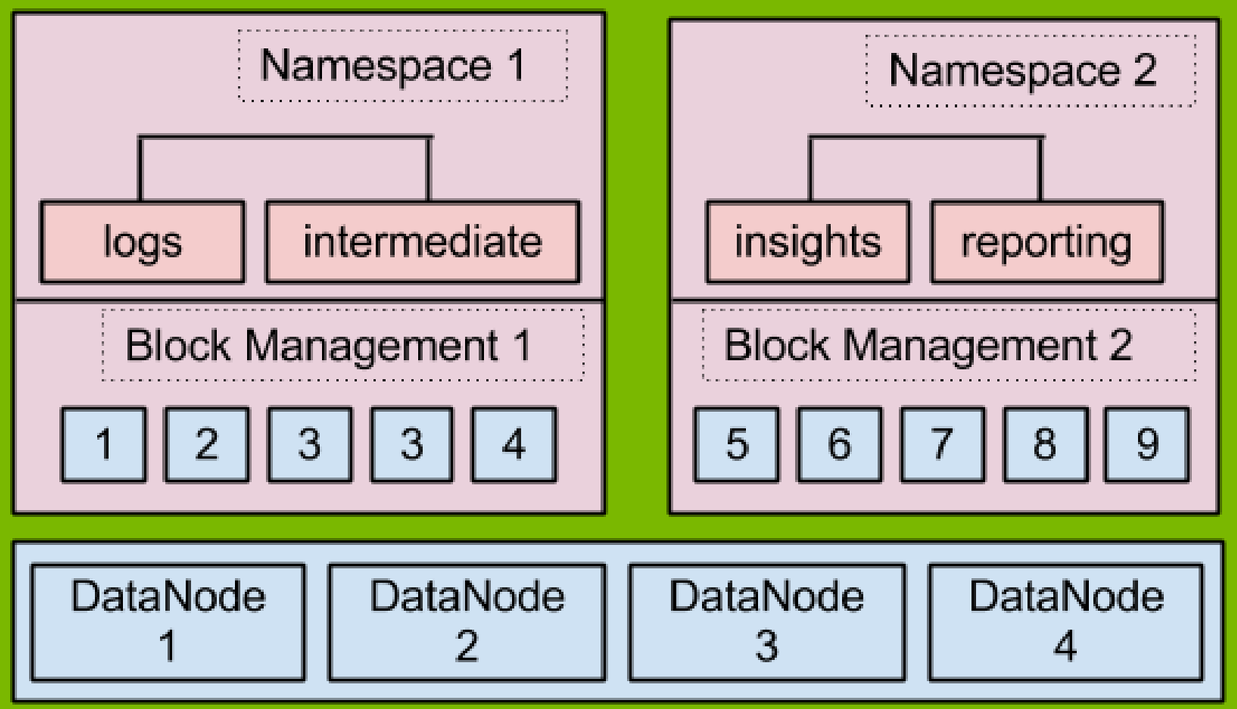
Multiple independent namespaces



NameNodes does not talk each other

NameNode manages only slice of namespace

Datanode can store blocks managed by any NameNode

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The client-view of the cluster

There are multiple namespaces (and corresponding NNs)

Client can use any of them to compose its own view of HDFS

Idea is much like the Linux `/etc/fstab` file

- Mapping between paths and NameNodes

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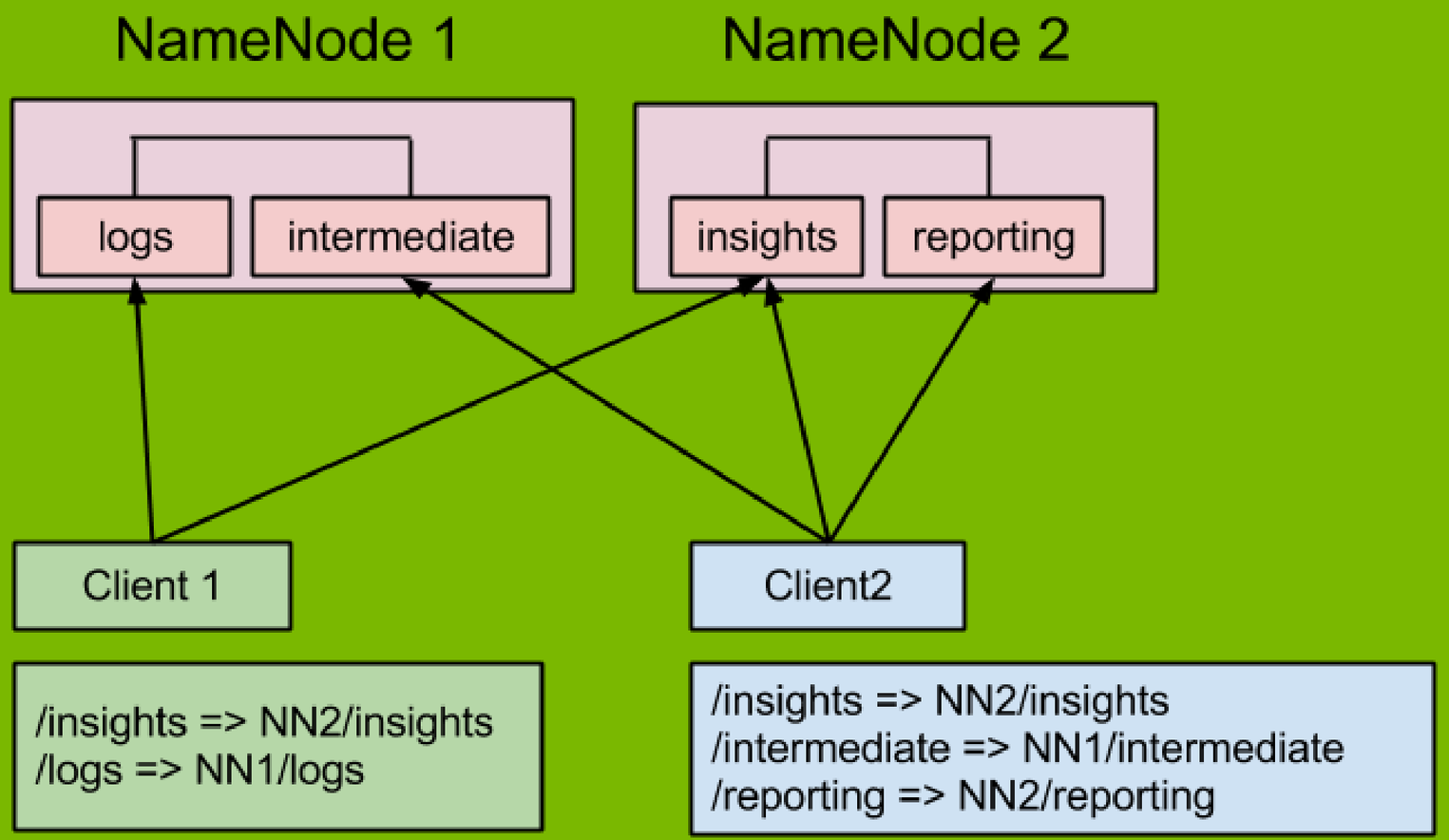
Client-side mount tables



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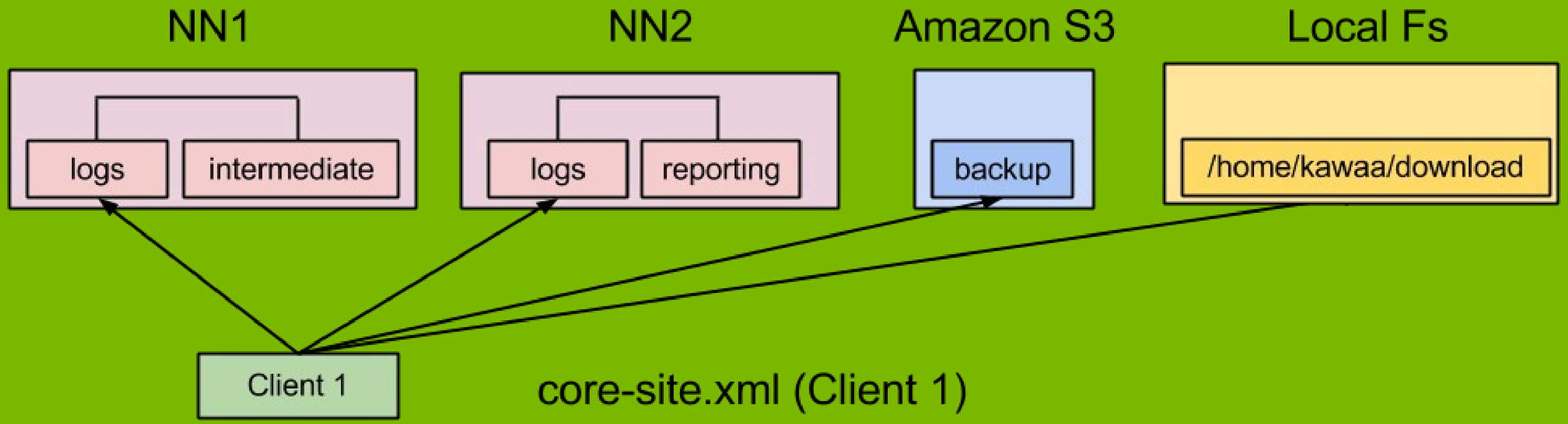
(More funky) Client-side mount tables



core-site.xml (Client 1)

```
/logs -> hdfs://NN1/logs,hdfs://NN2/logs
/backup -> s3://backup
/local_download -> file:///home/kawaa/download
```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Deploying HDFS Federation

Deploying HDFS Federation

- Useful for small (+isolation) and large (+scalability) cluster
- However not so many clusters use it

NameNodes can be added/removed at any time

- Cluster does have to be restarted

Add Federation to the existing cluster

- Do not format existing NN
- Newly added NN will be “empty”

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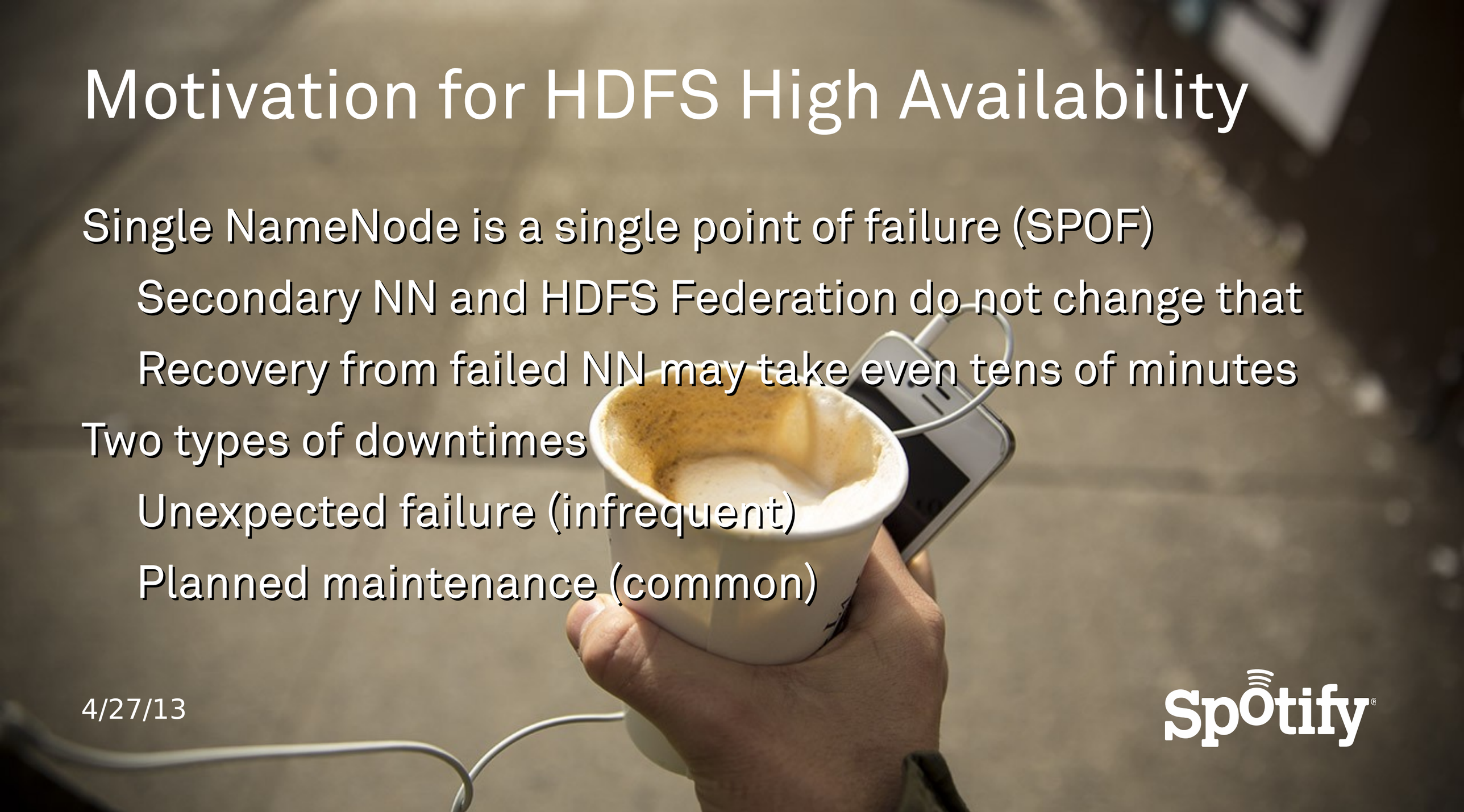
Motivation for HDFS High Availability



- Single NameNode is a single point of failure (SPOF)
  - Secondary NN and HDFS Federation do not change that
  - Recovery from failed NN may take even tens of minutes
- Two types of downtimes
  - Unexpected failure (infrequent)
  - Planned maintenance (common)

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HDFS High Availability

Introduces a pair of redundant NameNodes

- One Active and one Standby

If the Active NameNode crashes or is intentionally stopped,

- Then the Standby takes over quickly

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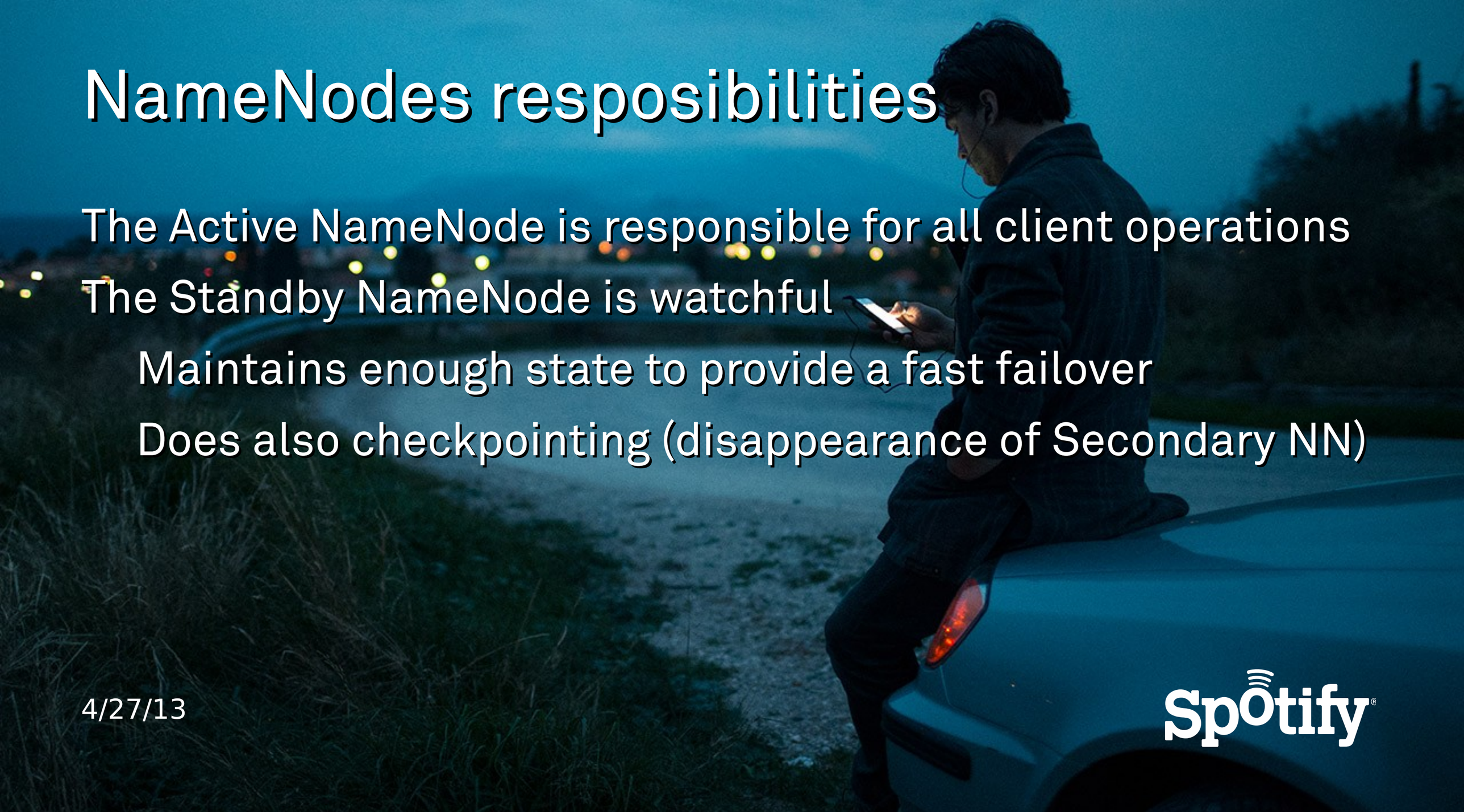
NameNodes resposibilities



The Active NameNode is responsible for all client operations

The Standby NameNode is watchful

- Maintains enough state to provide a fast failover
- Does also checkpointing (disappearance of Secondary NN)

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Synchronizing the state of metadata

The Standby must keep its state as up-to-date as possible

Edit logs - two alternative ways of sharing them

- Shared storage using NFS
- Quorum-based storage (recommended)

Block locations

- DataNodes send block reports to both NameNodes

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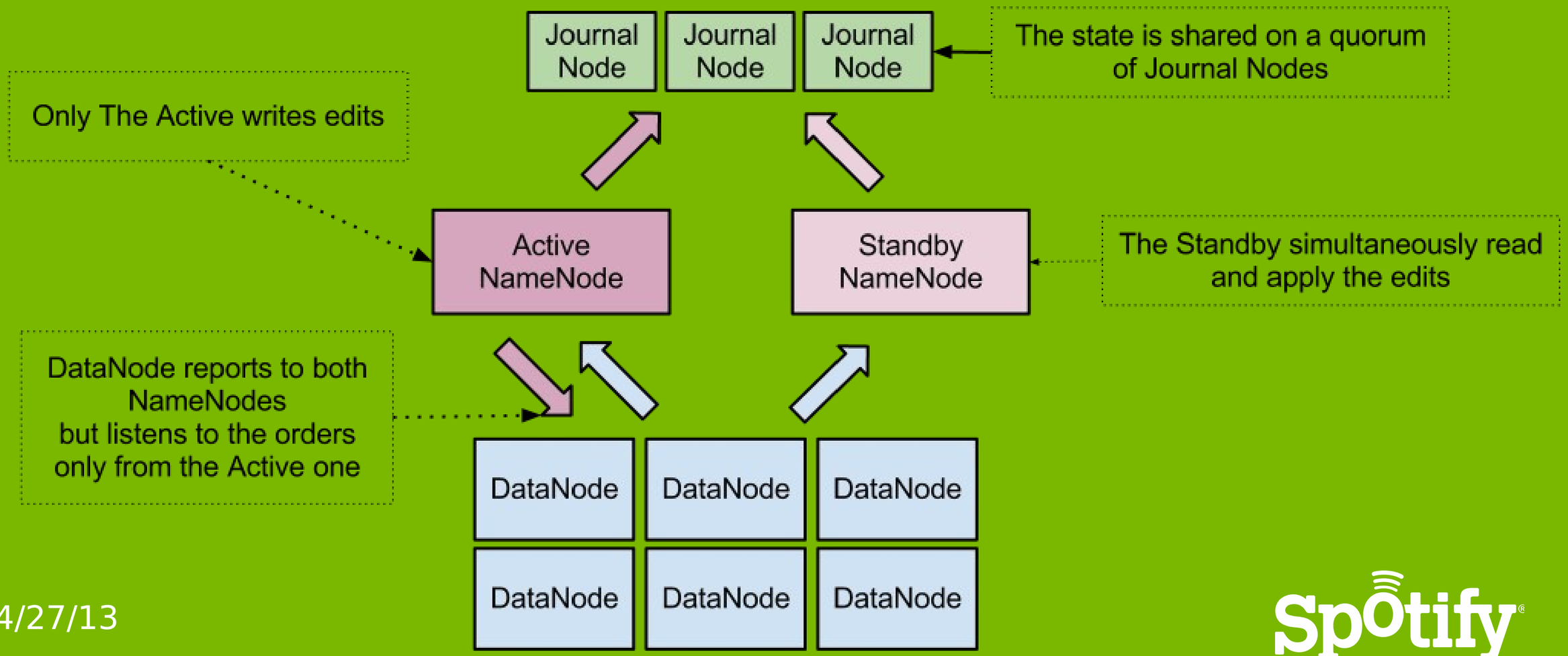
Quorum-based storage



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Supported failover modes

- Manual fail-over
  - Initiated by administrator by a dedicated command - 0-3 seconds
- Automatic fail-over
  - Detected by a fault in the active NN (more complicated and longer) - 30-40 seconds

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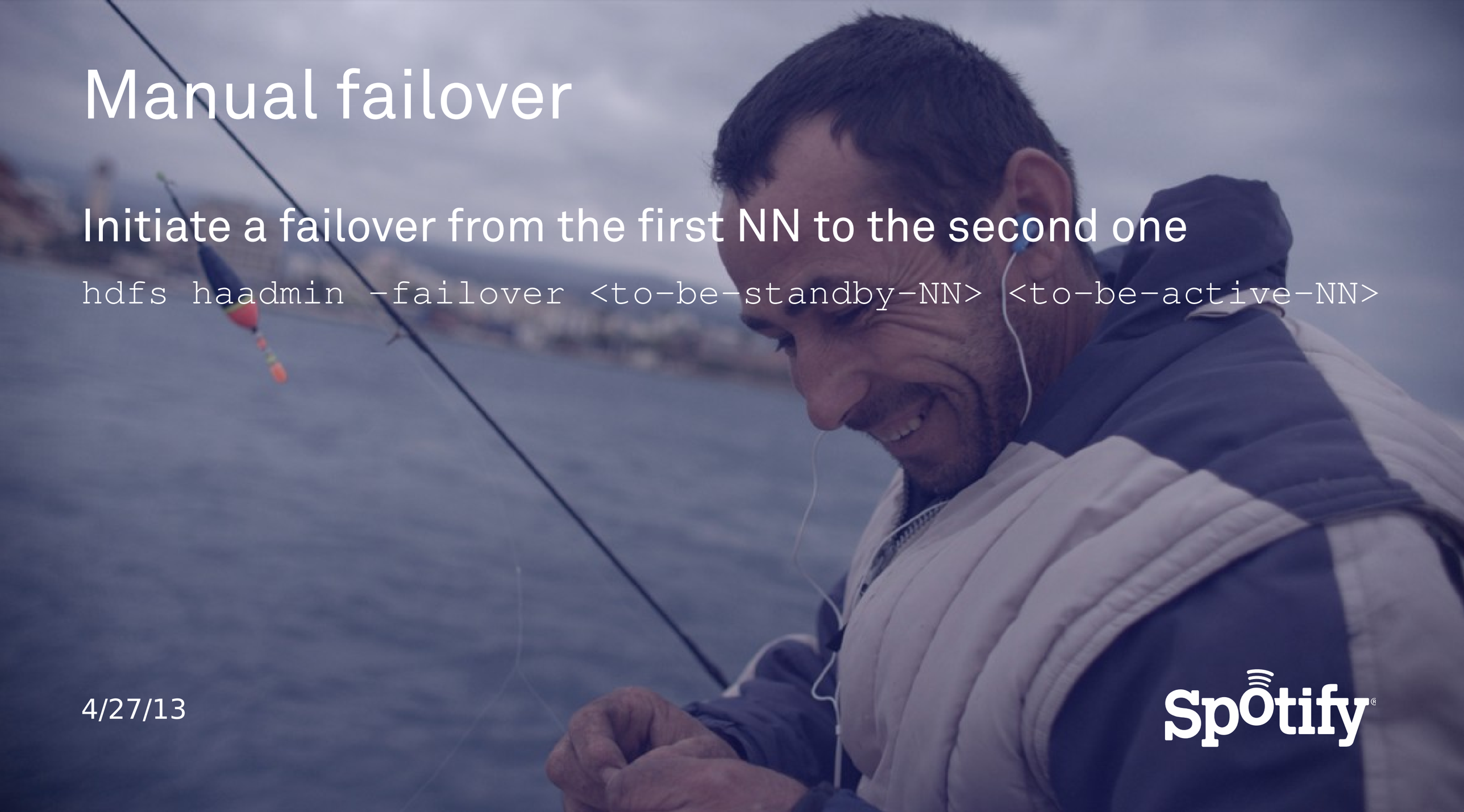
Manual failover

Initiate a failover from the first NN to the second one

```
hdfs haadmin -failover <to-be-standby-NN> <to-be-active-NN>
```



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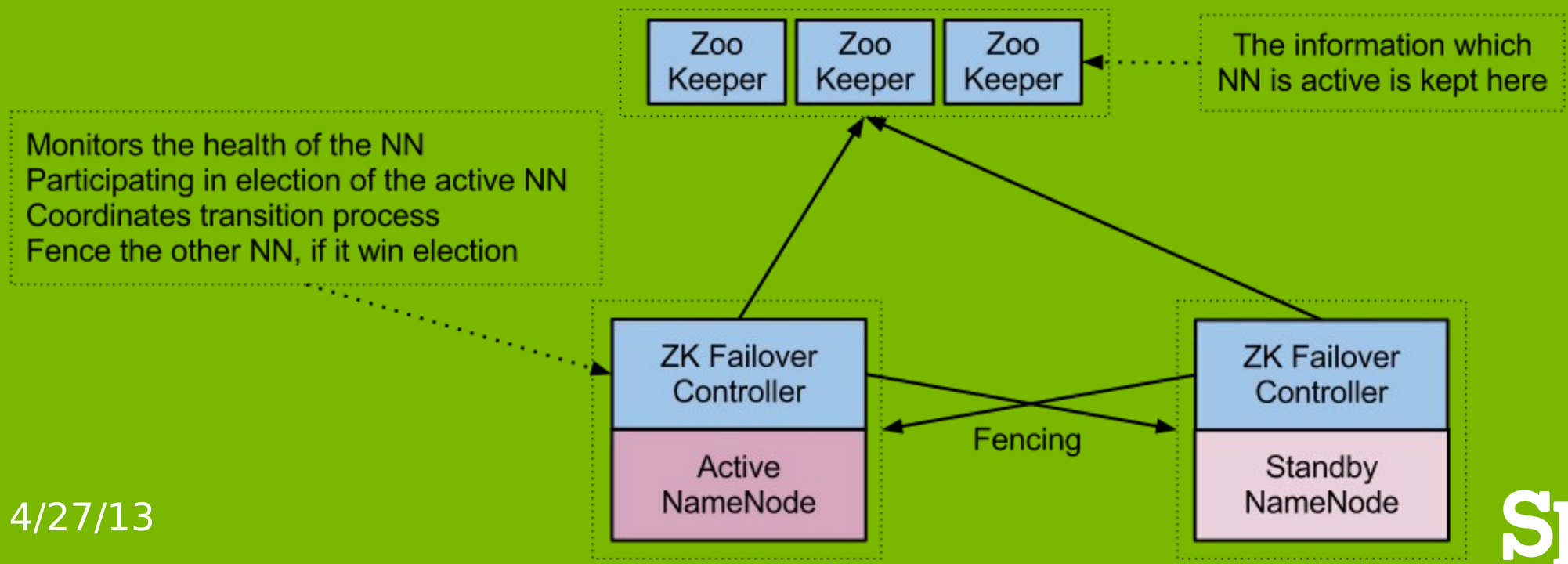
Automatic failover

Requires ZooKeeper and an additional process
"ZKFailoverController"



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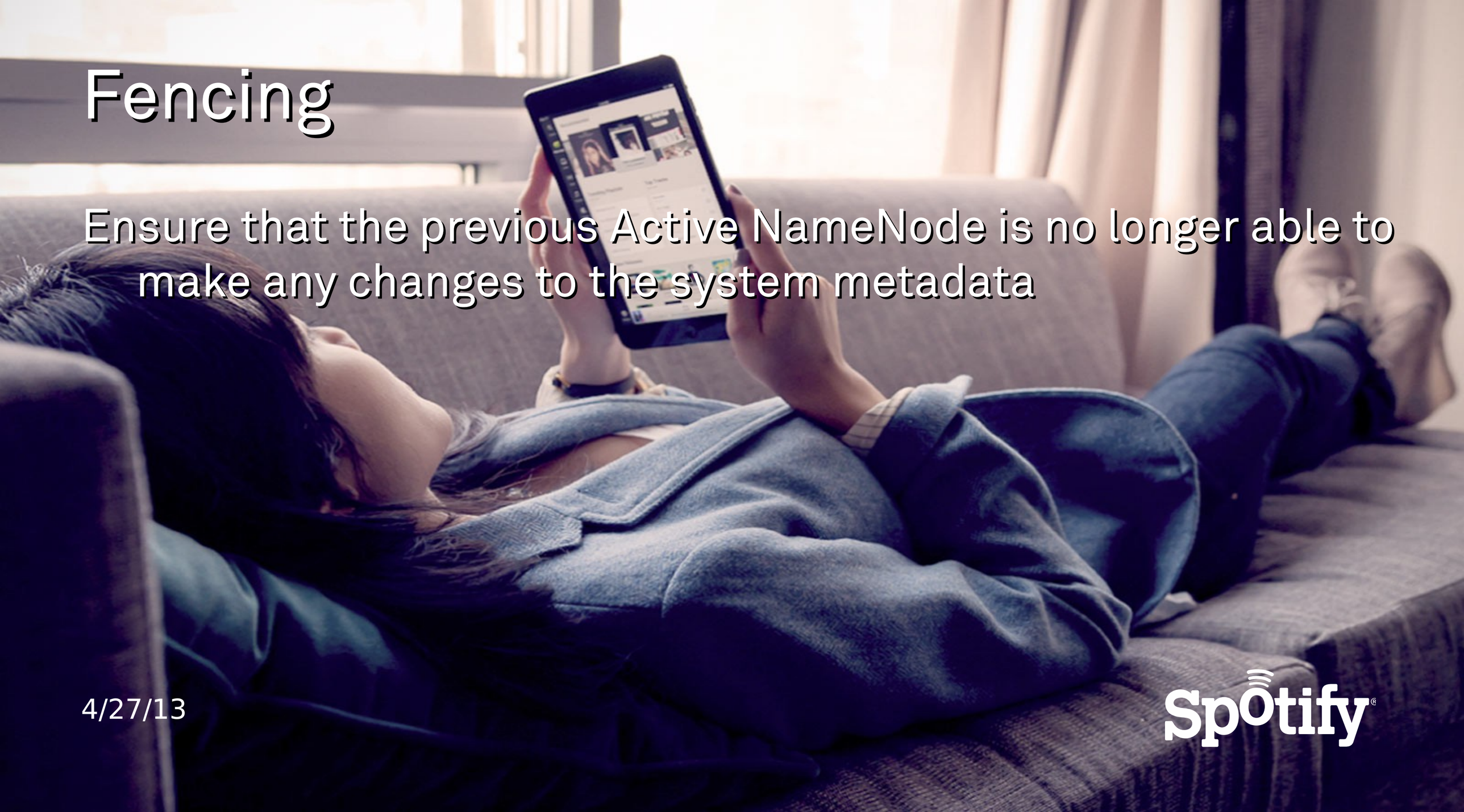
The split brain scenario

A potential scenario when two NameNodes

- Both think they are active
- Both make conflicting changes to the namespace

Example: The ZKFC crashes, but its NN is still running

Fencing



Ensure that the previous Active NameNode is no longer able to make any changes to the system metadata

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Fencing with Quorum-based storage

Only a single NN can be a writer to JournalNodes at a time

- Whenever NN becomes active, it generated an “epoch number”
- NN that has a higher “epoch number” can be a writer
- This prevents from corrupting the file system metadata

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“Read” requests fencing

Previous active NN will be fenced when tries to write to the JN

- Until it happens, it may still serve HDFS read requests

Try to fence this NN before that happens

- This prevents from reading outdated metadata
- Might be done automatically by ZKFC or hdfs haadmin

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HDFS Highly-Available Federated Cluster

Any combination is possible

- Federation without HA
- HA without Federation
- HA with Federation
  - e.g. NameNode HA for HBase, but not for the others

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“Classical” MapReduce Limitations

Limited scalability

Poor resource utilization

Lack of support for the alternative frameworks

Lack of wire-compatible protocols

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Limited Scalability

Scales to only

- ~4,000-node cluster
- ~40,000 concurrent tasks

Smaller and less-powerful clusters must be created

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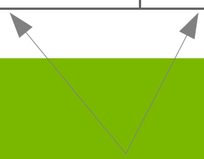
Image source: http://www.flickr.com/photos/rsms/660332848/sizes/l/in/set-72157607427138760/

Poor Cluster Resources Utilization

Cluster Summary (Heap Size is 12.58 GB/23.97 GB)

Running Map Tasks	Running Reduce Tasks	Total Submissions	Nodes	Occupied Map Slots	Occupied Reduce Slots	Reserved Map Slots	Reserved Reduce Slots	Map Task Capacity	Reduce Task Capacity	Avg. Tasks/Node
4512	285	2223	188	4512	285	0	0	4512	3008	40.00



Hard-coded values. TaskTrackers must be restarted after a change.

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Poor Cluster Resources Utilization

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4512	285	2223	188	4512	285	0	0	4512	3008	40.00

Map tasks are waiting for the slots
which are
NOT currently used by Reduce tasks

Hard-coded values. TaskTrackers must be restarted after a change.

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Resources Needs That Varies Over Time

How to hard-code the number of map and reduce slots efficiently?

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(Secondary) Benefits Of Better Utilization

The same calculation on more efficient Hadoop cluster

- Less data center space
- Less silicon waste
- Less power utilizations
- Less carbon emissions
- =
- Less disastrous environmental consequences

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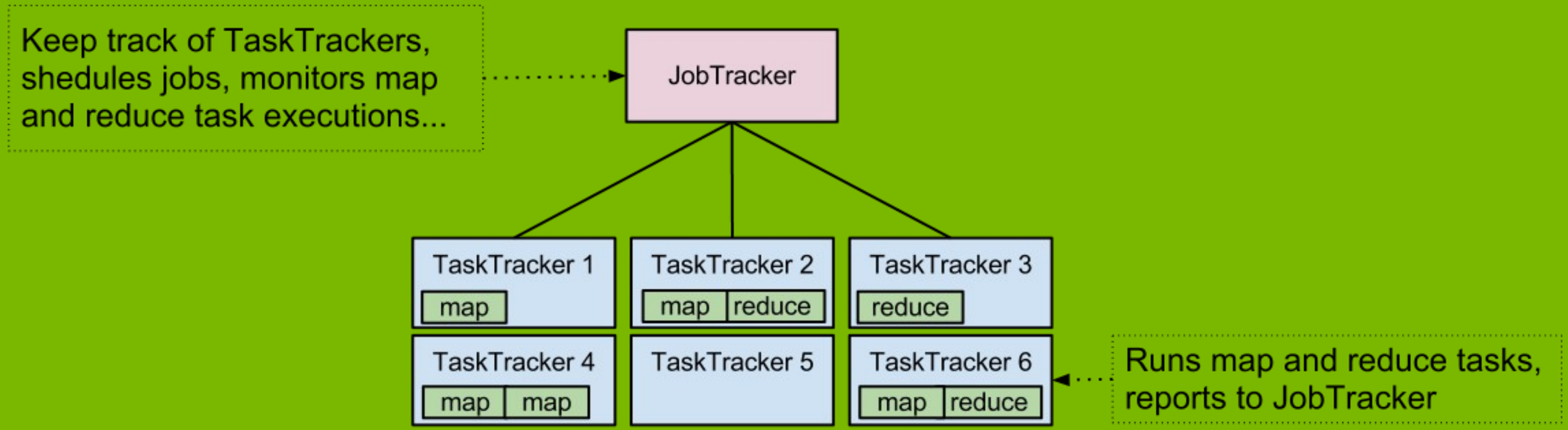
“Classical” MapReduce Daemons



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JobTracker Responsibilities

Manages the computational resources (map and reduce slots)

Schedules all user jobs

- Schedules all tasks that belongs to a job
- Monitors tasks executions
- Restarts failed and speculatively runs slow tasks
- Calculates job counters totals

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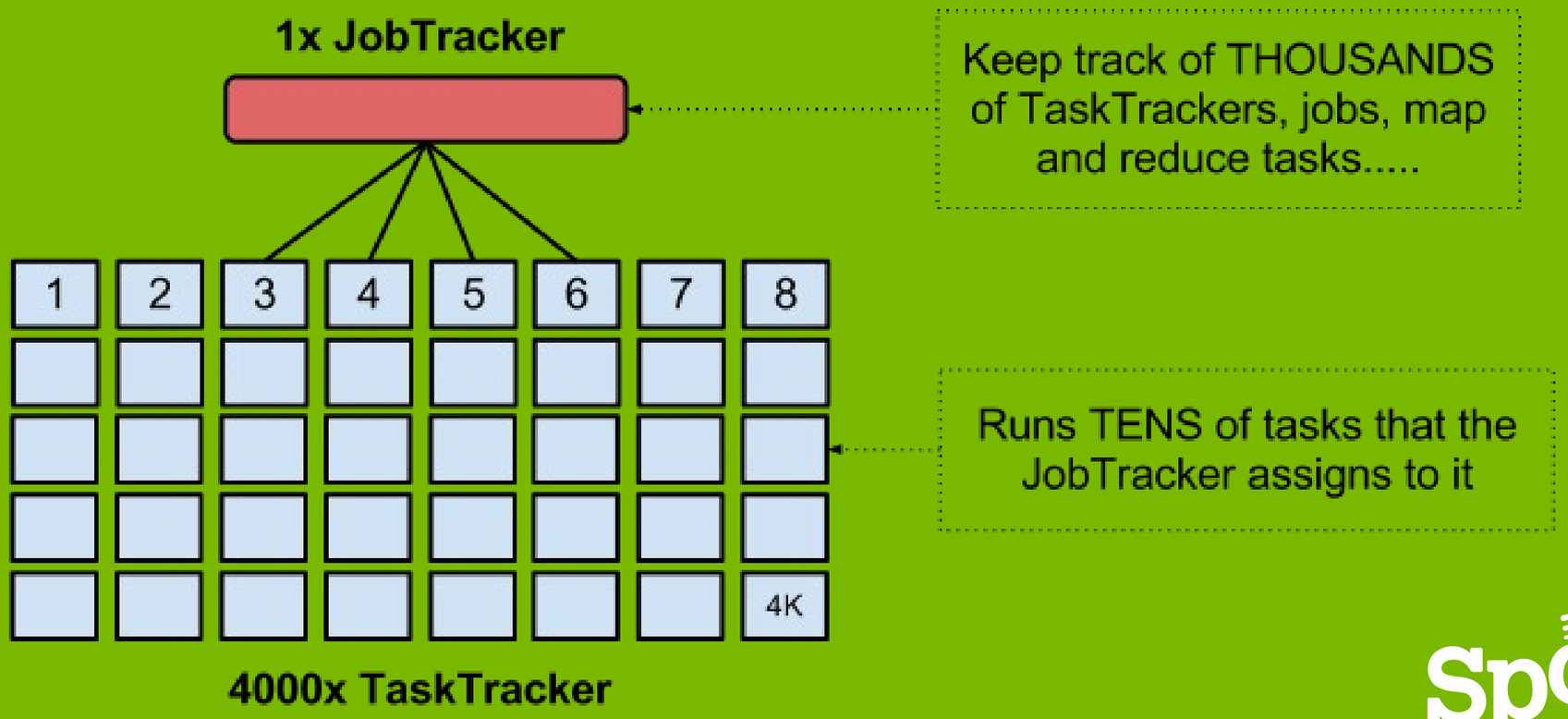
Simple Observation

JobTracker does a lot...



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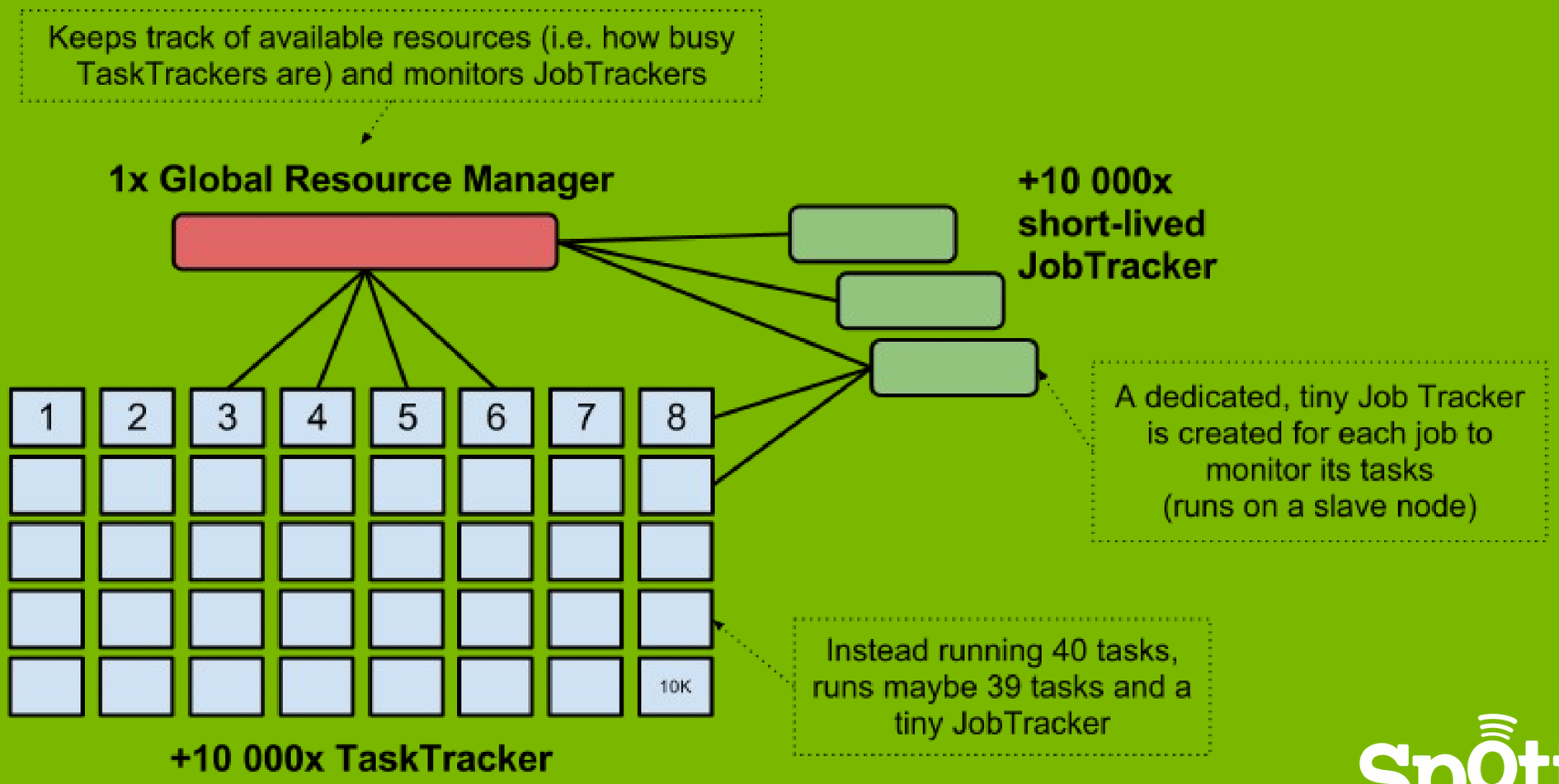
JobTracker Redesign Idea

- Reduce responsibilities of JobTracker
  - Separate cluster resource management from job coordination
  - Use slaves (many of them!) to manage jobs life-cycle
- Scale to (at least) 10K nodes, 10K jobs, 100K tasks

Disappearance Of The Centralized JobTracker



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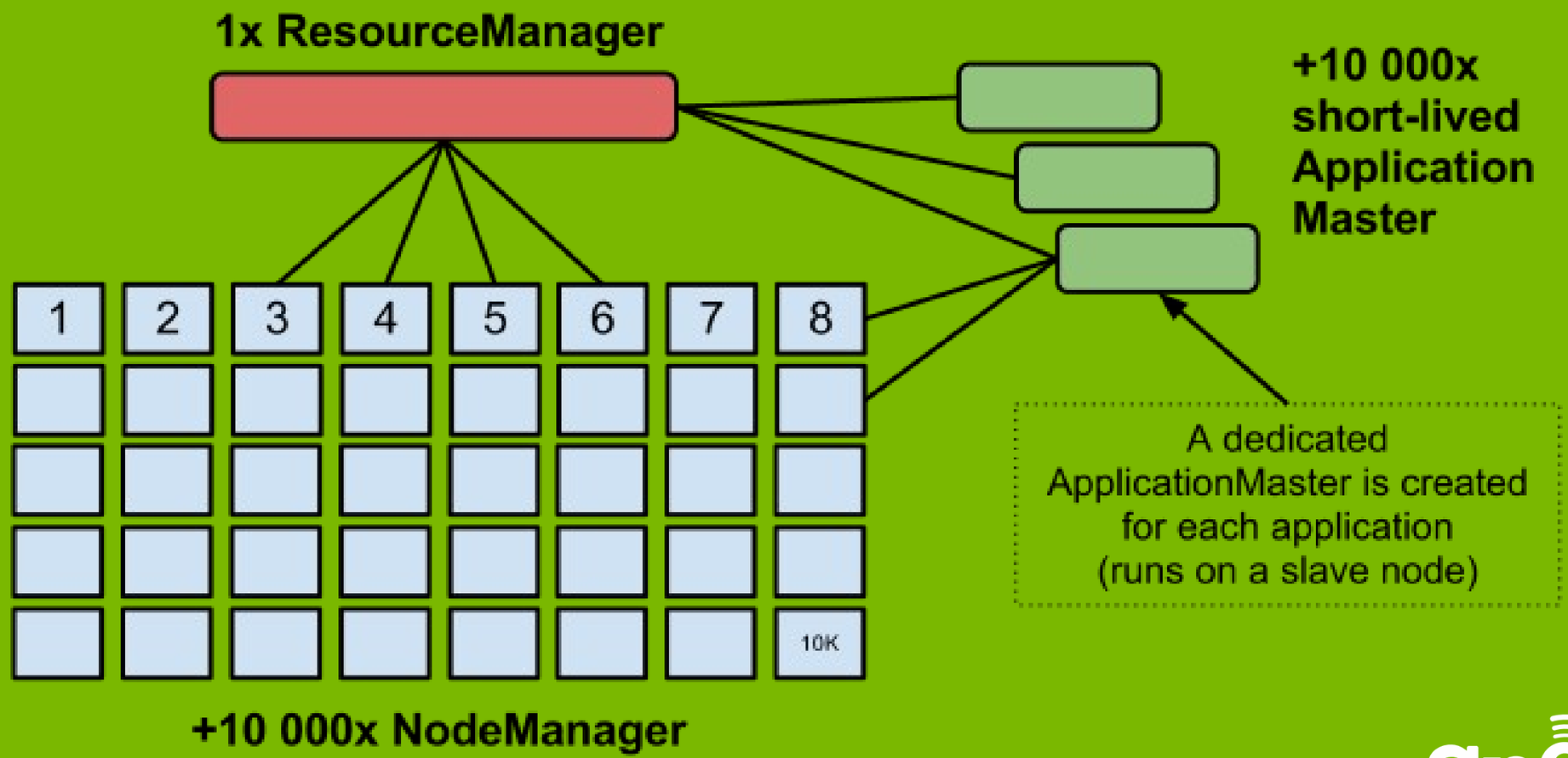
YARN – Yet Another Resource Negotiator



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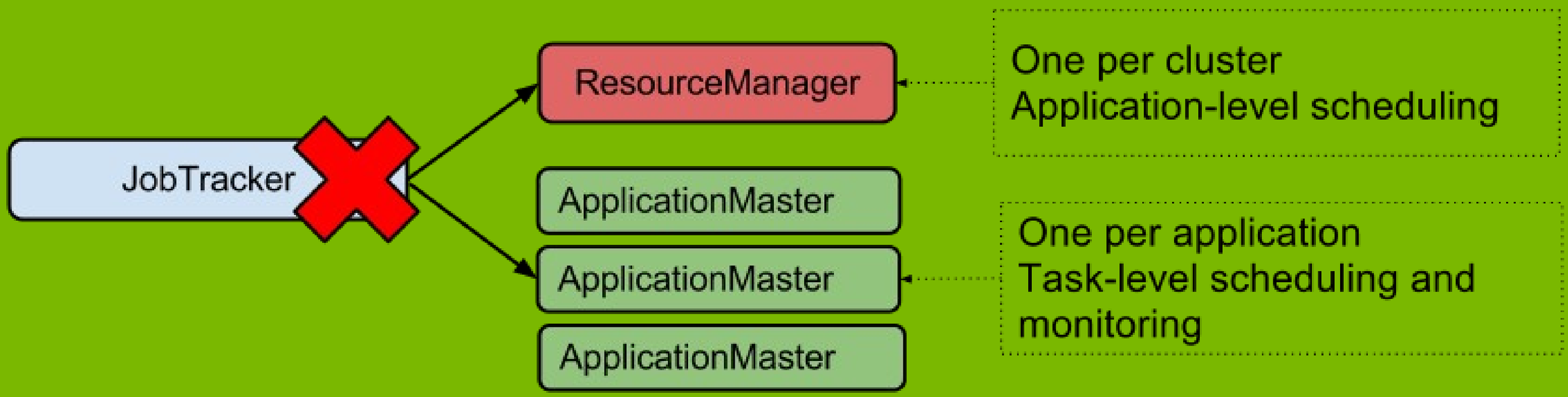
Resource Manager and Application Master



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YARN Applications

MRv2 (simply MRv1 rewritten to run on top of YARN)

No need to rewrite existing MapReduce jobs

Distributed shell

Spark, Apache S4 (a real-time processing)

Hamster (MPI on Hadoop)

Apache Giraph (a graph processing)

Apache HAMA (matrix, graph and network algorithms)

... and http://wiki.apache.org/hadoop/PoweredByYarn

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NodeManager

More flexible and efficient than TaskTracker

Executes any computation that makes sense to ApplicationMaster

- Not only map or reduce tasks

Containers with variable resource sizes (e.g. RAM, CPU, network, disk)

- No hard-coded split into map and reduce slots

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NodeManager Containers

NodeManager creates a container for each task

Container contains variable resources sizes

- e.g. 2GB RAM, 1 CPU, 1 disk

Number of created containers is limited

- By total sum of resources available on NodeManager

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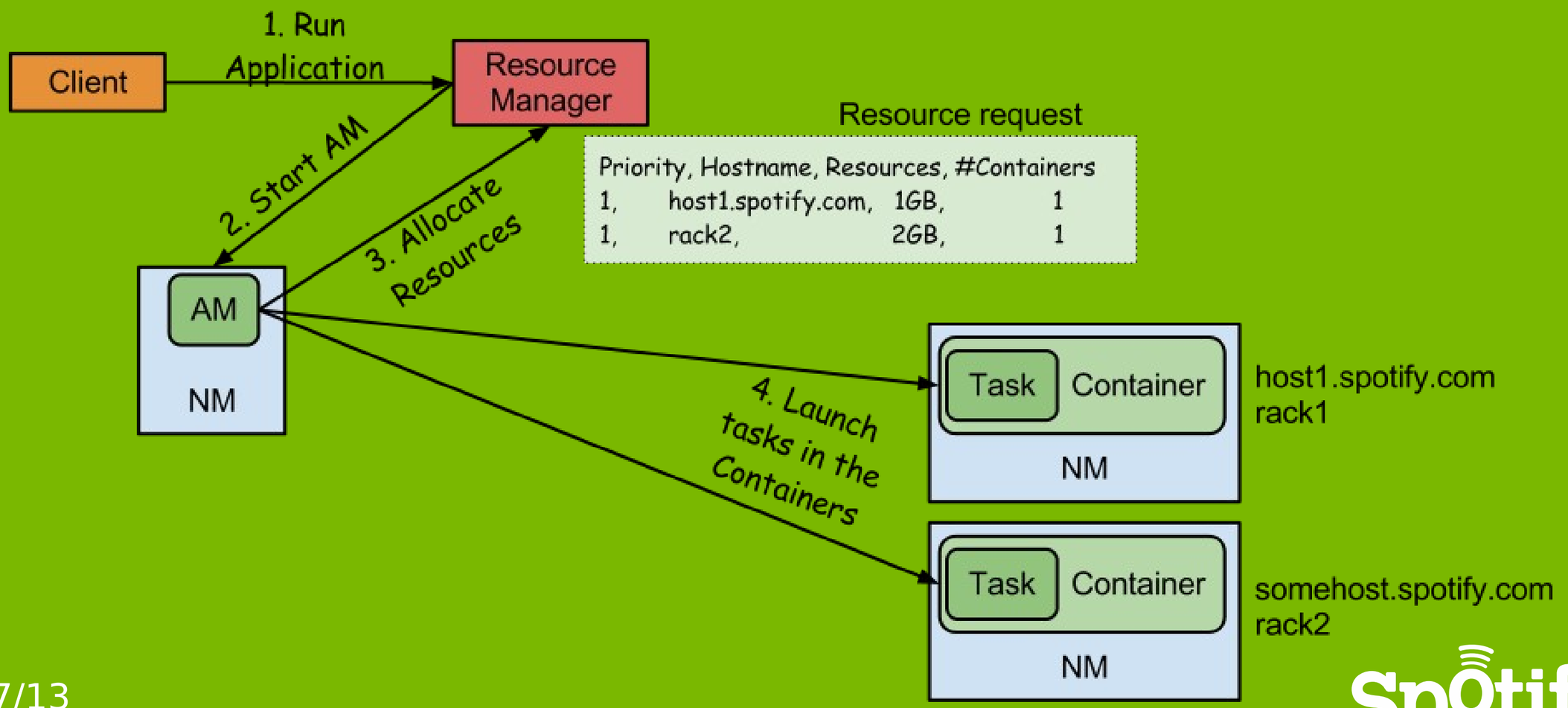
Application Submission In YARN



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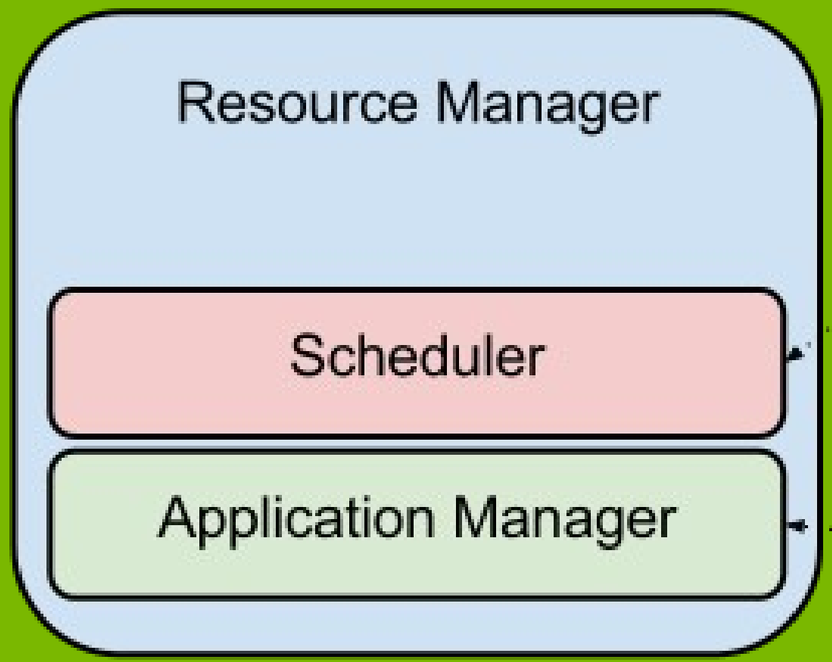
Resource Manager Components



Pure scheduling. No monitoring, no restarting of jobs or tasks.

Accepting application-submissions, negotiating the first container for the ApplicationMaster, restarting it on failure.

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Uberization

Running the small jobs in the same JVM as AplicationMaster

```
mapreduce.job.ubertask.enable       true (false is default)
mapreduce.job.ubertask.maxmaps      9*
mapreduce.job.ubertask.maxreduces   1*
mapreduce.job.ubertask.maxbytes     dfs.block.size*
```

* Users may override these values, but only downward

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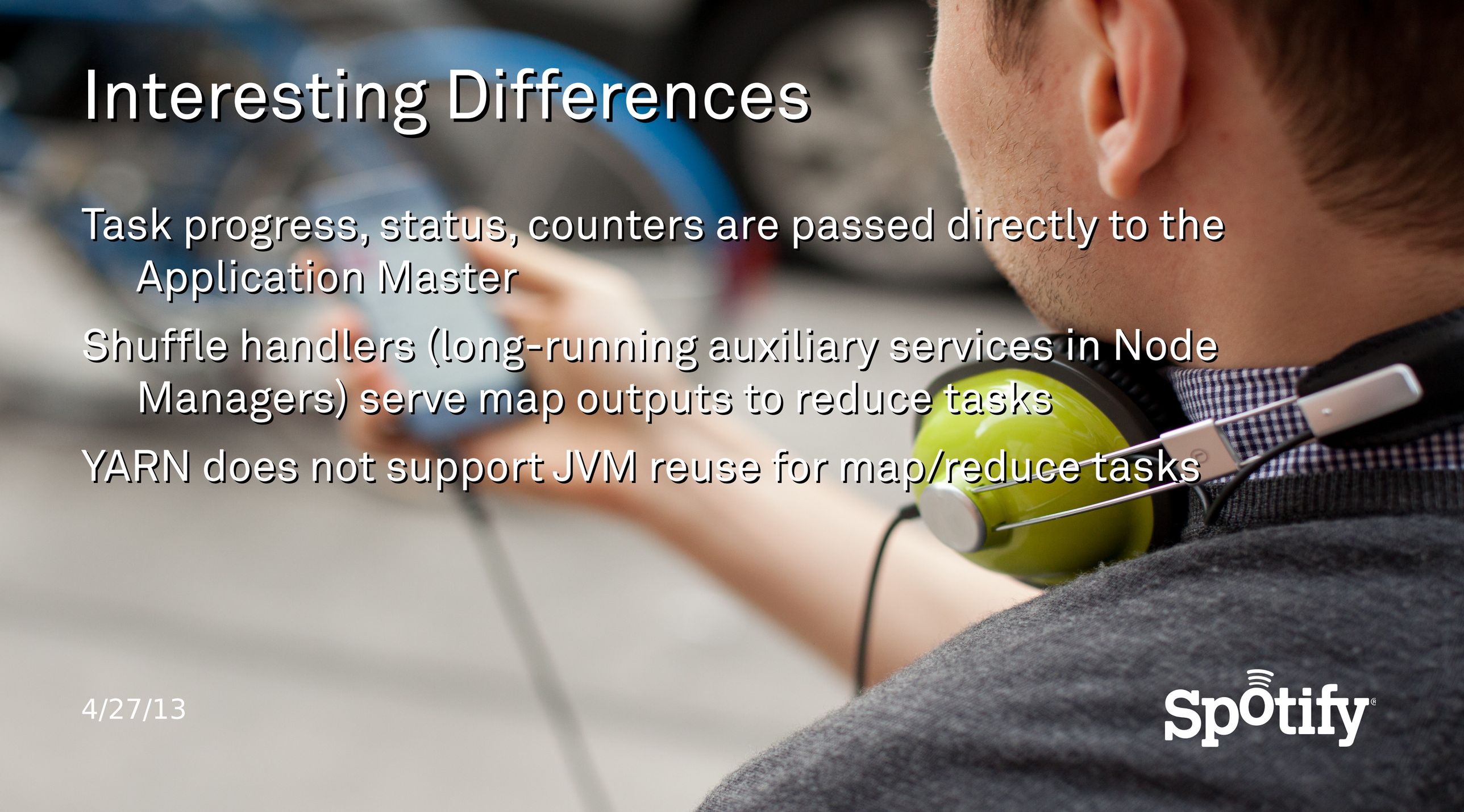
Interesting Differences



Task progress, status, counters are passed directly to the Application Master

Shuffle handlers (long-running auxiliary services in Node Managers) serve map outputs to reduce tasks

YARN does not support JVM reuse for map/reduce tasks

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Fault-Tollerance

Failure of the running tasks or NodeManagers is similar as in MRv1

Applications can be retried several times

```
yarn.resourcemanager.am.max-retries                1
yarn.app.mapreduce.am.job.recovery.enable    false
```

Resource Manager can start Application Master in a new container

```
yarn.app.mapreduce.am.job.recovery.enable    false
```


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Resource Manager Failure

Two interesting features

- RM restarts without the need to re-run currently running/submitted applications [YARN-128]
- ZK-based High Availability (HA) for RM [YARN-149] (still in progress)

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Wire-Compatible Protocol

Client and cluster may use different versions

More manageable upgrades

- Rolling upgrades without disrupting the service
- Active and standby NameNodes upgraded independently

Protocol buffers chosen for serialization (instead of Writables)

YARN Maturity

Still considered as both production and not production-ready

- The code is already promoted to the trunk
- Yahoo! runs it on 2000 and 6000-node clusters
  - Using Apache Hadoop 2.0.2 (Alpha)
- There is no production support for YARN yet

Anyway, it will replace MRv1 sooner than later

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How To Quickly Setup The YARN Cluster

cloudera®
Ask Bigger Questions

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Basic YARN Configuration Parameters

```
yarn.nodemanager.resource.memory-mb          8192
yarn.nodemanager.resource.cpu-cores          8

yarn.scheduler.minimum-allocation-mb         1024
yarn.scheduler.maximum-allocation-mb         8192
yarn.scheduler.minimum-allocation-vcores     1
yarn.scheduler.maximum-allocation-vcores     32
```


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Basic MR Apps Configuration Parameters

```
mapreduce.map.cpu.vcores      1
mapreduce.reduce.cpu.vcores   1

mapreduce.map.memory.mb       1536
mapreduce.map.java.opts       -Xmx1024M
mapreduce.reduce.memory.mb    3072
mapreduce.reduce.java.opts    -Xmx2560M
mapreduce.task.io.sort.mb     512
```


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Apache Whirr Configuration File

```
whirr.cluster-name=whug-yarn-cluster
whirr.instance-templates=1 hadoop-namenode+yarn-resourcemanager+mapreduce-histor
yserver,4 hadoop-datanode+yarn-nodemanager
whirr.provider=aws-ec2
whirr.identity=<cloud-provider-identity>
whirr.credential=<cloud-provider-credential>
whirr.private-key-file=${sys:user.home}/.ssh/id_rsa
whirr.public-key-file=${sys:user.home}/.ssh/id_rsa.pub
whirr.env.mapreduce_version=2
whirr.env.repo=cdh4
whirr.hadoop.install-function=install_cdh_hadoop
whirr.hadoop.configure-function=configure_cdh_hadoop
whirr.mr_jobhistory.start-function=start_cdh_mr_jobhistory
whirr.yarn.configure-function=configure_cdh_yarn
whirr.yarn.start-function=start_cdh_yarn
whirr.hardware-id=m1.large
whirr.image-id=us-east-1/ami-ccb35ea5
whirr.location-id=us-east-1
~
```


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Running And Destroying Cluster

```
$ whirr launch-cluster --config hadoop-yarn.properties
$ whirr destroy-cluster --config hadoop-yarn.properties
```


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Running And Destroying Cluster

```
$ whirr launch-cluster --config hadoop-yarn.properties
$ whirr destroy-cluster --config hadoop-yarn.properties
```

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It Might Be A Demo

But what about running
production applications
on the real cluster
consisting of hundreds of nodes?

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Thank You!

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