Hadoop Architecture

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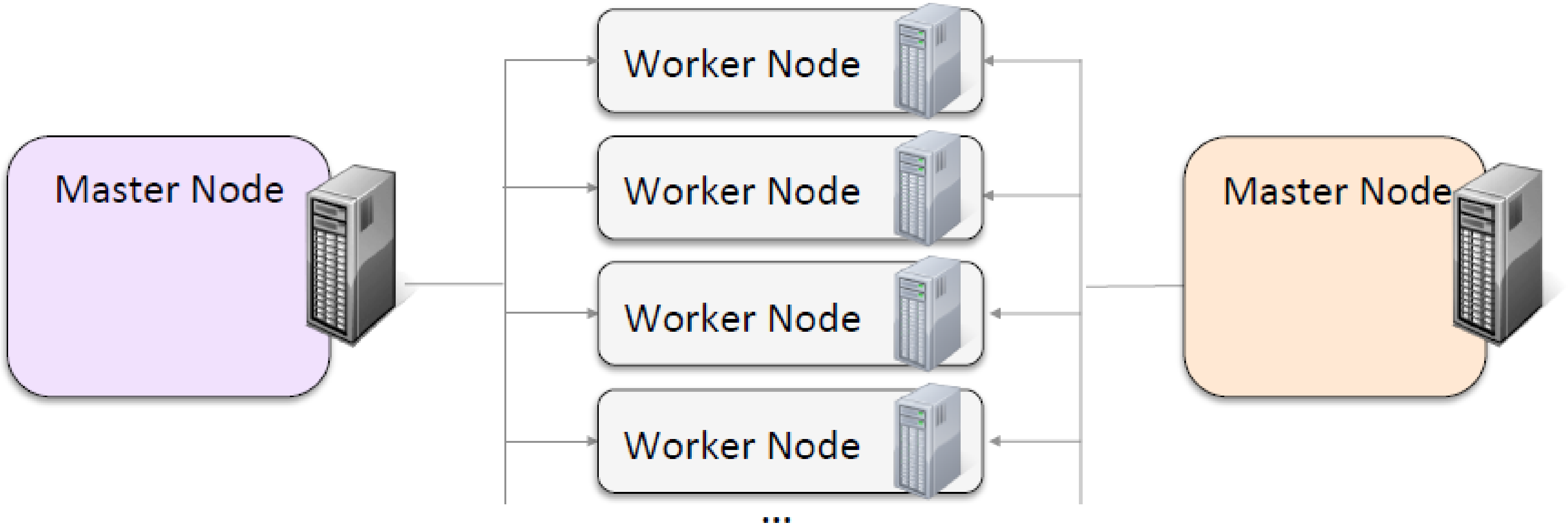
Hadoop Architecture and HDFS

In this chapter you will learn

- How Hadoop Distributed File System stores data across a cluster
- How to use HDFS using the Hue File Browser or the `hdfs` command
- How Hadoop YARN provides cluster resource management for distributed data processing
- How to use Hue, the YARN Web UI or the yarn command to monitor your cluster

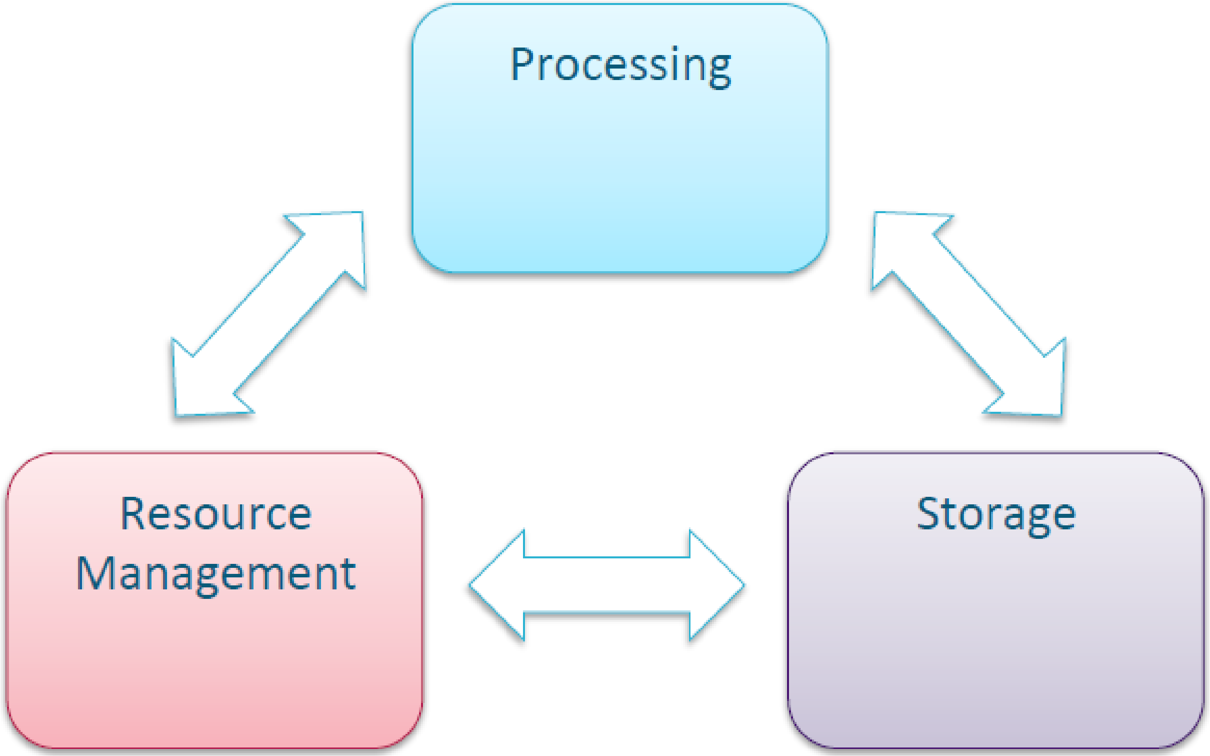
Hadoop Cluster Terminology

- **A *cluster* is a group of computers working together**
  - Provides data storage, data processing, and resource management
- **A *node* is an individual computer in the cluster**
  - *Master* nodes manage distribution of work and data to *worker* nodes
- **A *daemon* is a program running on a node**
  - Each Hadoop daemon performs a specific function in the cluster



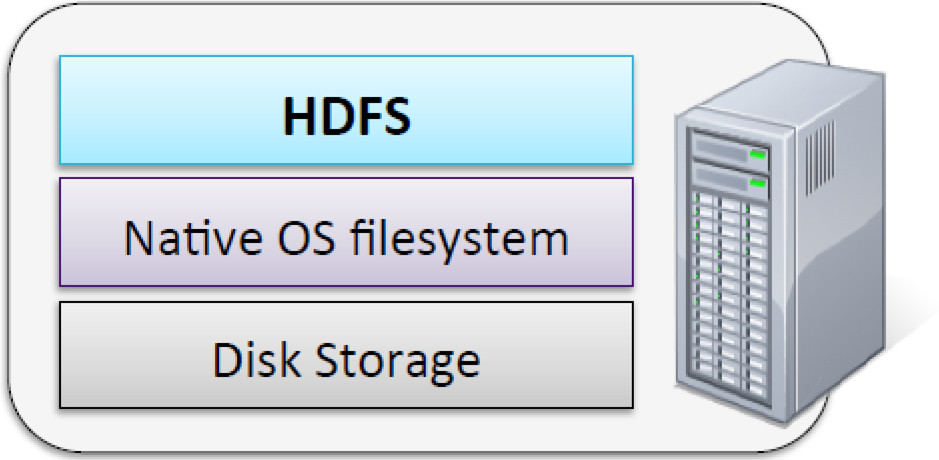
Cluster Components

- **Three main components of a cluster**
- **Work together to provide distributed data processing**
- **We will start with the Storage component**
  - HDFS



HDFS Basic Concepts (1)

- **HDFS is a filesystem written in Java**
  - Based on Google's GFS
- **Sits on top of a native filesystem**
  - Such as ext3, ext4, or xfs
- **Provides redundant storage for massive amounts of data**
  - Using readily-available, industry-standard computers

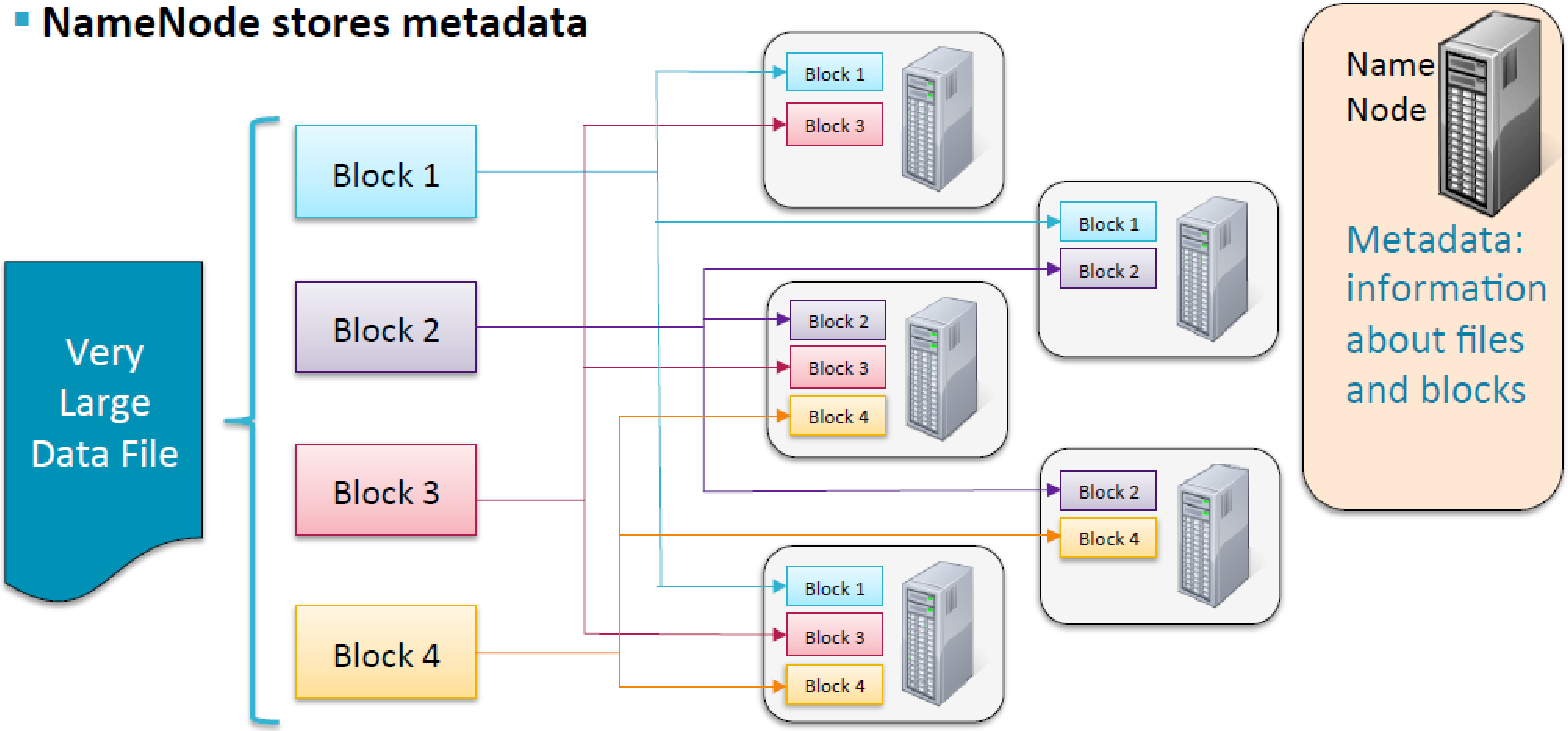


HDFS Basic Concepts (2)

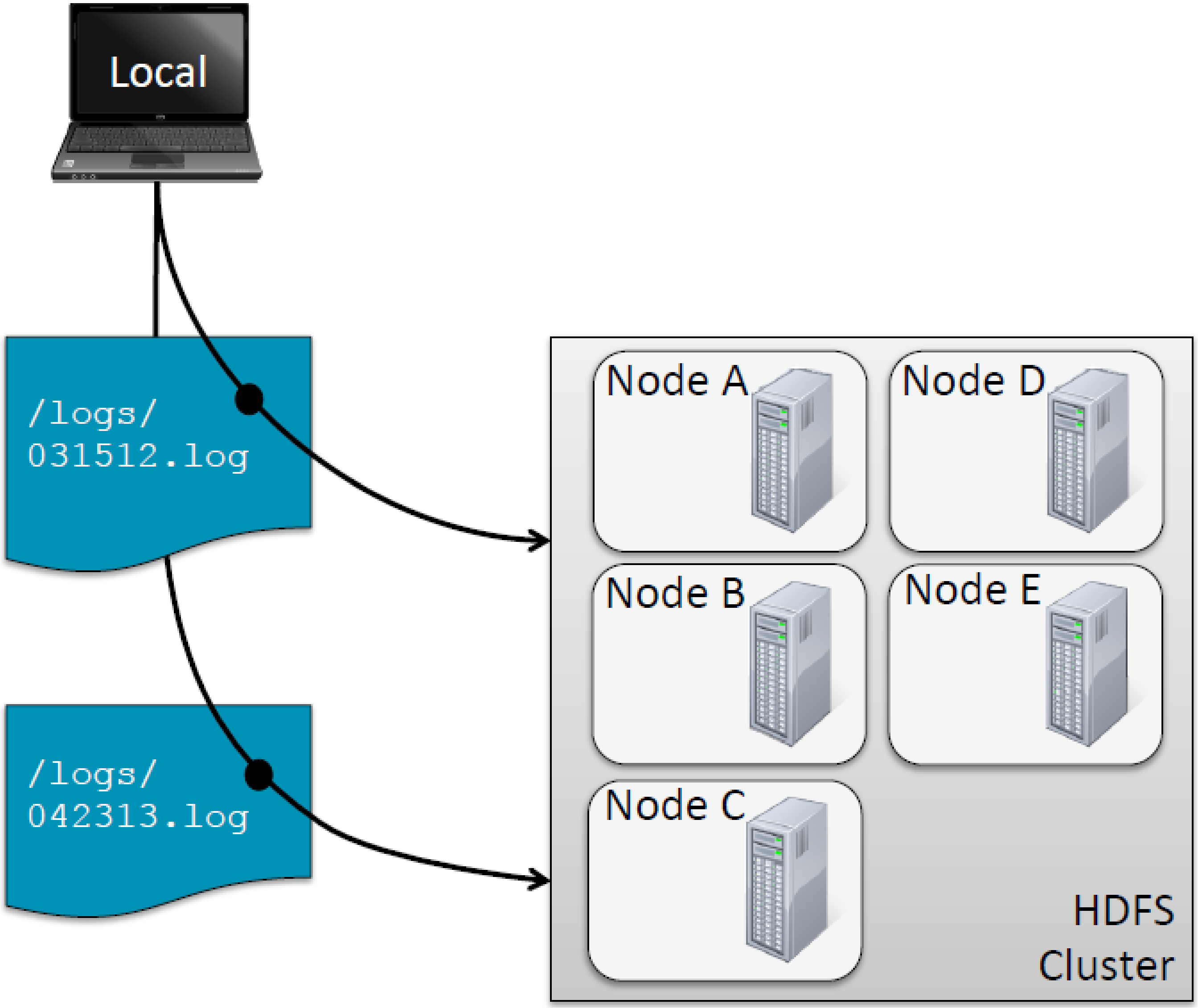
- **HDFS performs best with a ‘modest’ number of large files**
  - Millions, rather than billions, of files
  - Each file typically 100MB or more
- **Files in HDFS are ‘write once’**
  - No random writes to files are allowed
- **HDFS is optimized for large, streaming reads of files**
  - Rather than random reads

How Files Are Stored

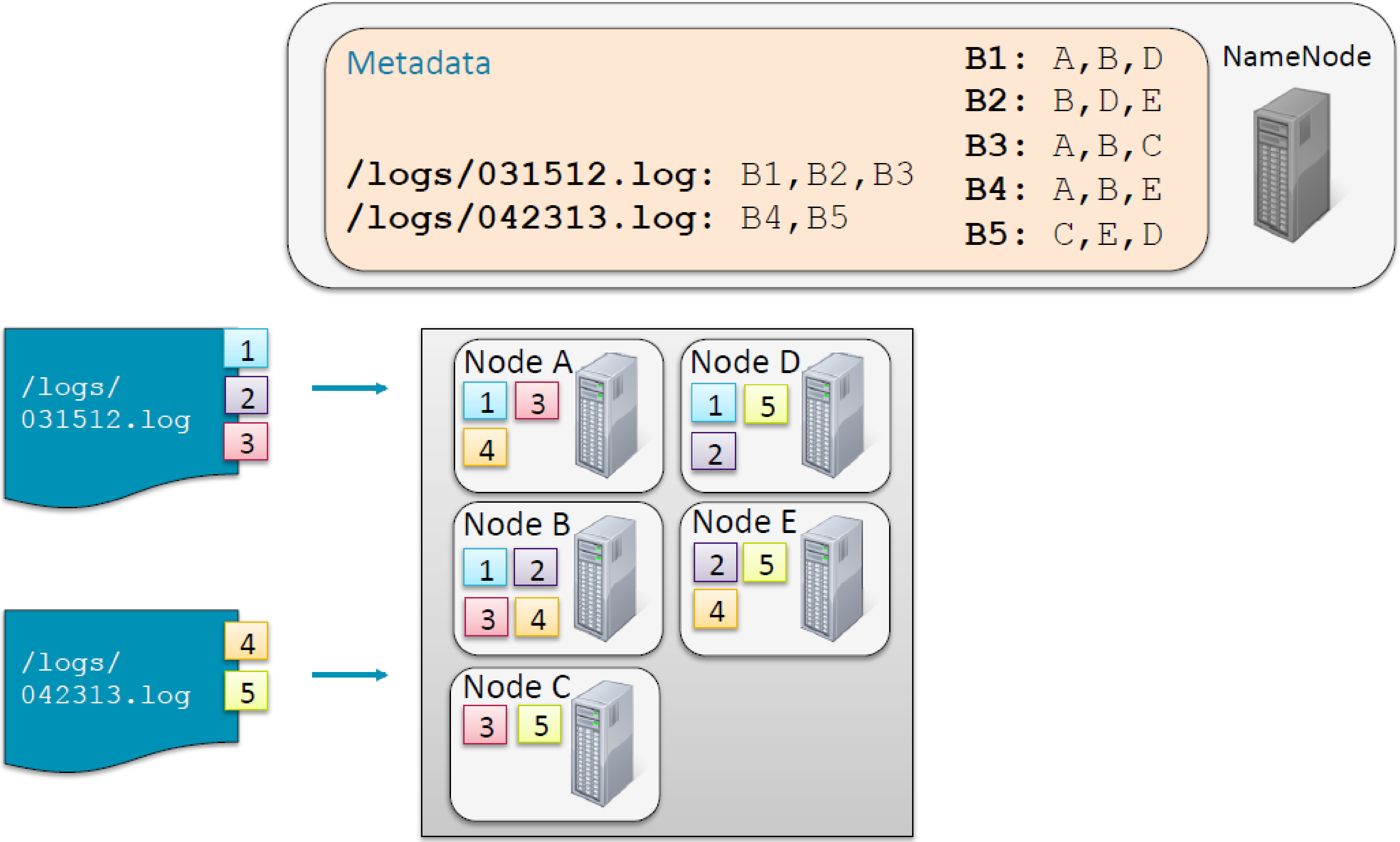
- Data files are split into 128MB blocks which are distributed at load time
- Each block is replicated on multiple data nodes (default 3x)
- NameNode stores metadata



Example: Storing and Retrieving Files (1)



Example: Storing and Retrieving Files (2)

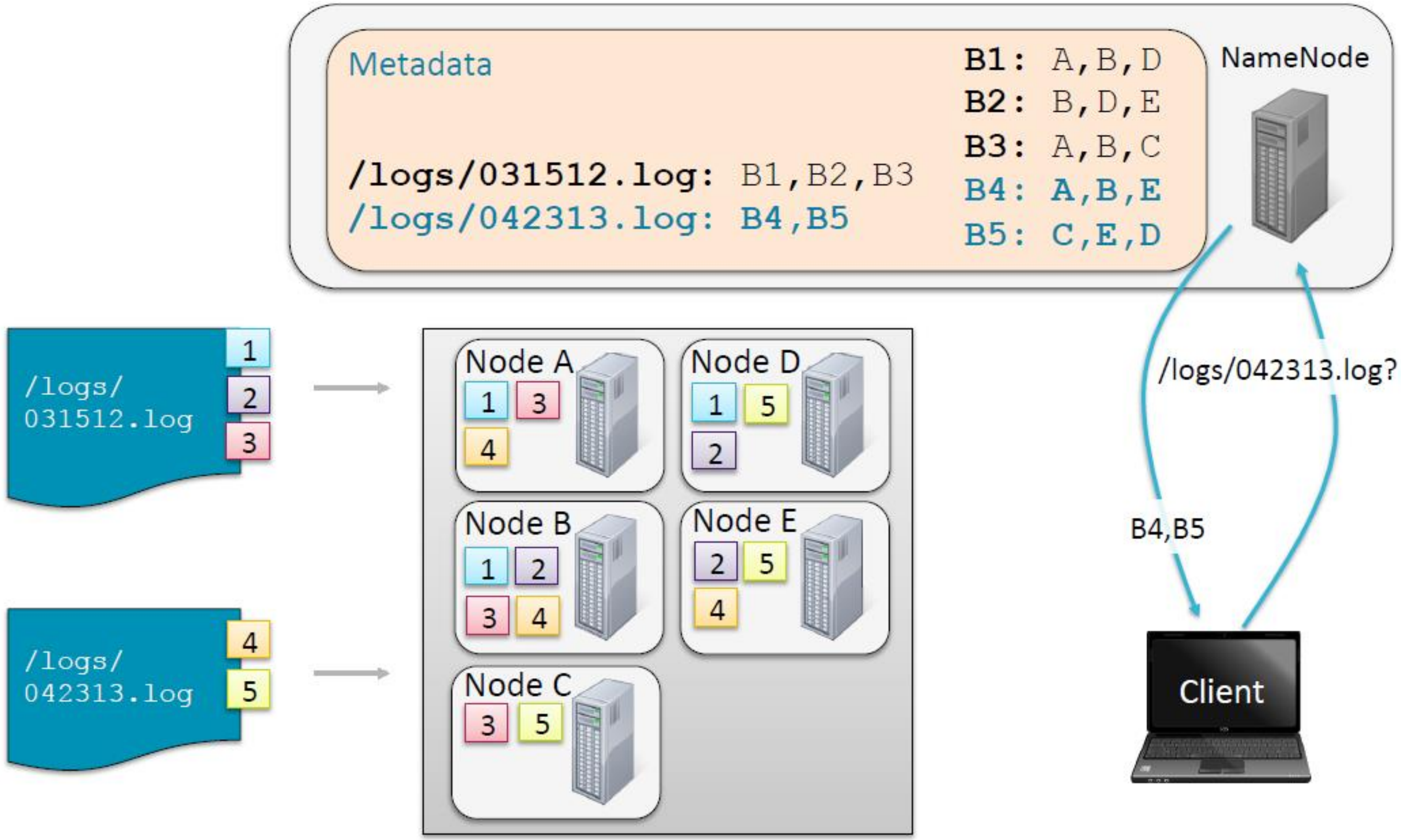


Metadata

```
/logs/031512.log: B1,B2,B3
/logs/042313.log: B4,B5
```

```
B1: A,B,D
B2: B,D,E
B3: A,B,C
B4: A,B,E
B5: C,E,D
```

Example: Storing and Retrieving Files (3)



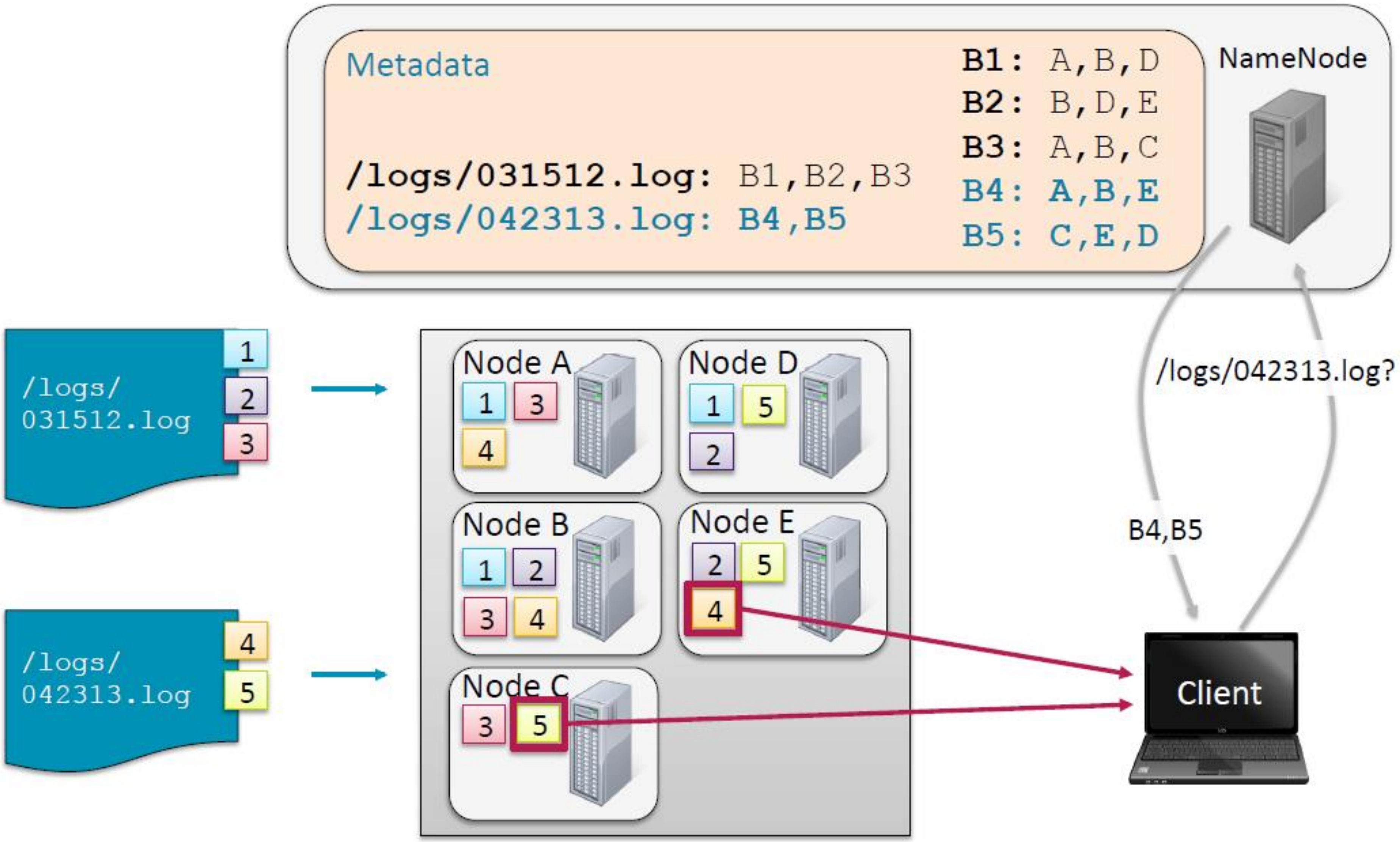
Metadata

/logs/031512.log: B1,B2,B3
/logs/042313.log: B4,B5

B1: A,B,D
B2: B,D,E
B3: A,B,C
B4: A,B,E
B5: C,E,D

NameNode

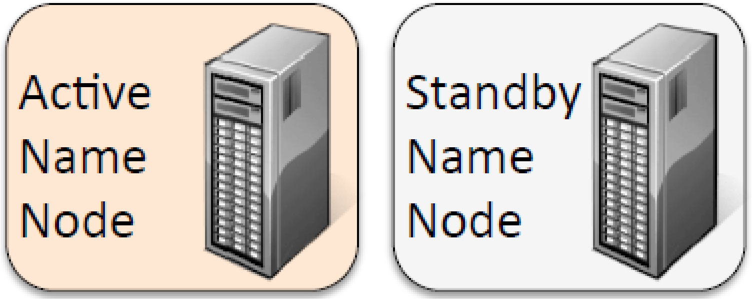
Example: Storing and Retrieving Files (4)



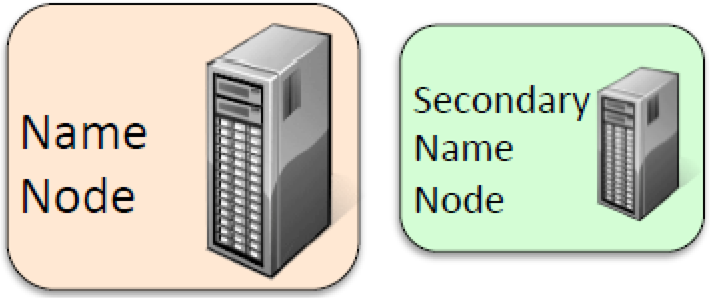
HDFS NameNode Availability

- **The NameNode daemon must be running at all times**
  - If the NameNode stops, the cluster becomes inaccessible

- **HDFS is typically set up for High Availability**
  - Two NameNodes: Active and Standby



- **Small clusters may use ‘Classic mode’**
  - One NameNode
  - One “helper” node called the Secondary NameNode
    - Bookkeeping, not backup



Options for Accessing HDFS

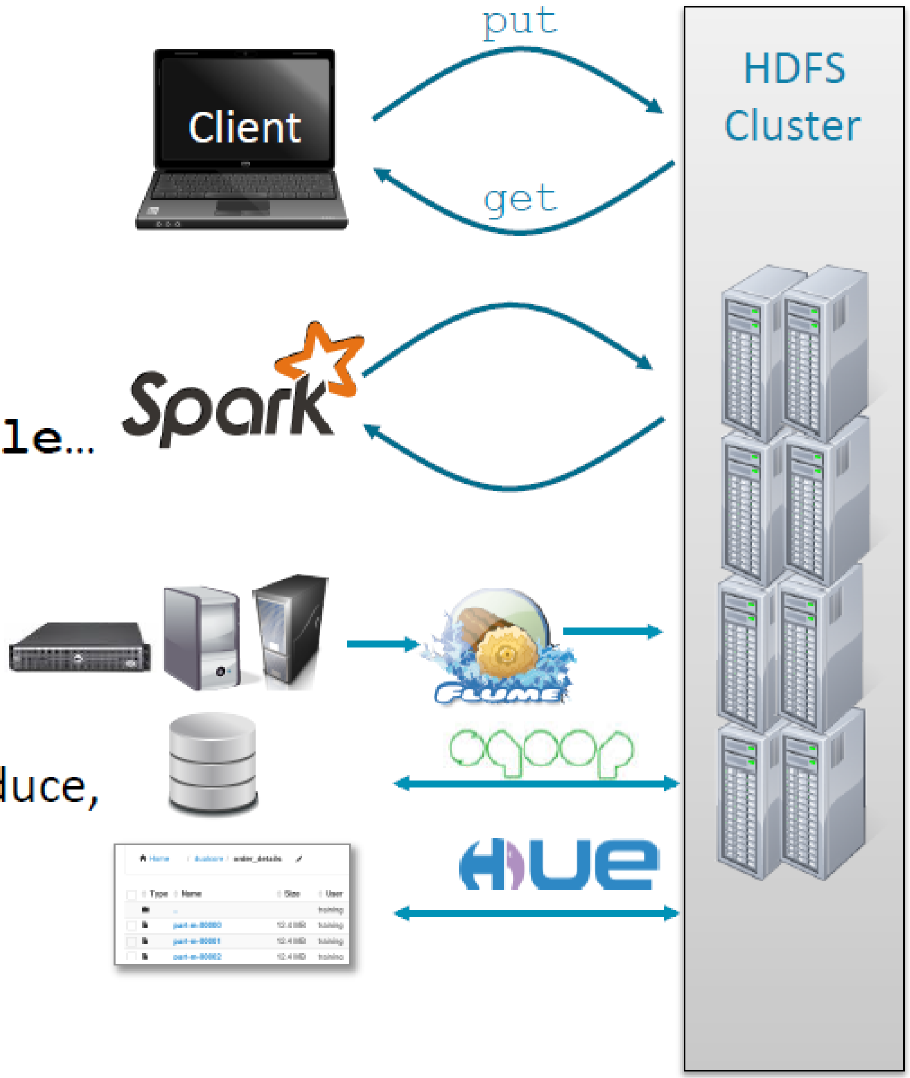
- **From the command line**
  - FsShell:

```
$ hdfs dfs
```

- **In Spark**
  - By URI, e.g.

```
hdfs://nnhost:port/file…
```

- **Other programs**
  - Java API
    - Used by Hadoop MapReduce, Impala, Hue, Sqoop, Flume, etc.
  - RESTful interface



HDFS Command Line Examples (1)

- **Copy file `foo.txt` from local disk to the user's directory in HDFS**

```
$ hdfs dfs -put foo.txt foo.txt
```

  - This will copy the file to `/user/`*`username`*`/foo.txt`

- **Get a directory listing of the user's home directory in HDFS**

```
$ hdfs dfs -ls
```

- **Get a directory listing of the HDFS root directory**

```
$ hdfs dfs -ls /
```

HDFS Command Line Examples (2)

- Display the contents of the HDFS file `/user/fred/bar.txt`

```
$ hdfs dfs -cat /user/fred/bar.txt
```

- Copy that file to the local disk, named as `baz.txt`

```
$ hdfs dfs -get /user/fred/bar.txt baz.txt
```

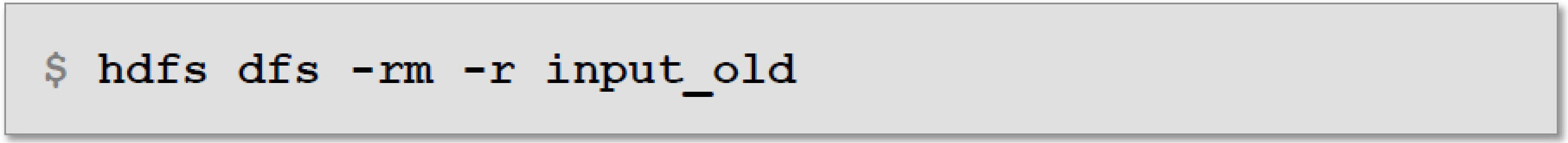
- Create a directory called `input` under the user's home directory

```
$ hdfs dfs -mkdir input
```

Note: `copyFromLocal` is a synonym for `put`; `copyToLocal` is a synonym for `get`

HDFS Command Line Examples (3)

- Delete the directory input_old and all its contents



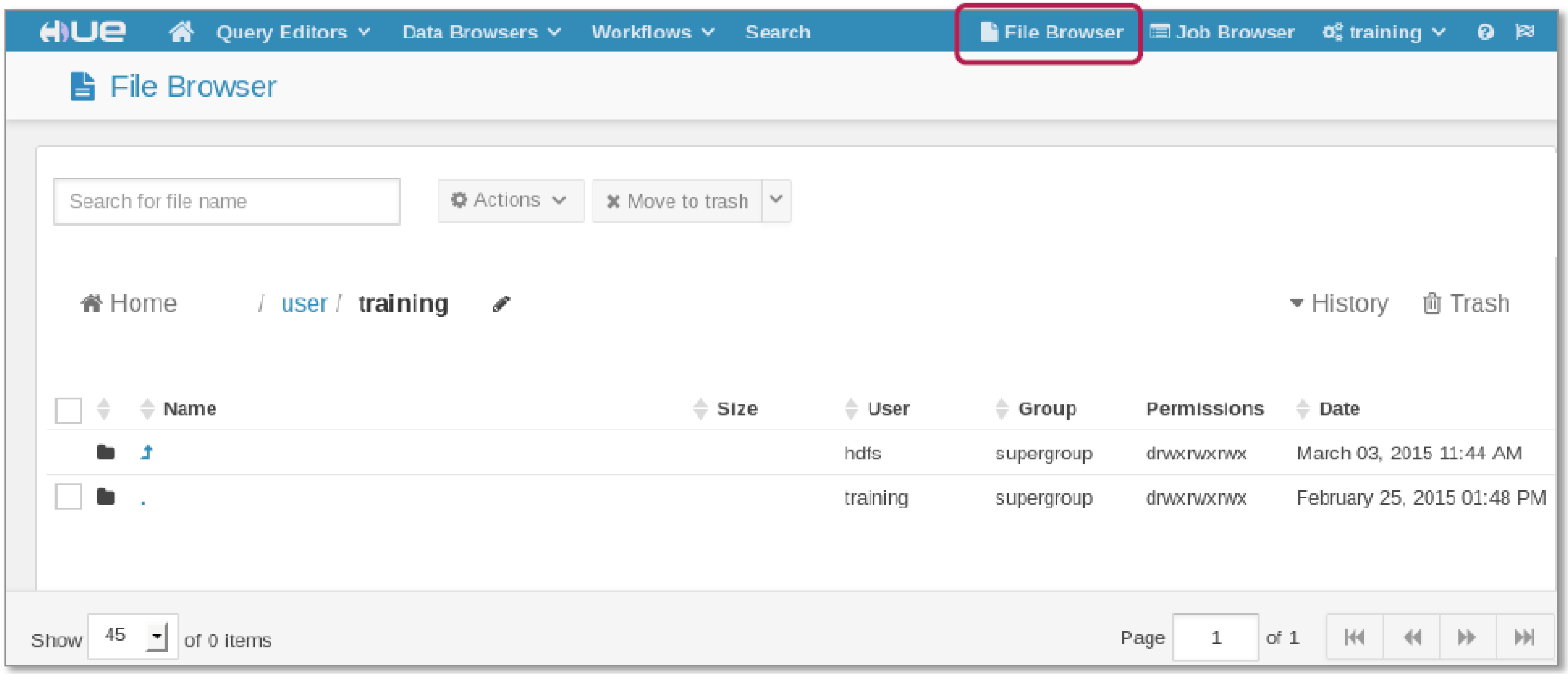
```
$ hdfs dfs -rm -r input_old
```

Practice1: Access HDFS with Command Line

- **In this homework lab you will**
  - Create a `/loudacre` base directory for course homework
  - Practice uploading and viewing data files
- **Please refer to the Homework description**

The Hue HDFS File Browser

- **The File Browser in Hue lets you view and manage your HDFS directories and files**
  - Create, move, rename, modify, upload, download and delete directories and files
  - View file contents



□	Name	Size	User	Group	Permissions	Date
	↥		hdfs	supergroup	drwxrwxrwx	March 03, 2015 11:44 AM
□	.		training	supergroup	drwxrwxrwx	February 25, 2015 01:48 PM

HDFS Recommendations

- **HDFS is a repository for all your data**
  - Structure and organize carefully!
- **Best practices include**
  - Define a standard directory structure
  - Include separate locations for staging data
- **Example organization**
  - `/user/`… – data and configuration belonging only to a single user
  - `/etl` – Work in progress in Extract/Transform/Load stage
  - `/tmp` – Temporary generated data shared between users
  - `/data` – Data sets that are processed and available across the organization for analysis
  - `/app` – Non-data files such as configuration, JAR files, SQL files, etc.

Practice2: Access HDFS with Hue

- **In this homework lab you will**
  - Create a `/loudacre` base directory for course homework
  - Practice uploading and viewing data files
- **Please refer to the Homework description**

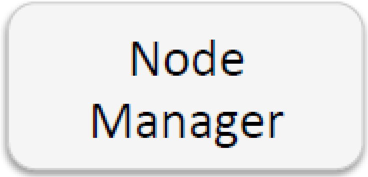
What is YARN?

- **YARN = Yet Another Resource Negotiator**
- **YARN is the Hadoop processing layer that contains**
  - A resource manager
  - A job scheduler
- **YARN allows multiple data processing engines to run on a single Hadoop cluster**
  - Batch programs (e.g. Spark, MapReduce)
  - Interactive SQL (e.g. Impala)
  - Advanced analytics (e.g. Spark, Impala)
  - Streaming (e.g. Spark Streaming)

YARN Daemons

- **Resource Manager (RM)**
  - Runs on master node
  - Global resource scheduler
  - Arbitrates system resources between competing applications
  - Has a pluggable scheduler to support different algorithms (capacity, fair scheduler, etc.)

- **Node Manager (NM)**
  - Runs on slave nodes
  - Communicates with RM



Running an Application in YARN

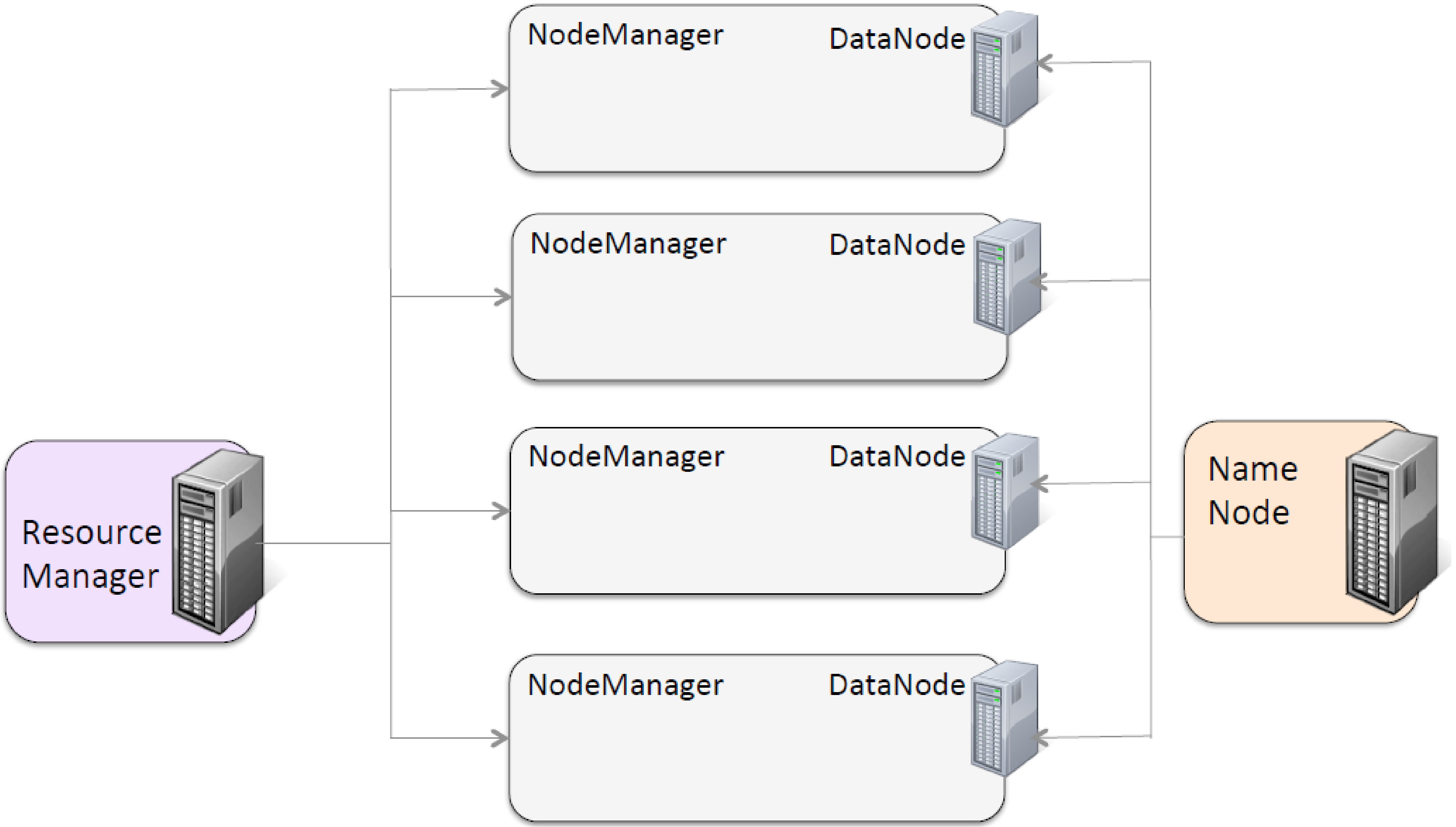
- **Containers**
  - Created by the RM upon request
  - Allocate a certain amount of resources (memory, CPU) on a slave node
  - Applications run in one or more containers

Container

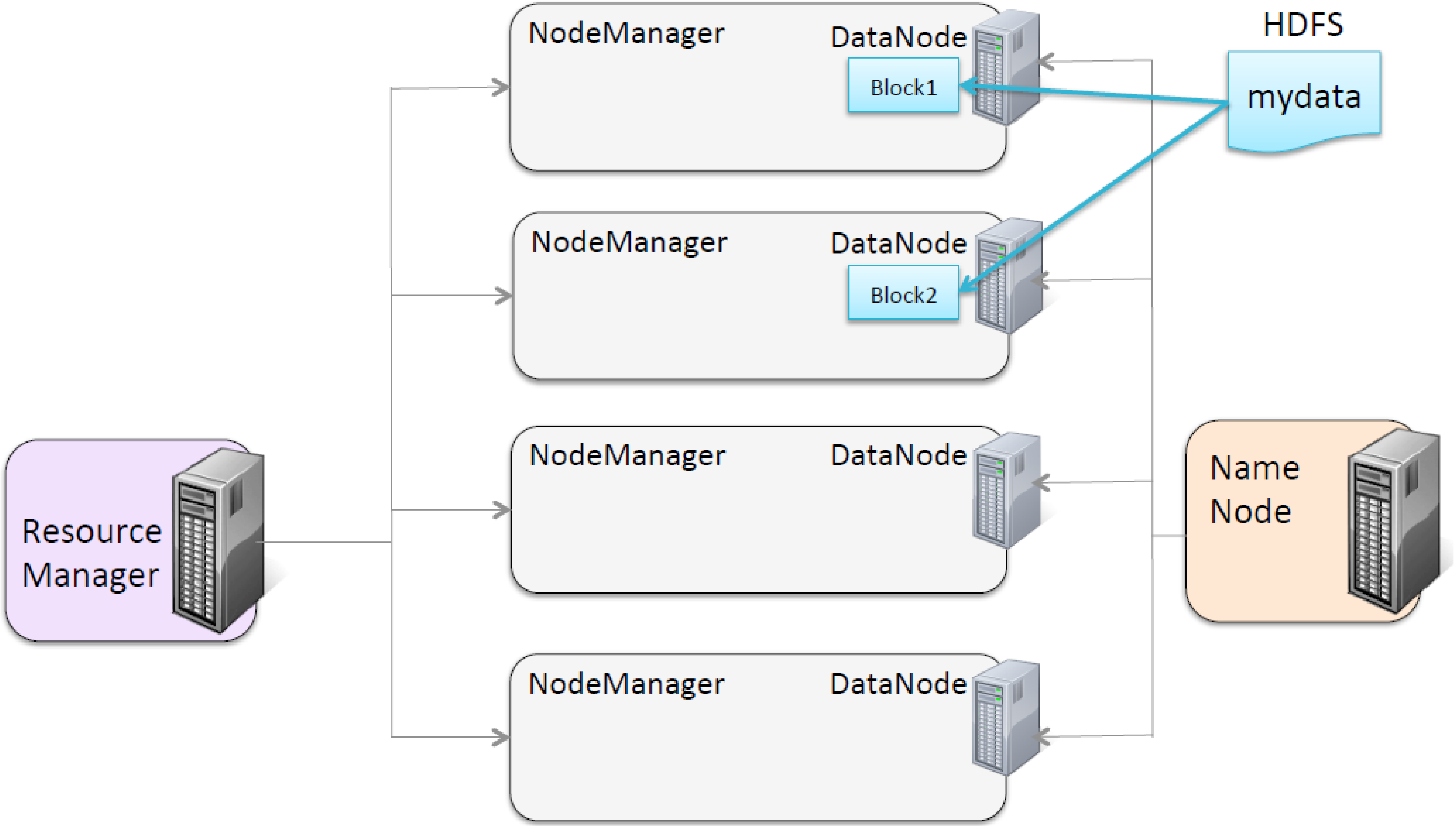
- **Application Master (AM)**
  - One per application
  - Framework/application specific
  - Runs in a container
  - Requests more containers to run application tasks

Application Master

Running an Application on YARN (1)

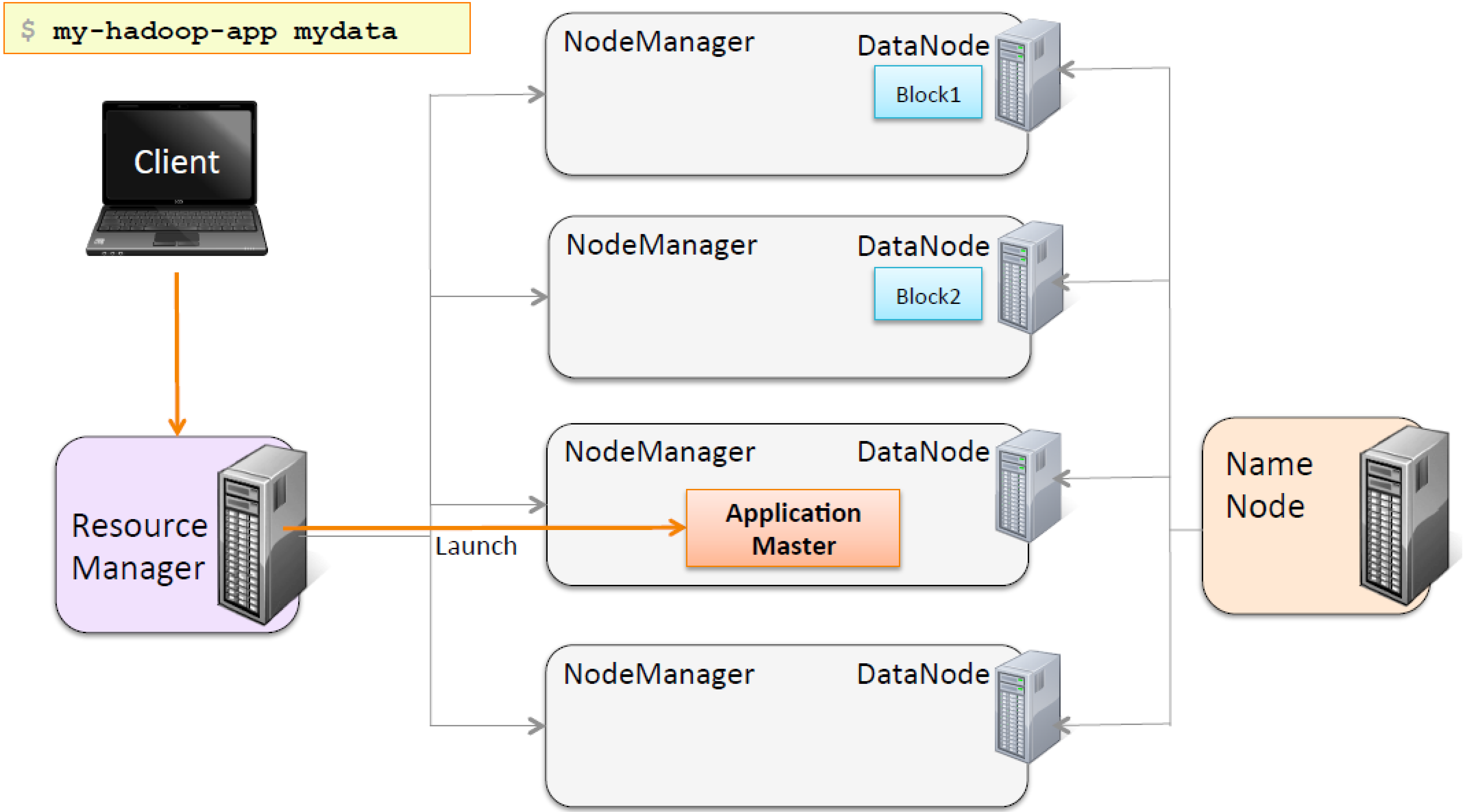


Running an Application on YARN (2)



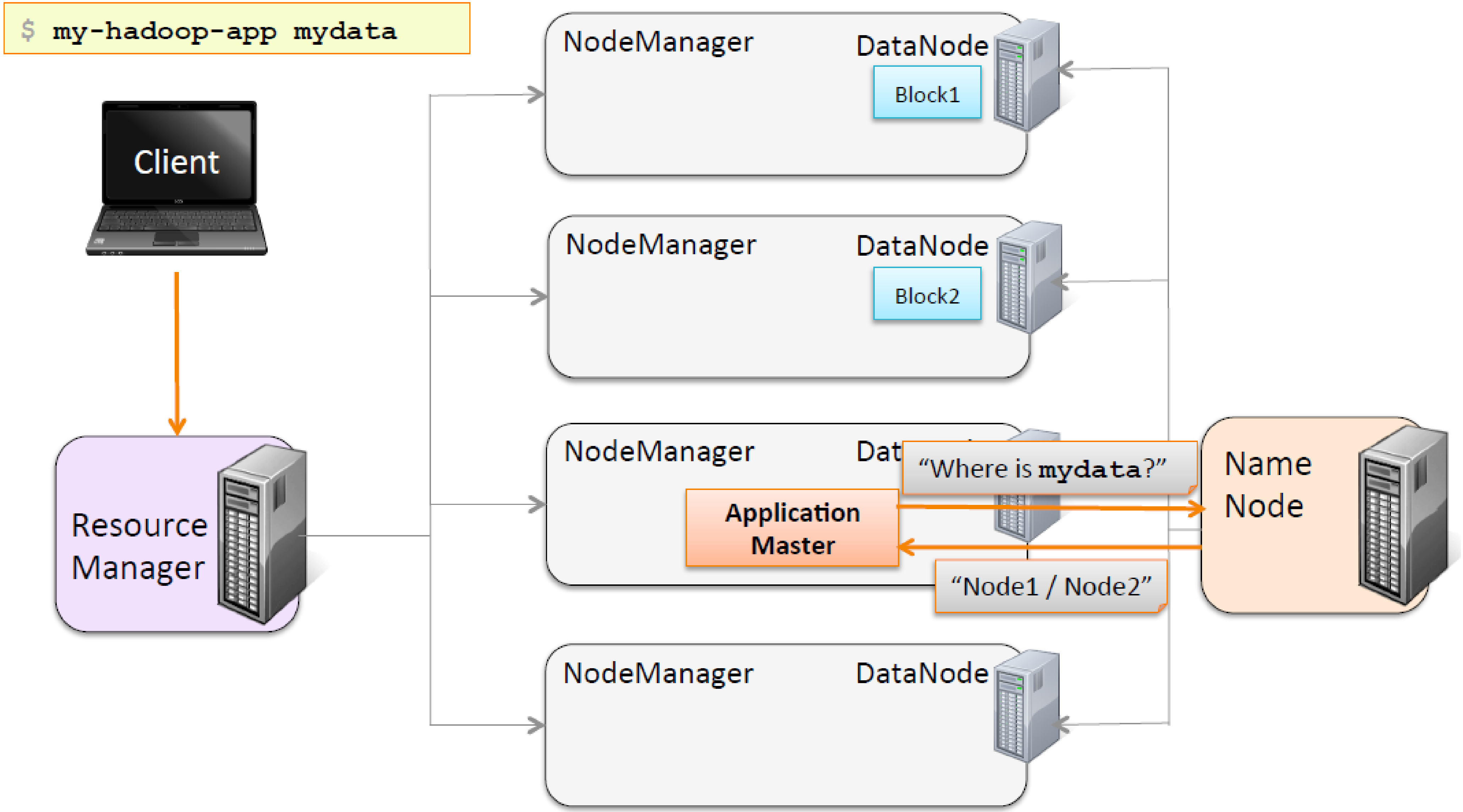
Running an Application on YARN (3)

```
$ my-hadoop-app mydata
```



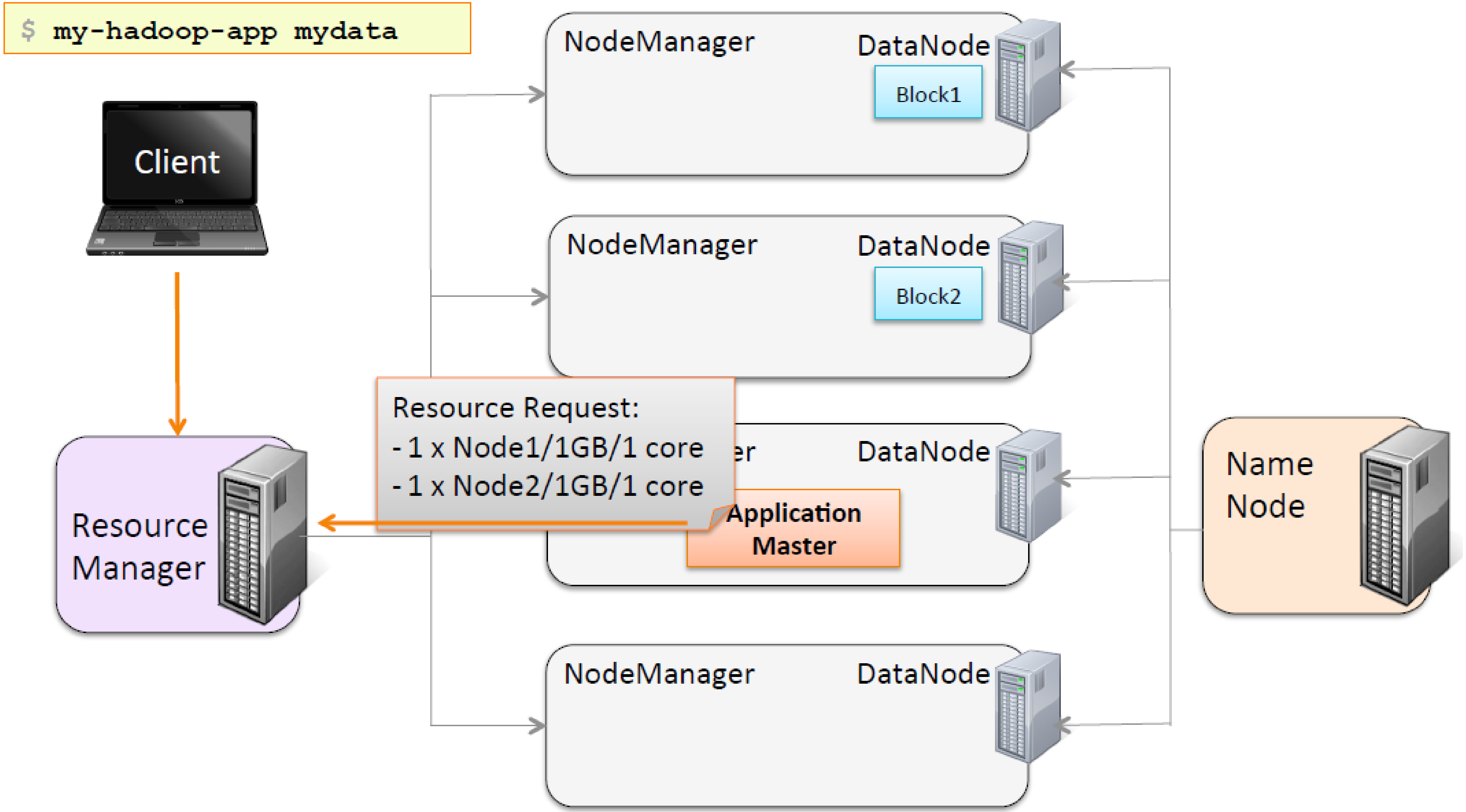
Running an Application on YARN (4)

```
$ my-hadoop-app mydata
```



Running an Application on YARN (5)

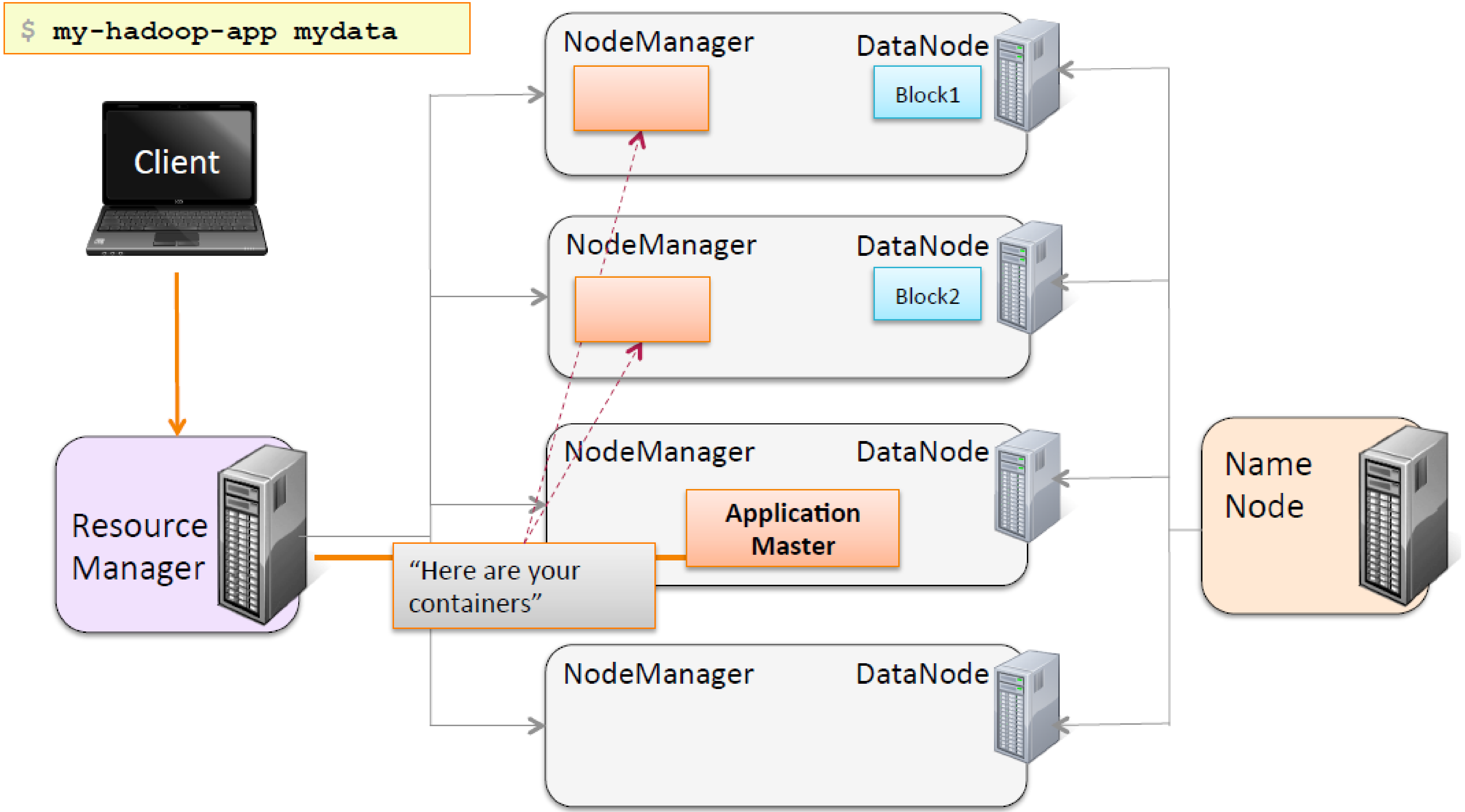
```
$ my-hadoop-app mydata
```



Resource Request:
- 1 x Node1/1GB/1 core
- 1 x Node2/1GB/1 core

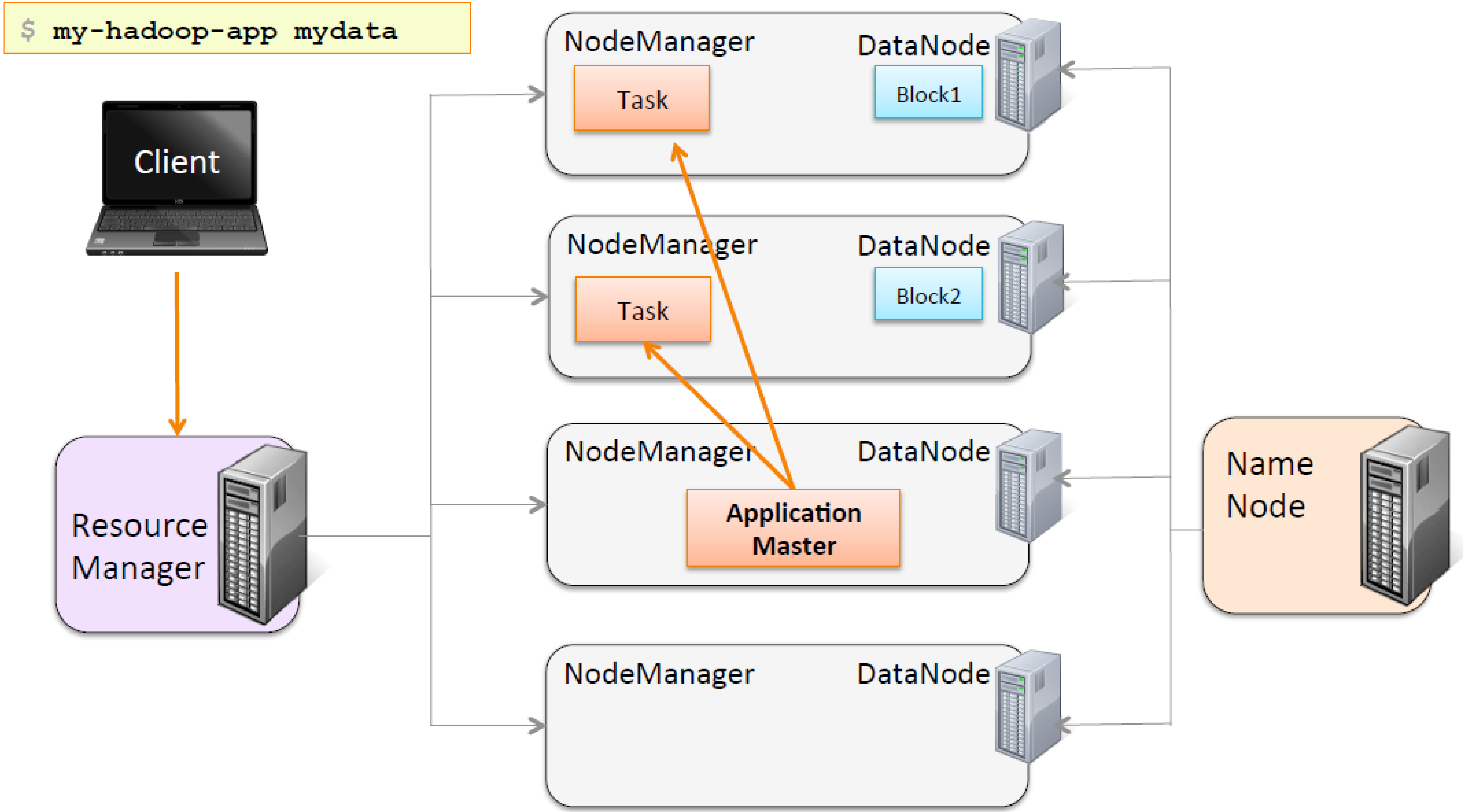
Running an Application on YARN (6)

```
$ my-hadoop-app mydata
```



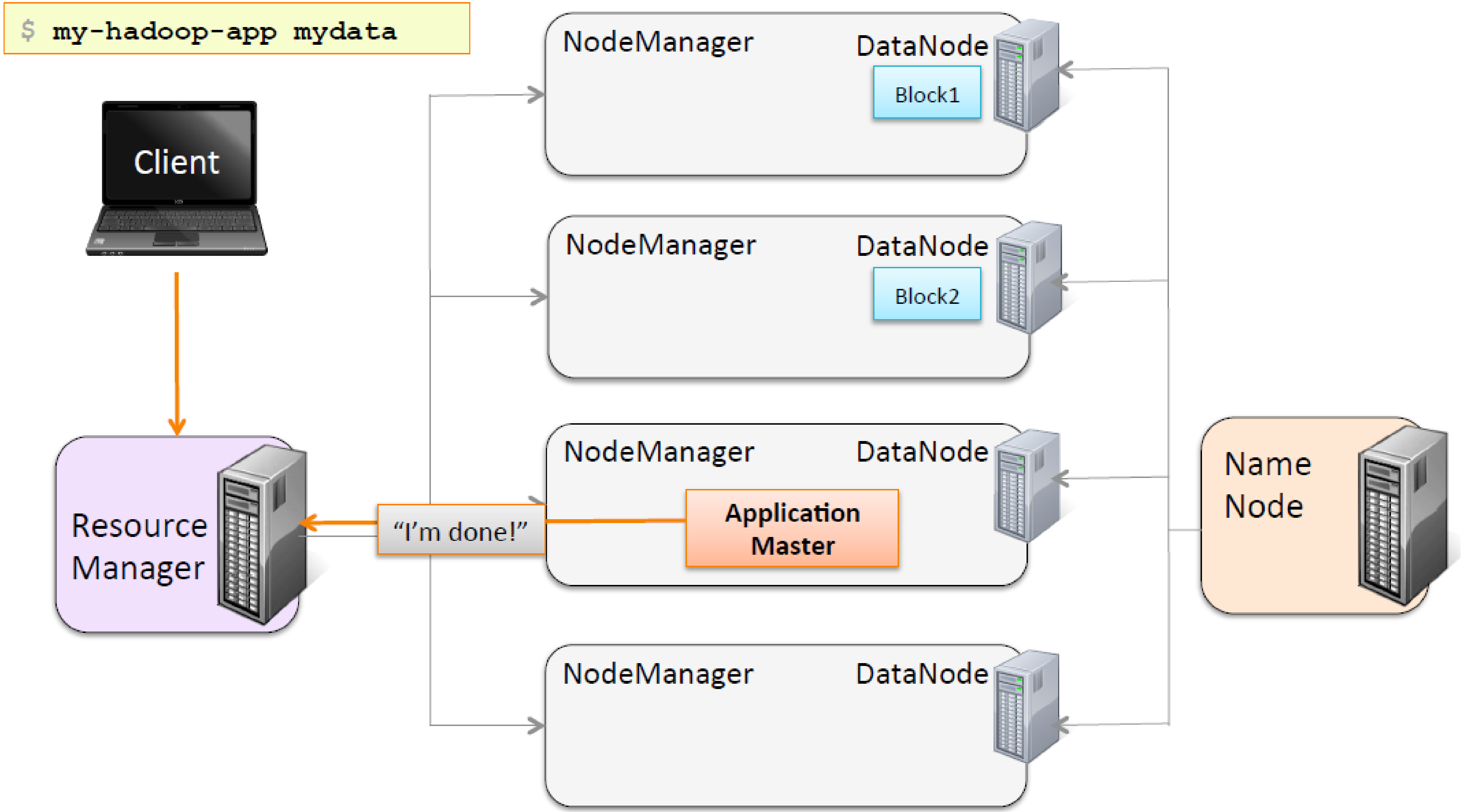
Running an Application on YARN (7)

```
$ my-hadoop-app mydata
```



Running an Application on YARN (8)

```
$ my-hadoop-app mydata
```

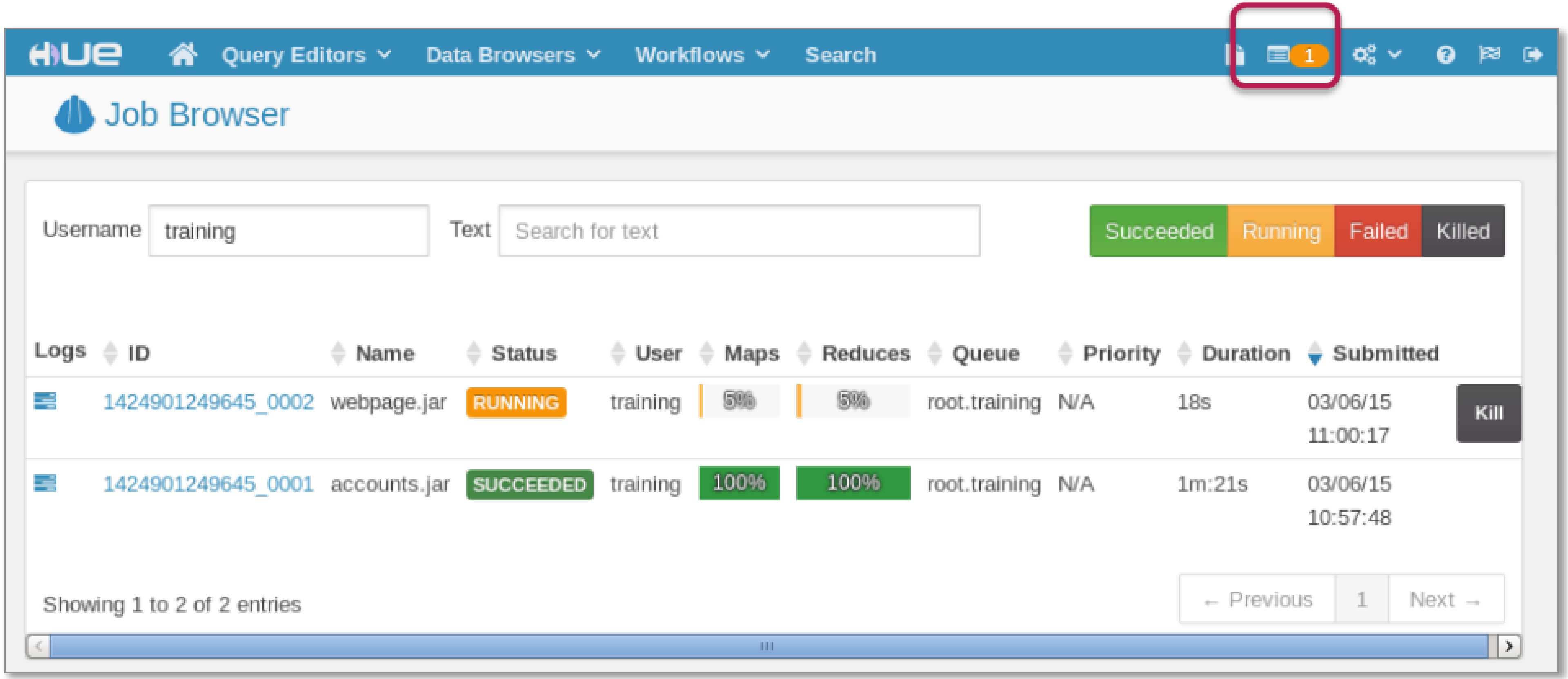


Working with YARN

- **Developers need to be able to**
  - Submit jobs (applications) to run on the YARN cluster
  - Monitor and manage jobs
- **Hadoop includes three major YARN tools for developers**
  - The Hue Job Browser
  - The YARN Web UI
  - The YARN command line

The Hue Job Browser

- **The Hue Job Browser allows you to**
  - Monitor the status of a job
  - View the logs
  - Kill a running job



Username: training

Text: Search for text

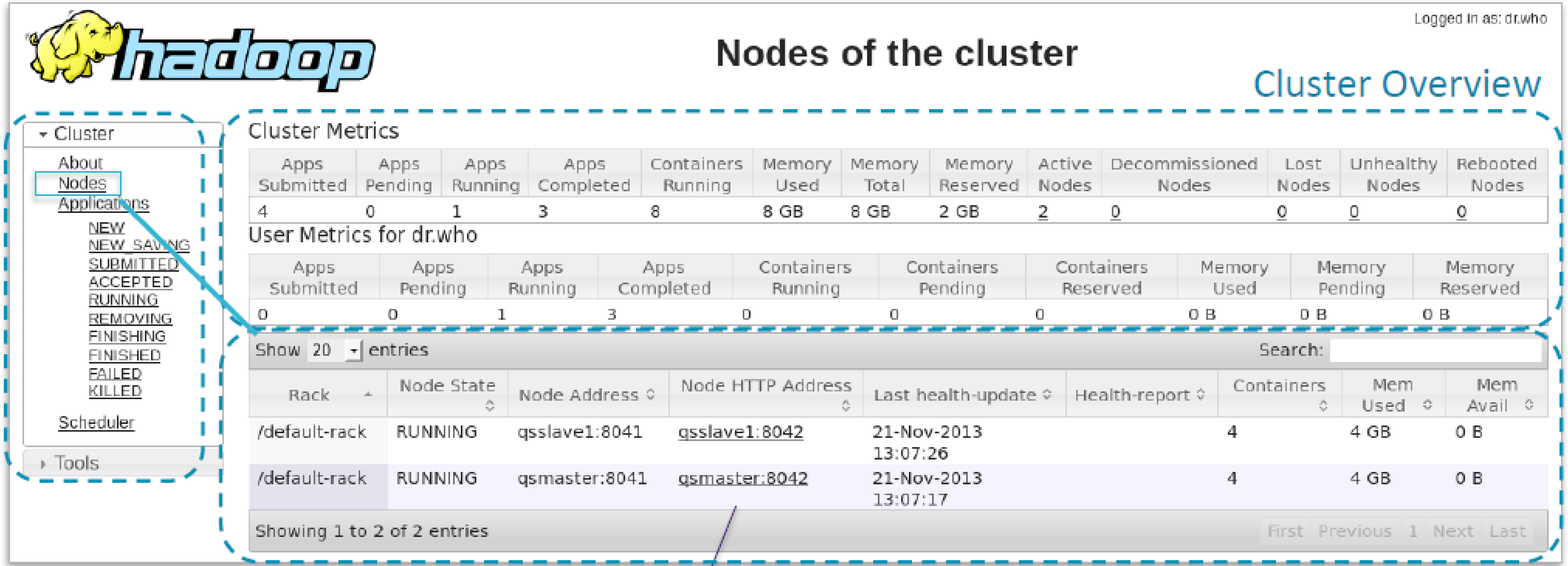
Logs	ID	Name	Status	User	Maps	Reduces	Queue	Priority	Duration	Submitted	
☰	1424901249645_0002	webpage.jar	RUNNING	training	5%	5%	root.training	N/A	18s	03/06/15 11:00:17	Kill
☰	1424901249645_0001	accounts.jar	SUCCEEDED	training	100%	100%	root.training	N/A	1m:21s	03/06/15 10:57:48	

Showing 1 to 2 of 2 entries

The YARN Web UI

- **Resource Manager UI is the main entry point**
  - Runs on the RM host on port 8080 by default
- **Provides more detailed view than Hue**
- **Does not provide any control or configuration**

Resource Manager UI: Nodes



Logged in as: dr.who

Nodes of the cluster

Cluster Overview

Cluster Metrics

Apps Submitted	Apps Pending	Apps Running	Apps Completed	Containers Running	Memory Used	Memory Total	Memory Reserved	Active Nodes	Decommissioned Nodes	Lost Nodes	Unhealthy Nodes	Rebooted Nodes
4	0	1	3	8	8 GB	8 GB	2 GB	2	0	0	0	0

User Metrics for dr.who

Apps Submitted	Apps Pending	Apps Running	Apps Completed	Containers Running	Containers Pending	Containers Reserved	Memory Used	Memory Pending	Memory Reserved
0	0	1	3	0	0	0	0 B	0 B	0 B

Show 20 entries Search:

Rack	Node State	Node Address	Node HTTP Address	Last health-update	Health-report	Containers	Mem Used	Mem Avail
/default-rack	RUNNING	qsslave1:8041	qsslave1:8042	21-Nov-2013 13:07:26		4	4 GB	0 B
/default-rack	RUNNING	qsmaster:8041	qsmaster:8042	21-Nov-2013 13:07:17		4	4 GB	0 B

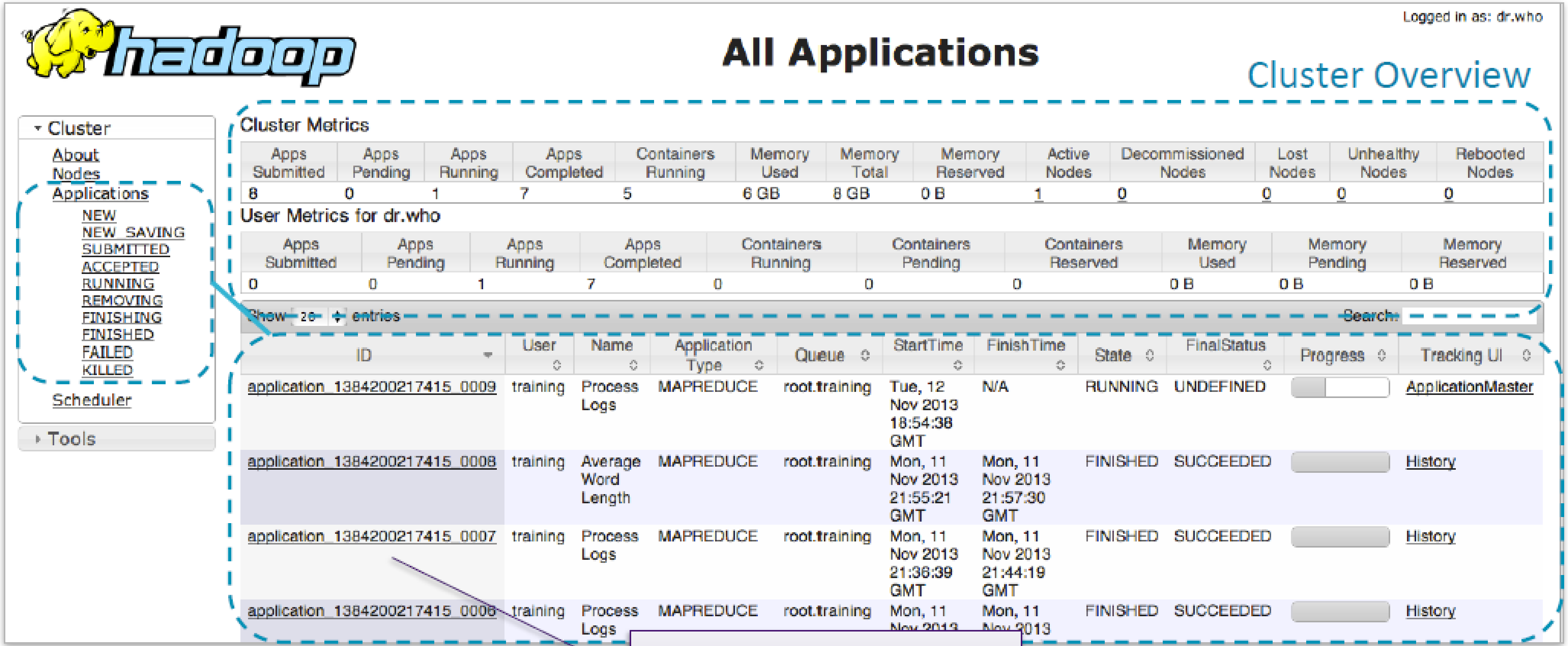
Showing 1 to 2 of 2 entries

First Previous 1 Next Last

link to Node Manager UI

List of each node in cluster

Resource Manager UI: Applications



Logged in as: dr.who

All Applications

Cluster Overview

- Cluster
  - About
  - Nodes
  - Applications
    - NEW
    - NEW_SAVING
    - SUBMITTED
    - ACCEPTED
    - RUNNING
    - REMOVING
    - FINISHING
    - FINISHED
    - FAILED
    - KILLED
  - Scheduler
- Tools

Cluster Metrics

Apps Submitted	Apps Pending	Apps Running	Apps Completed	Containers Running	Memory Used	Memory Total	Memory Reserved	Active Nodes	Decommissioned Nodes	Lost Nodes	Unhealthy Nodes	Rebooted Nodes
8	0	1	7	5	6 GB	8 GB	0 B	1	0	0	0	0

User Metrics for dr.who

Apps Submitted	Apps Pending	Apps Running	Apps Completed	Containers Running	Containers Pending	Containers Reserved	Memory Used	Memory Pending	Memory Reserved
0	0	1	7	0	0	0	0 B	0 B	0 B

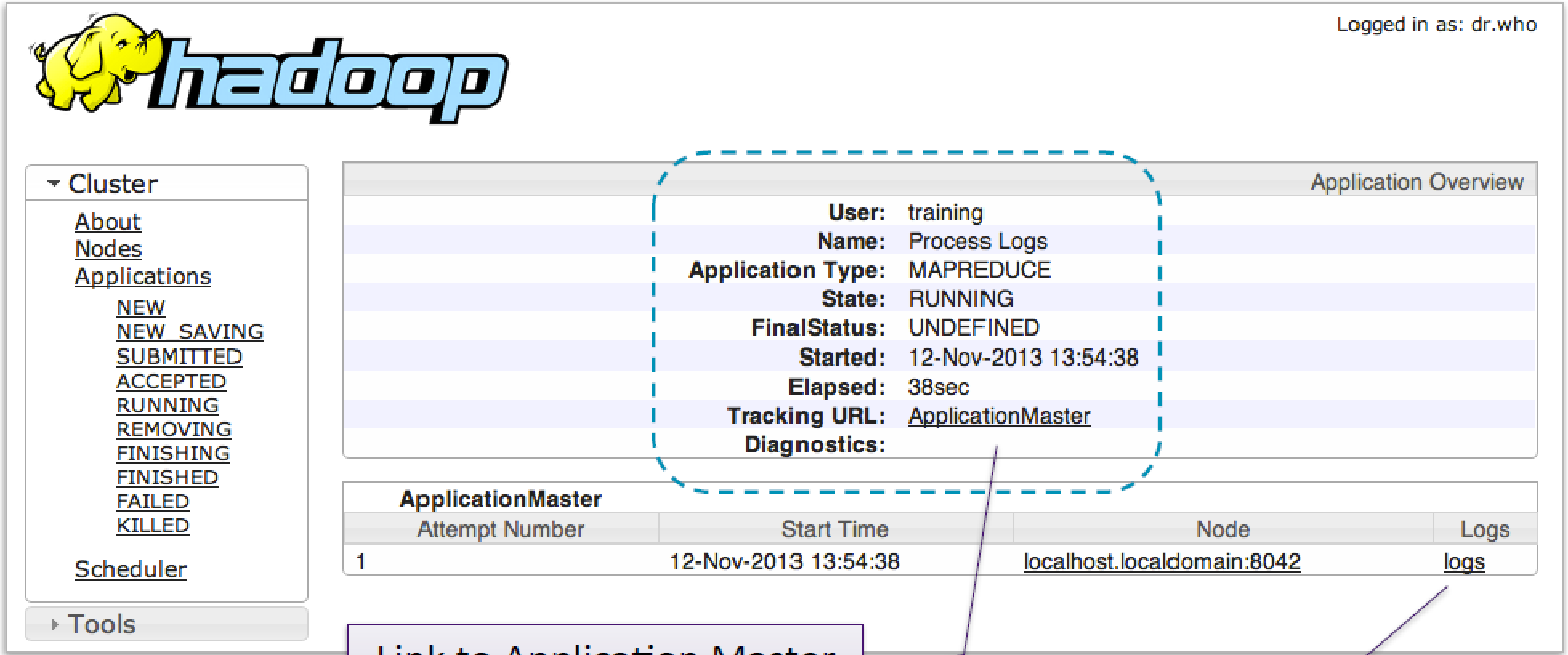
Show 20 entries Search:

ID	User	Name	Application Type	Queue	StartTime	FinishTime	State	FinalStatus	Progress	Tracking UI
application_1384200217415_0009	training	Process Logs	MAPREDUCE	root.training	Tue, 12 Nov 2013 18:54:38 GMT	N/A	RUNNING	UNDEFINED		ApplicationMaster
application_1384200217415_0008	training	Average Word Length	MAPREDUCE	root.training	Mon, 11 Nov 2013 21:55:21 GMT	Mon, 11 Nov 2013 21:57:30 GMT	FINISHED	SUCCEEDED		History
application_1384200217415_0007	training	Process Logs	MAPREDUCE	root.training	Mon, 11 Nov 2013 21:36:39 GMT	Mon, 11 Nov 2013 21:44:19 GMT	FINISHED	SUCCEEDED		History
application_1384200217415_0006	training	Process Logs	MAPREDUCE	root.training	Mon, 11 Nov 2013	Mon, 11 Nov 2013	FINISHED	SUCCEEDED		History

Link to Application Details… (next slide)

List of running and recent applications

Resource Manager UI: Application Detail



Application Overview

User:	training
Name:	Process Logs
Application Type:	MAPREDUCE
State:	RUNNING
FinalStatus:	UNDEFINED
Started:	12-Nov-2013 13:54:38
Elapsed:	38sec
Tracking URL:	ApplicationMaster
Diagnostics:	

ApplicationMaster

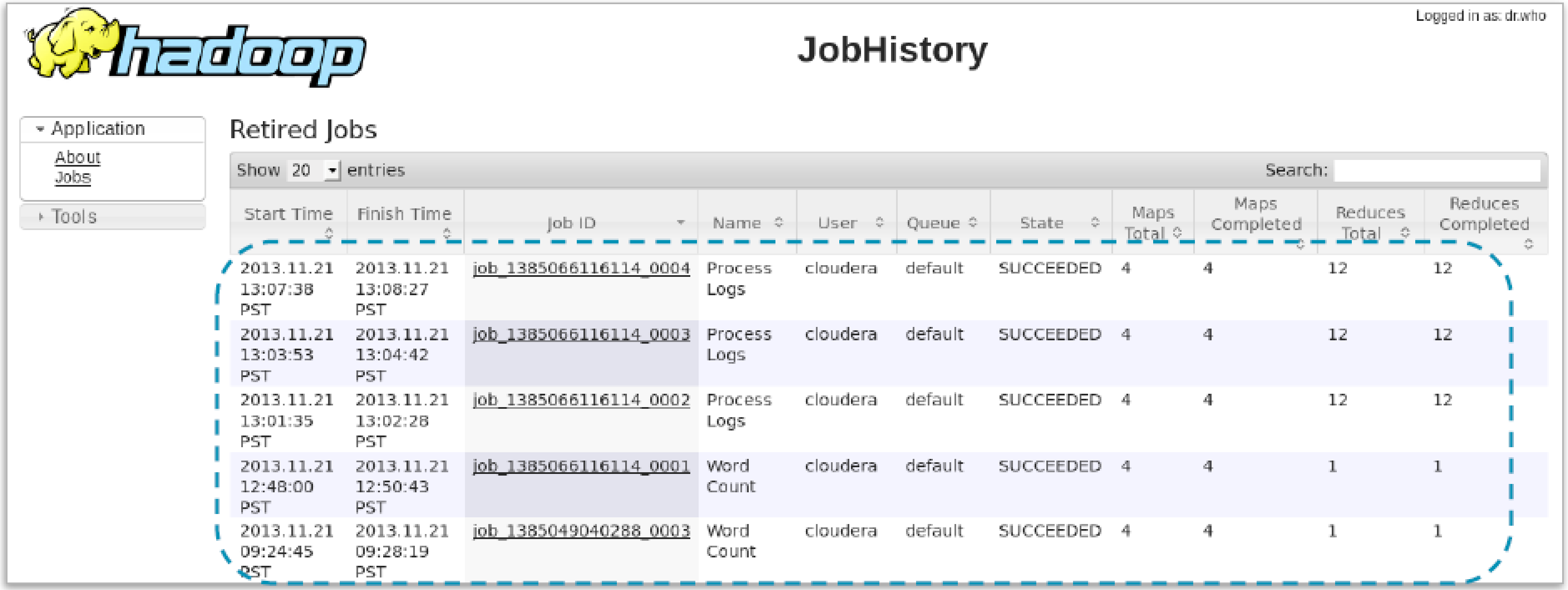
Attempt Number	Start Time	Node	Logs
1	12-Nov-2013 13:54:38	localhost.localdomain:8042	logs

Link to Application Master (UI depends on specific framework)

View aggregated log files (optional)

Job History Server

- **YARN does not keep track of job history**
- **Spark and MapReduce each provide a Job History Server**
  - Archives job’s metrics and metadata
  - Can be accessed through Job History UI or Hue



Logged in as: dr.who

JobHistory

- Application
  - About
  - Jobs
- Tools

Retired Jobs

Show 20 entries

Search:

Start Time	Finish Time	Job ID	Name	User	Queue	State	Maps Total	Maps Completed	Reduces Total	Reduces Completed
2013.11.21 13:07:38 PST	2013.11.21 13:08:27 PST	job_1385066116114_0004	Process Logs	cloudera	default	SUCCEEDED	4	4	12	12
2013.11.21 13:03:53 PST	2013.11.21 13:04:42 PST	job_1385066116114_0003	Process Logs	cloudera	default	SUCCEEDED	4	4	12	12
2013.11.21 13:01:35 PST	2013.11.21 13:02:28 PST	job_1385066116114_0002	Process Logs	cloudera	default	SUCCEEDED	4	4	12	12
2013.11.21 12:48:00 PST	2013.11.21 12:50:43 PST	job_1385066116114_0001	Word Count	cloudera	default	SUCCEEDED	4	4	1	1
2013.11.21 09:24:45 PST	2013.11.21 09:28:19 PST	job_1385049040288_0003	Word Count	cloudera	default	SUCCEEDED	4	4	1	1

YARN Command Line

- **Command to configure and view information about the YARN cluster**
  - **`yarn <command>`**
- **Most YARN command line tools are for administrators rather than developers**
- **Some helpful commands for developers**
  - **`yarn application`**
    - Use **`-list`** to see running applications
    - Use **`-kill`** to kill a running application
  - **`yarn logs -applicationId <app-id>`**
    - View the logs of the specified application

Practice3: Run a YARN Job

- **In this homework, you will**
  - Use the YARN Web UI to view your YARN cluster “at rest”
  - Submit an application to run on the cluster
  - Monitor the job using both the YARN UI and Hue
- **Please refer to the Homework description**

Essential Points

- HDFS is the storage layer for Hadoop
- Chunks data into blocks and distributes them across the cluster when data is stored
- Slave nodes run DataNode daemons, managed by a single NameNode on a master node
- Access HDFS using Hue, the `hdfs` command or via the HDFS API
- YARN manages resources in a Hadoop cluster and schedules jobs
- YARN works with HDFS to run tasks where the data is stored
- Slave nodes run NodeManager daemons, managed by a ResourceManager on a master node
- Monitor jobs using Hue, the YARN Web UI or the yarn command