MapReduce

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Data Science Immersive

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Objectives

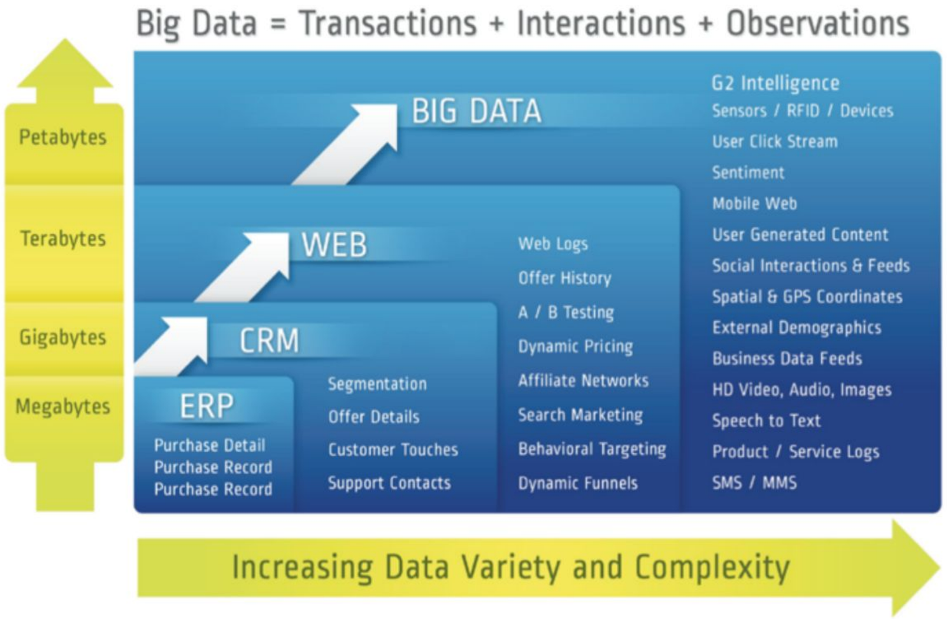
After this lecture you will be able to:

- Define BIG DATA
- List advantages and disadvantages of distributed computing
- Describe the major hardware components of a server farm
- List several components of the Hadoop Ecosystem
- List the major software components of **HDFS** and **MapReduce**.
- Track and explain computation through the MapReduce workflow
- Use Python's `mrjob` package to test some small MapReduce jobs locally

Big Data

Big Data

- Data so large that it cannot be stored on one machine.
- Can be
  - Structured: highly organized, searchable, fits into relational tables
  - Unstructured: no predefined format, multiple formats
- Often describes as 3 Vs: (high volume, velocity, and variety)

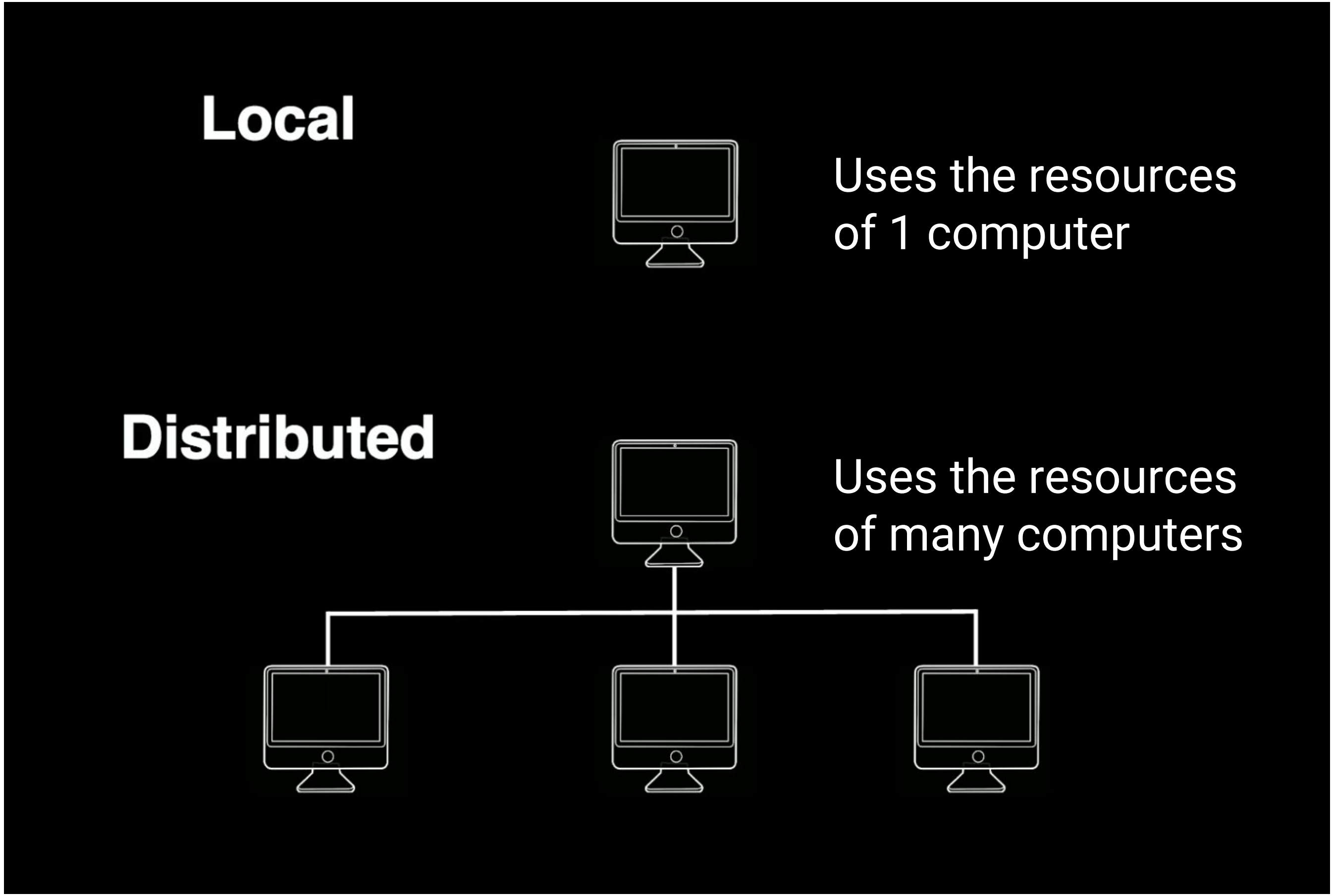


- Two possible solutions to Big Data:
  - Make bigger computers (scale up)
  - Distribute data and computation onto multiple computers (scale out)

ERP: Enterprise resource planning
CRM: Customer relationship management

Local and distributed computing

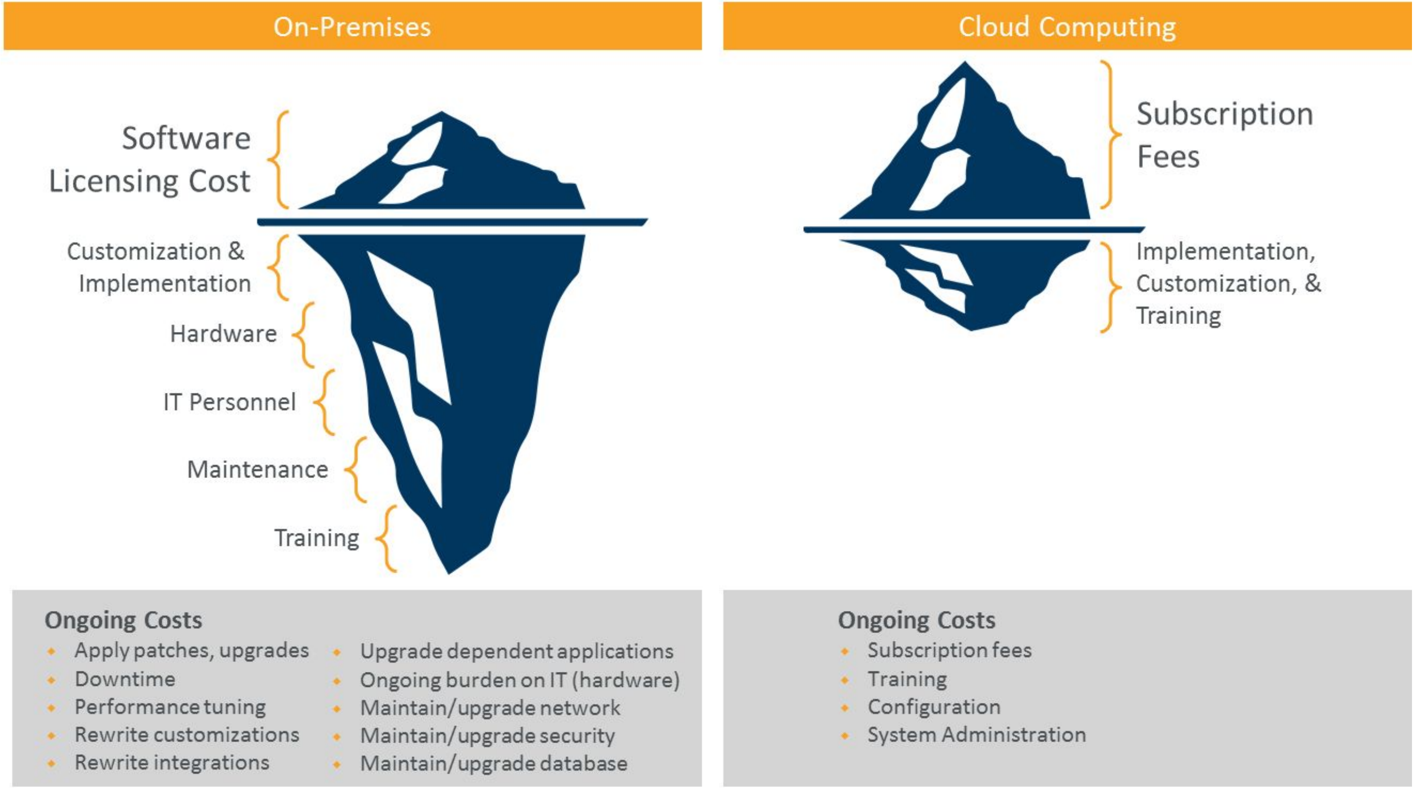
Local versus Distributed



Tangent: On-premise vs. the Cloud

<u>On-premise</u>:
Software and/or hardware that are installed on the premises of the company that uses them.

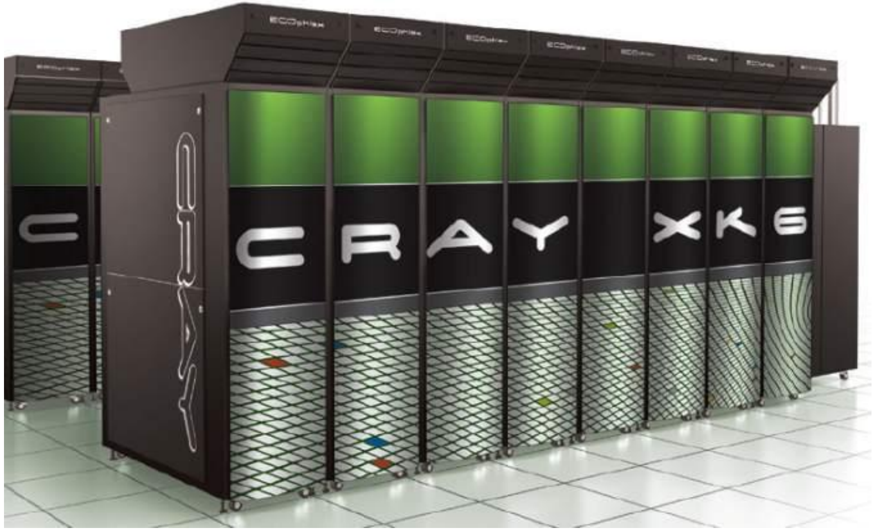
<u>Cloud</u>:
Software and/or hardware installed at a remote facility and provided to companies for a fee.



https://www.adeaca.com/blog/cloud-erp-lower-total-cost-of-ownership/#iLightbox[gallery11765]/0

Regardless if it’s on-premise or cloud, which is better?

Let’s say we have a problem that requires faster computation and more storage than any one commercial grade computer….



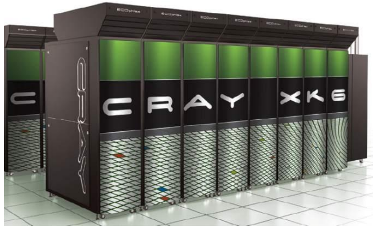
Why use a server rack
(look at all those cables!)
Distributed example: scale out

instead of

The Amazing Cray XK6
SUPERCOMPUTER
Local example: scale up

Where do Distributed vs. Local advantages lie?

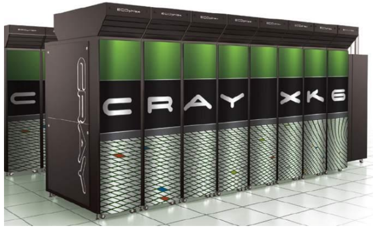
Distributed



Local

Number of cores and amount of storage		
Speed of communication between cores and storage		
Ability of cores to work on the same task		
Scalability (resource needs have changed)		
Availability (if one thing fails is whole system down?)		
Initial cost		
Operation and maintenance		

Where do Distributed vs. Local advantages lie?



	Distributed	Local
Number of cores and amount of storage	*Tie*	*Tie*
Speed of communication between cores and storage		✓
Ability of cores to work on the same task		✓
Scalability (resource needs have changed)	✓	
Availability (if one thing fails is whole system down?)	✓	
Initial cost	✓	
Operation and maintenance	?	?

Enablers of distributed computing

"Cluster computing … is changing dramatically with the advent of commodity <u>high performance processors</u>, <u>low-latency/high-bandwidth networks</u>, and <u>software infrastructure and development tools</u> to facilitate the use of the cluster.

The <u>performance of an individual processor used in a high-end personal workstation rivals that of a processor in a high-end supercomputer</u> … and the performance of the commodity processors is improving rapidly."

D.A. Bader and R. Pennington, ``Cluster Computing: Applications,'' The International Journal of High Performance Computing, 15(2):181-185, May 2001.

When to think about using distributed computing

Size of data	Analysis tools	Data storage	Examples
< 10 GB	R/Python	Local: can fit in one machine's RAM	Thousands of sales figures
10 GB - 1 TB	R/Python with indexed files (key, record)	Local: fits on one machine's hard drive	Millions of web pages
> 1 TB	Hadoop, Spark, Distributed Databases	Distributed: Stored across multiple machines	Billions of web clicks, about 1 month of tweets

Of course, for the purposes of this class and project you are free to consider using Hadoop or Spark (later in curriculum) on much smaller datasets to get experience and potentially list it on your resume. *Just be advised: there is a learning curve and time is short.*

Distributed computing

Specifically: Hadoop

Apache Hadoop

- Hadoop (the full proper name is Apache™ Hadoop®) is an open-source framework that was created to make it easier to work with big data.
- It provides a method to access and process data that are distributed among multiple clustered computers, and manage the required computing and network resources.
- “Hadoop” typically refers to four core components, though sometimes it refers to the ecosystem (next slide). The four components:
  - Hadoop Distributed File System (HDFS) - Manages and provides access to distributed data.
  - Hadoop YARN - Provides framework to schedule and manage jobs across the cluster.
  - Hadoop MapReduce - YARN-based parallel processing system for large datasets.
  - Hadoop Common - A set of utilities that support the other three core modules.

See http://www.bmc.com/guides/hadoop-introduction.html

The Hadoop Ecosystem

See: https://hadoopecosystemtable.github.io/

Headings:

- Distributed File System (HDFS is one)
- Distributed Computing (See MapReduce, Spark)
- SQL-on-Hadoop (See Hive)
- NoSQL databases
- NewSQL databases (!?)
- And many other headings

HDFS software: DataNodes and the NameNode

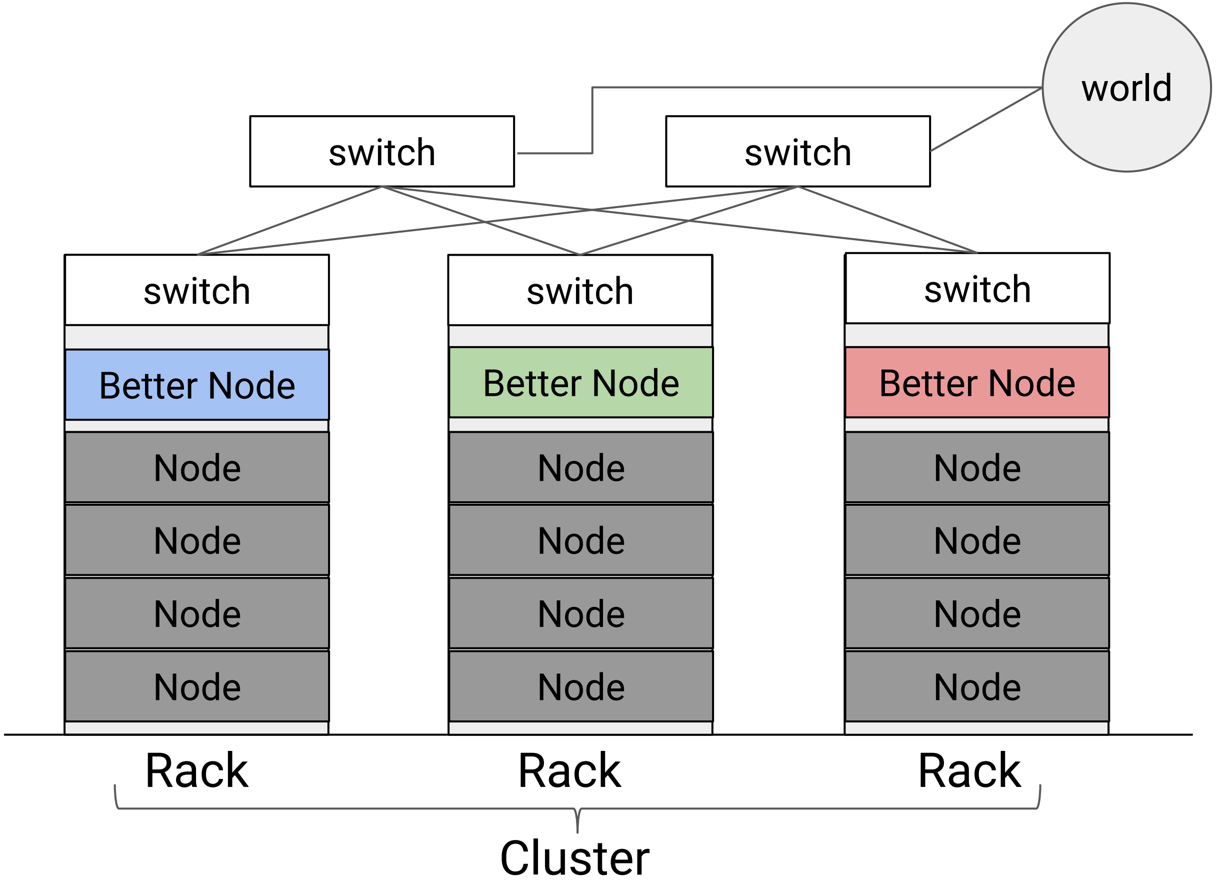
DataNode software

- DataNode installed on the nodes (servers) whose responsibility is to store and compute.
- It manages storing and locating blocks (chunks) of 64 MB of data on the node.
- It communicates with and responds to requests from the NameNode, including the “heartbeat.”
- Can communicate with other DataNodes (e.g. to copy data) and the Client.

NameNode software

- Tracks where data blocks are stored in the cluster.
- Interacts with client applications.
- Is the potential single point of failure for the entire HDFS. This is why there is a backup NameNode and its construction and components are “enterprise class”.
- Manages backing up of data blocks (generally stored in 3 different nodes in different racks).

Where Hadoop software runs: server farm



A node (server), per Cloudera

Typical Node Specifications

Here are the recommended specifications for DataNode/TaskTrackers in a balanced Hadoop cluster:

- 12-24 1-4TB hard disks in a JBOD (Just a Bunch Of Disks) configuration
- 2 quad-/hex-/octo-core CPUs, running at least 2-2.5GHz
- 64-512GB of RAM
- Bonded Gigabit Ethernet or 10Gigabit Ethernet (the more storage density, the higher the network throughput needed)

"Better" Node Specifications

Here are the recommended specifications for NameNode/JobTracker/Standby NameNode nodes. The drive count will fluctuate depending on the amount of redundancy:

- 4–6 1TB hard disks in a JBOD configuration (1 for the OS, 2 for the FS image [RAID 1], 1 for Apache ZooKeeper, and 1 for Journal node)
- 2 quad-/hex-/octo-core CPUs, running at least 2-2.5GHz
- 64-128GB of RAM
- Bonded Gigabit Ethernet or 10Gigabit Ethernet

Should use "enterprise class" components

Distributed computing
data processing software:

MapReduce

MapReduce - the general idea and steps

- **Send the computation to the data rather than trying to bring the data to the computation.**
- Computation and communication are handled as (key, value) pairs.
- In the "map" step, the **mapper** maps a function on the data that transforms it into (key, value) pairs. A **local combiner** may be run after the map to aggregate the results in (key, local aggregated values).
- After the mapping phase is complete, the (key, value) or (key, local aggregated value) results need to be brought together, sorted by key. This is called the "shuffle and sort" step.
- Results with the same key are all sent to the same MapReduce TaskTracker for aggregation in the **reducer**. This is the "reduce" step.
- The final reduced results are communicated to the Client.

MapReduce - the general idea and steps

- It's really Divide and Conquer:
  - 1) Split one large tasks into many smaller sub-tasks that can be solved in parallel on different nodes (servers)
  - 2) Solve these tasks independently
  - 3) Recombine the results of the sub-tasks for the final results.

- The types of problems MapReduce is especially suited for:
  - Count (morning assignment), sum, avg, sort, graph traversal and analysis (afternoon assignment)
  - Some machine learning algorithms

MapReduce software: TaskTracker and the JobTracker

TaskTracker software

- Installed on nodes with the DataNode software.
- Performs the map, shuffle and sort, and reduce operations.
- Monitors status of these operations and reports progress to JobTracker. Also sends a “heartbeat” to JobTracker to indicate that it’s functioning properly.
- Can communicate with other TaskTrackers.

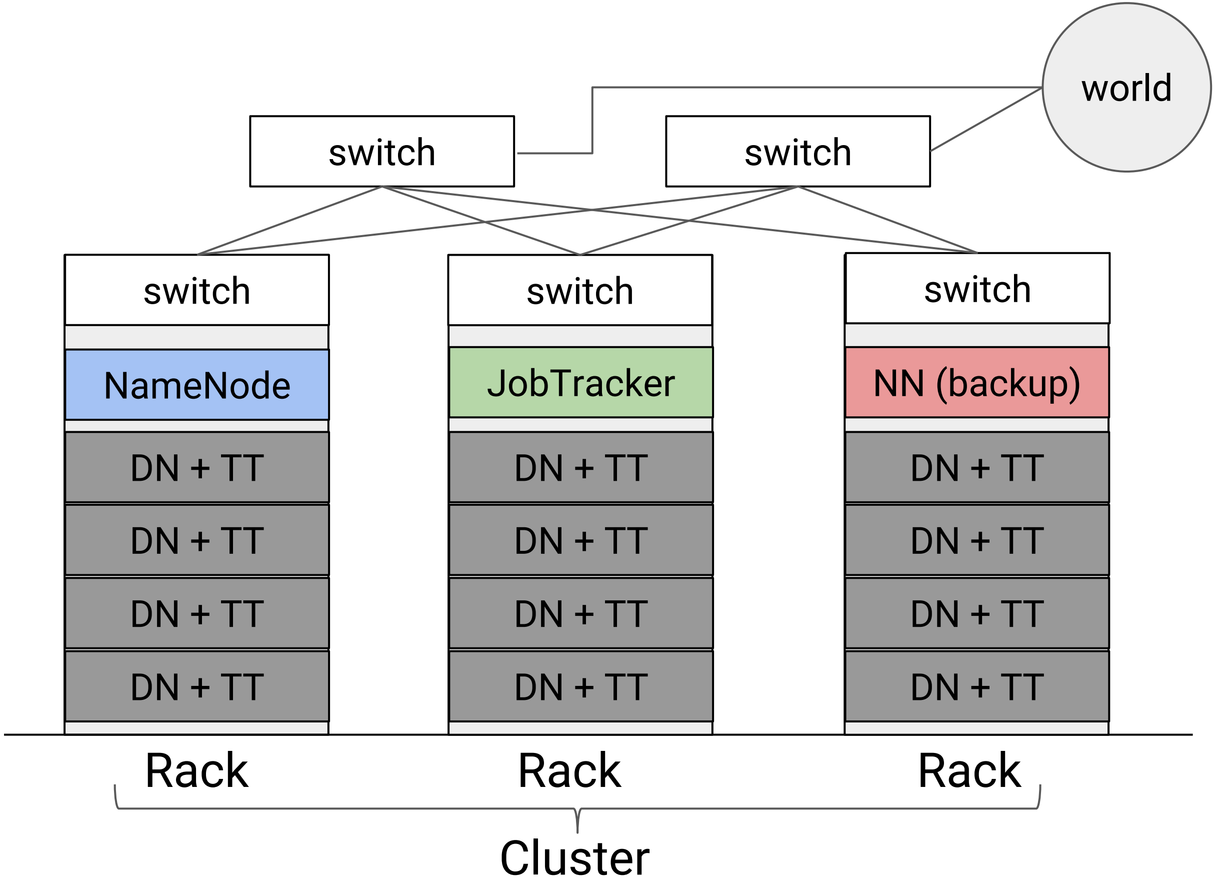
JobTracker software

- Coordinates data processing.
- Interacts with NameNode to determine where data is stored.
- Will schedule a different TaskTracker if a TaskTracker doesn’t submit a “heartbeat” or has corrupt data.
- Communicates with the Client.
- Just like the NameNode, the JobTracker is given “enterprise” hardware.

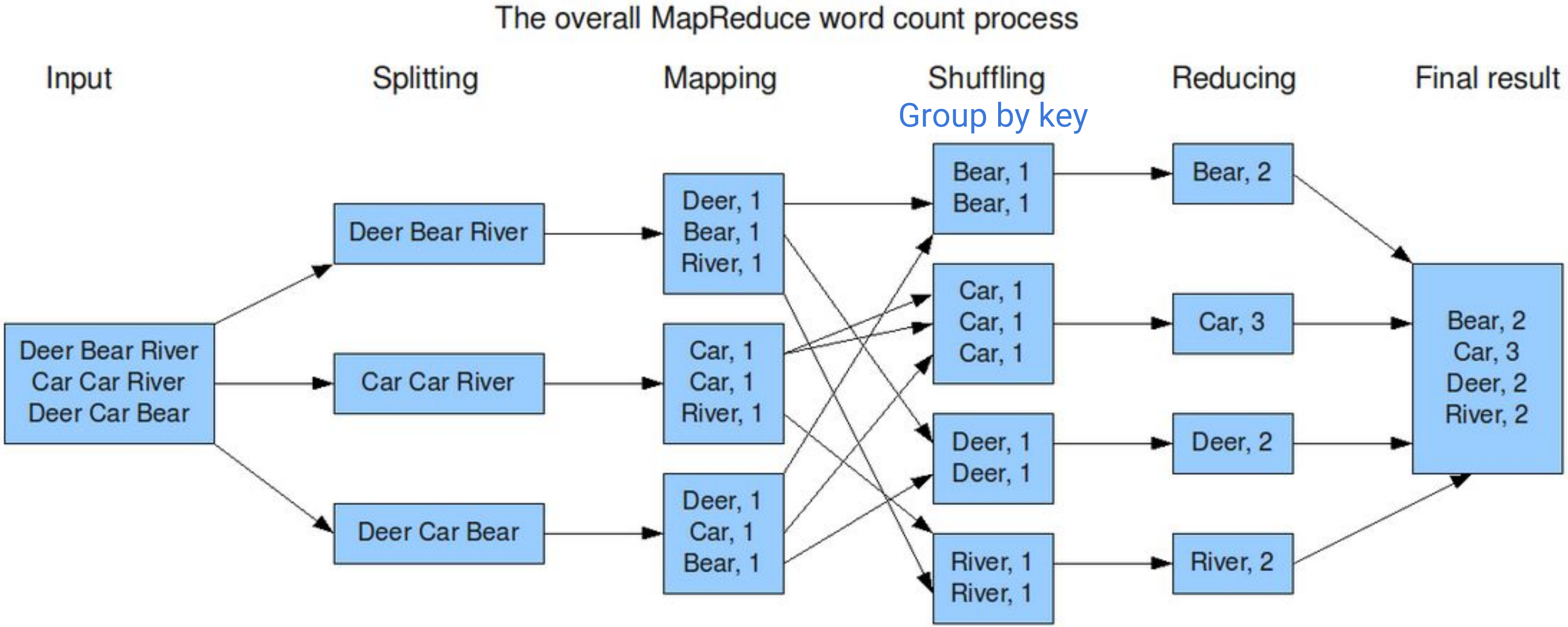
Take-aways

- Hadoop - open-source framework made to handle big data through distributed computing.
- HDFS - data management component of Hadoop
    - NameNode - keeps track of where data is, makes sure it's backed up
    - DataNode - stores the data
- MapReduce - computation component of Hadoop
    - JobTracker - coordinates jobs, communicates with client
    - TaskTracker - performs computations on local data
        - A local mapper maps a function on data, perhaps using local combiner, then sends the results somewhere to be reduced
        - Data is handled as (key, value) pairs
        - All computations written to hard disk (for redundancy, but slow)
- Many other components in Hadoop Ecosystem

Bring it all together: HDFS and MapReduce

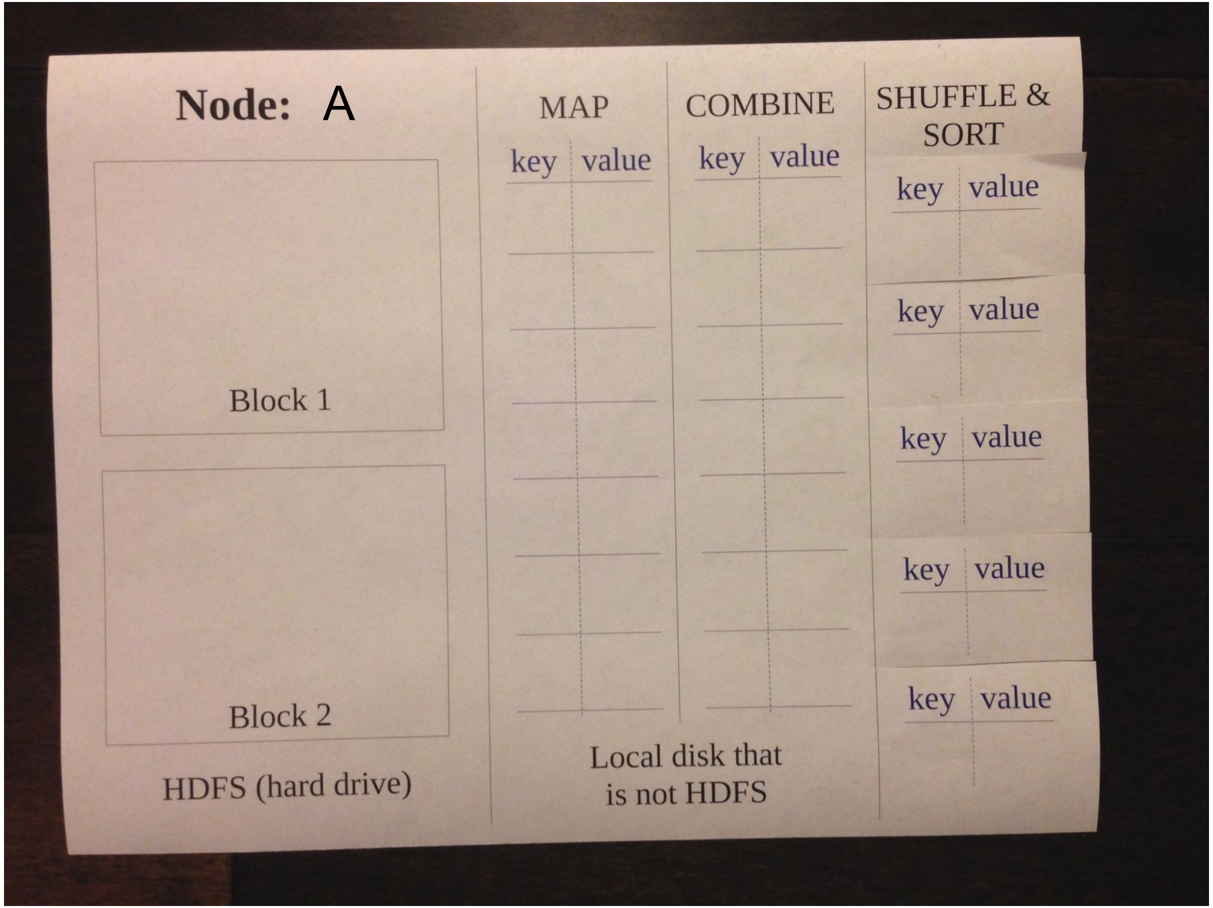


MapReduce illustrated: word count

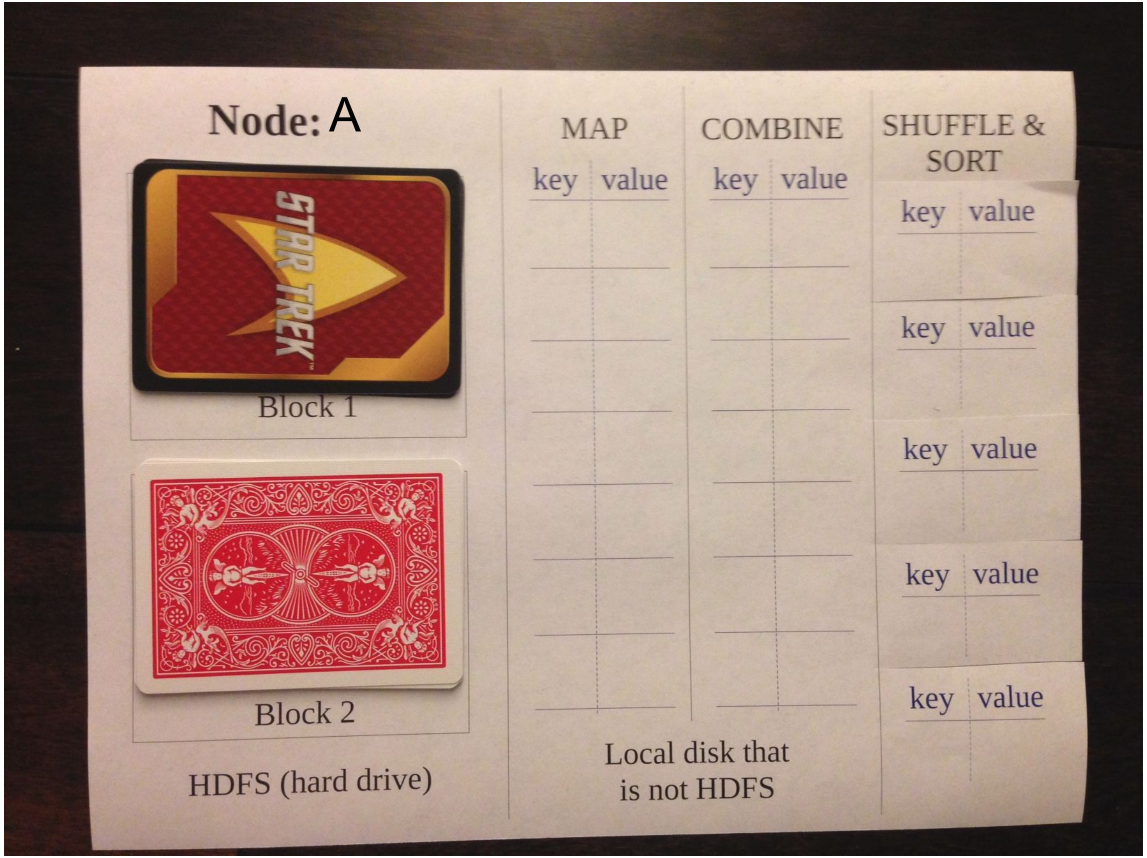


MapReduce Example

Just a node on a rack:



Just a node on a rack, with data



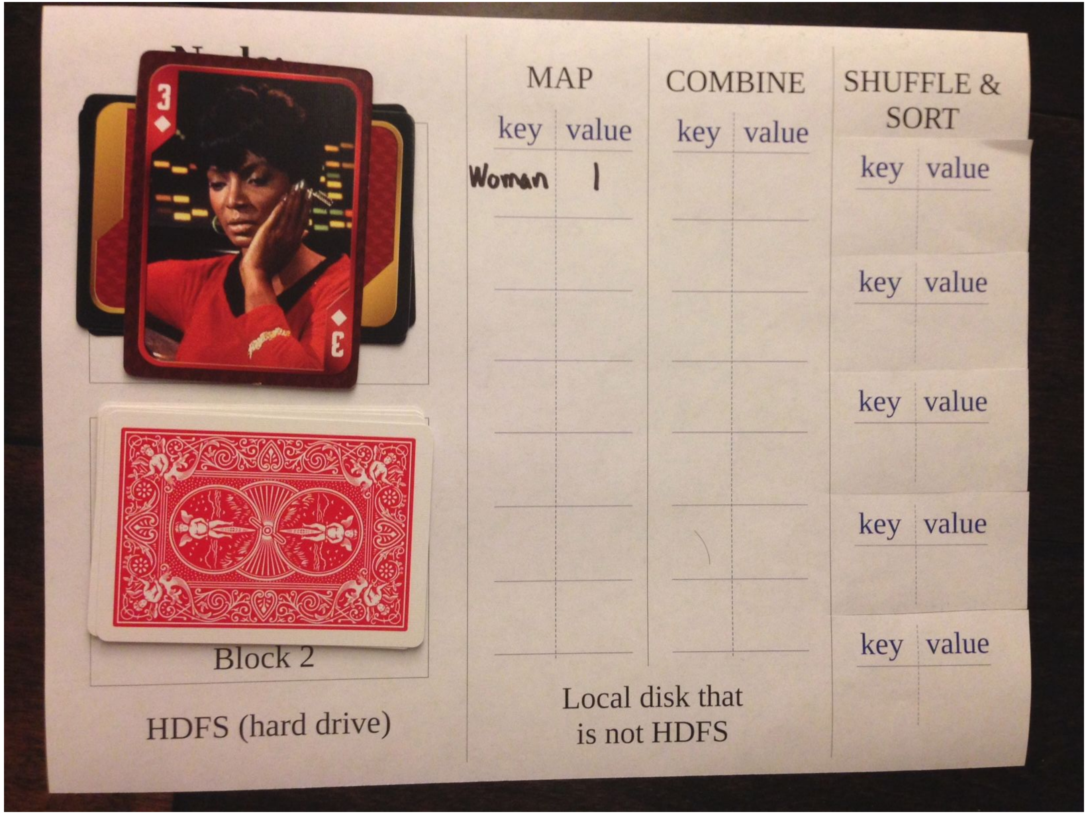
Just a node on a rack, with purpose

But then the **JobTracker** speaks:

TaskTrackers: Get me the count of the number of 'women' and 'aliens' in the Star Trek data blocks!

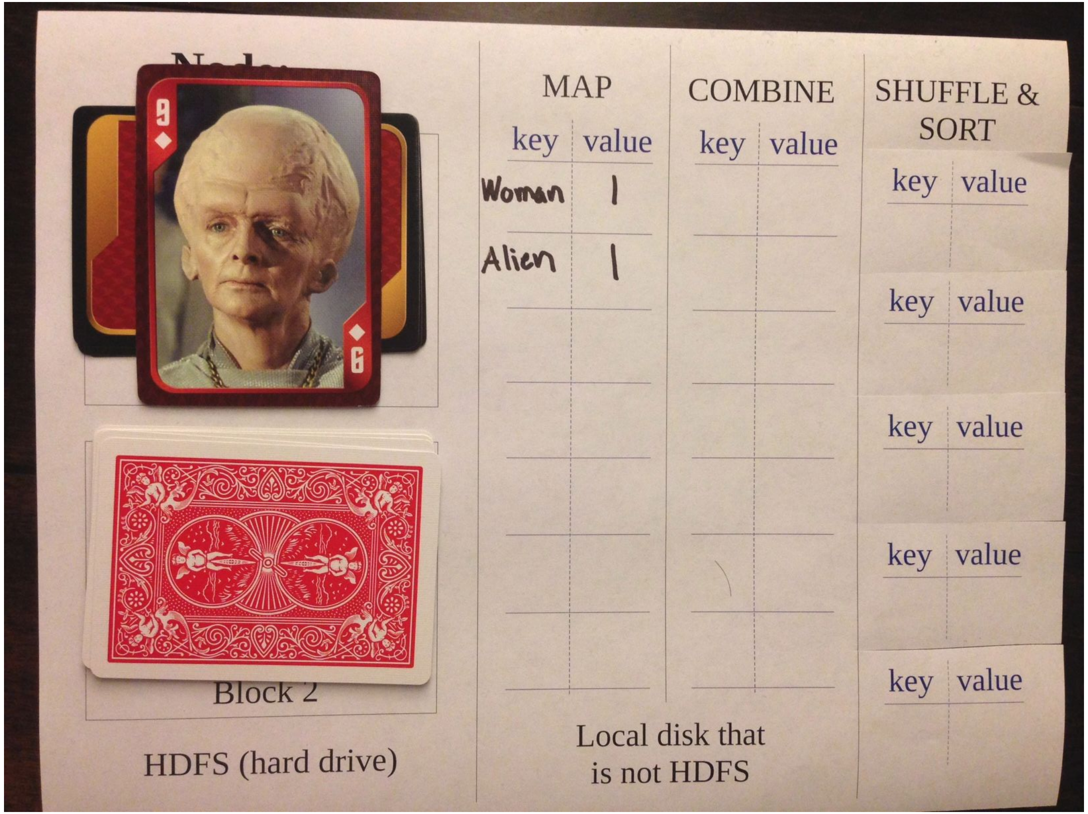
All TaskTrackers are instructed to send 'women' results to node Y TaskTracker for reduction, and 'aliens' results to node Z TaskTracker for reduction.

Just a node on a rack, Map step



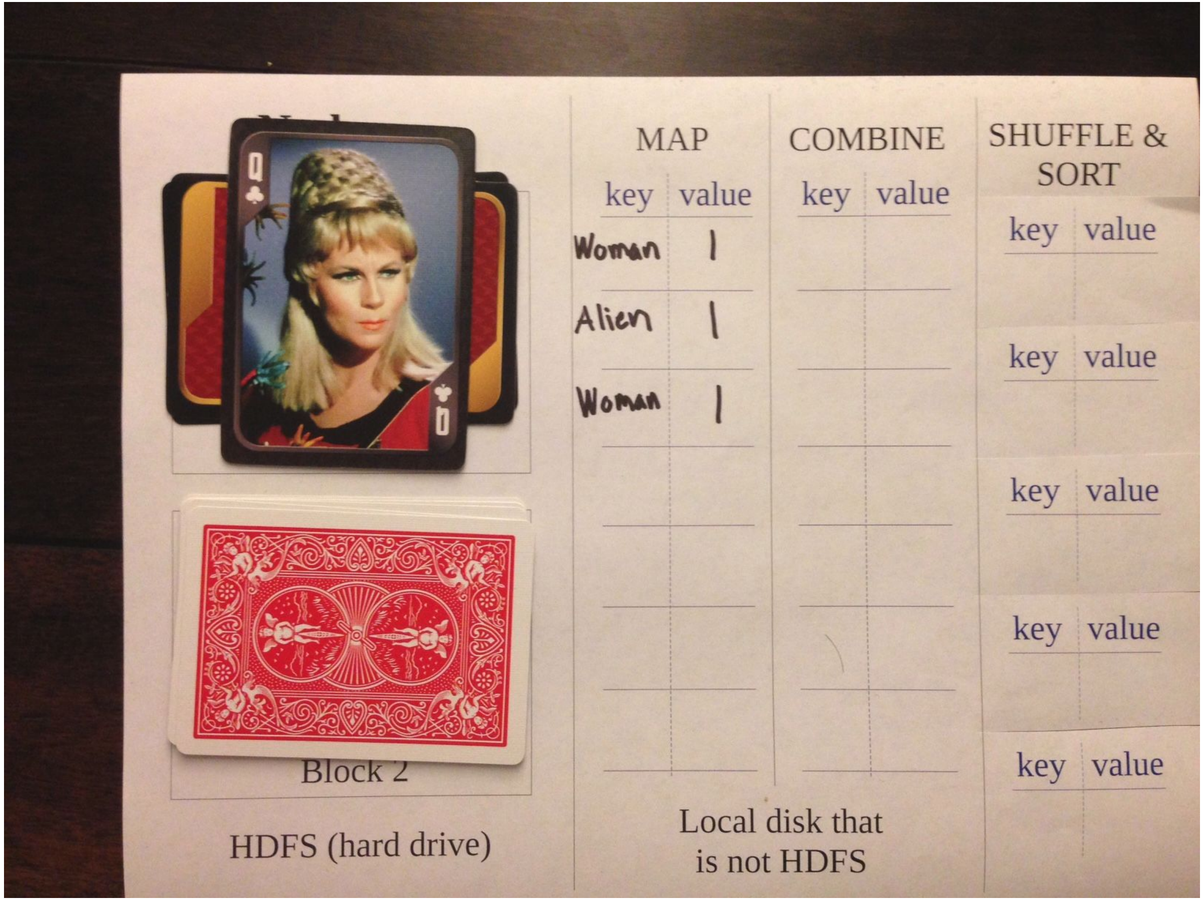
Directive: Number of women and aliens.

Just a node on a rack, Map step



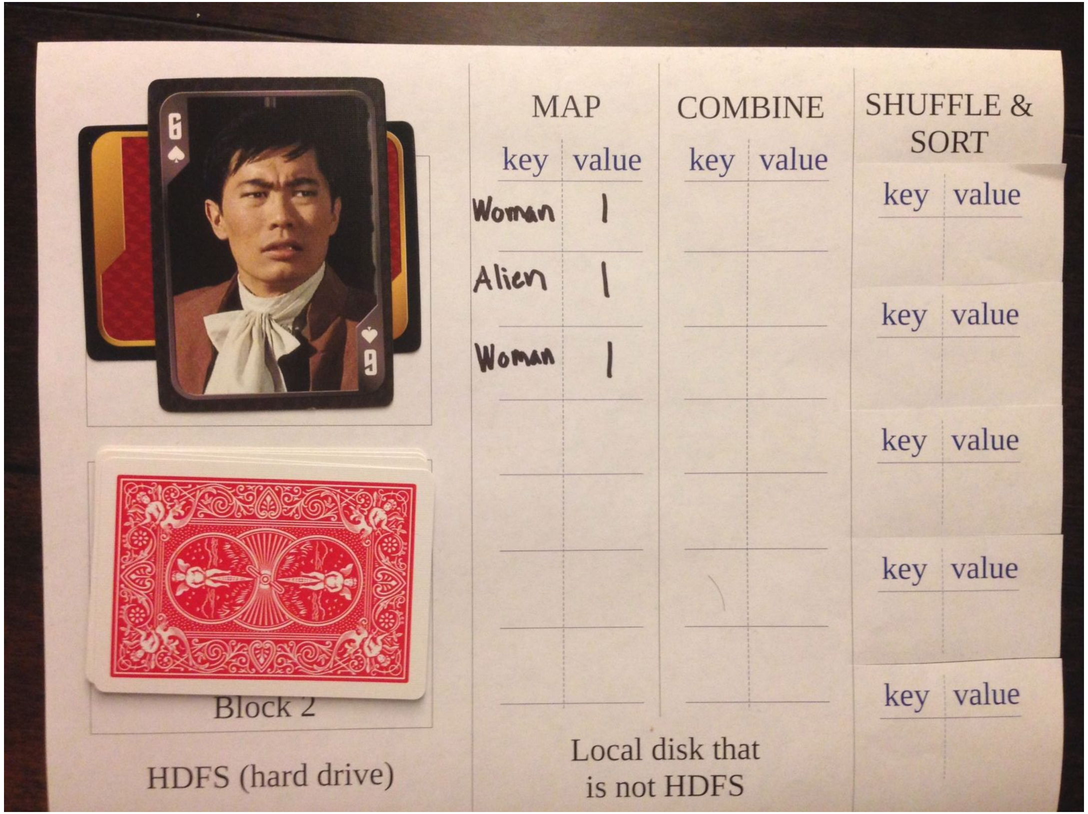
Directive: Number of women and aliens.

Just a node on a rack, Map step



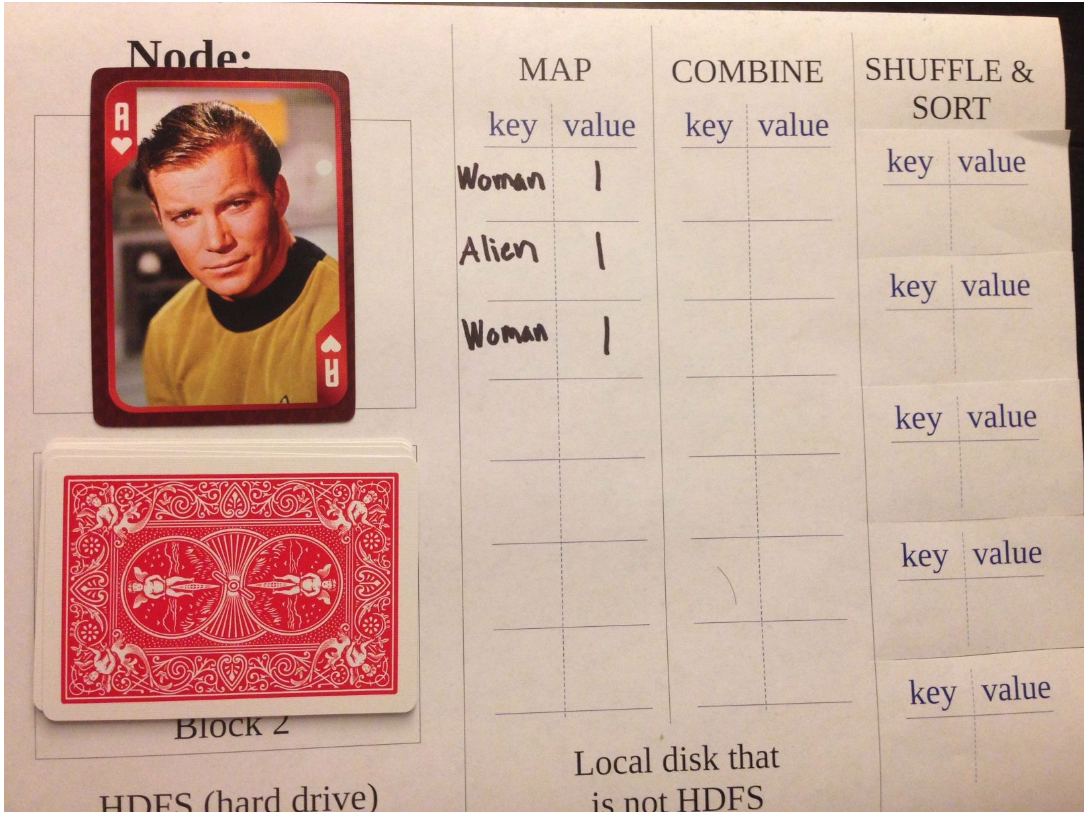
Directive:
Number of women and aliens.

Just a node on a rack, Map step



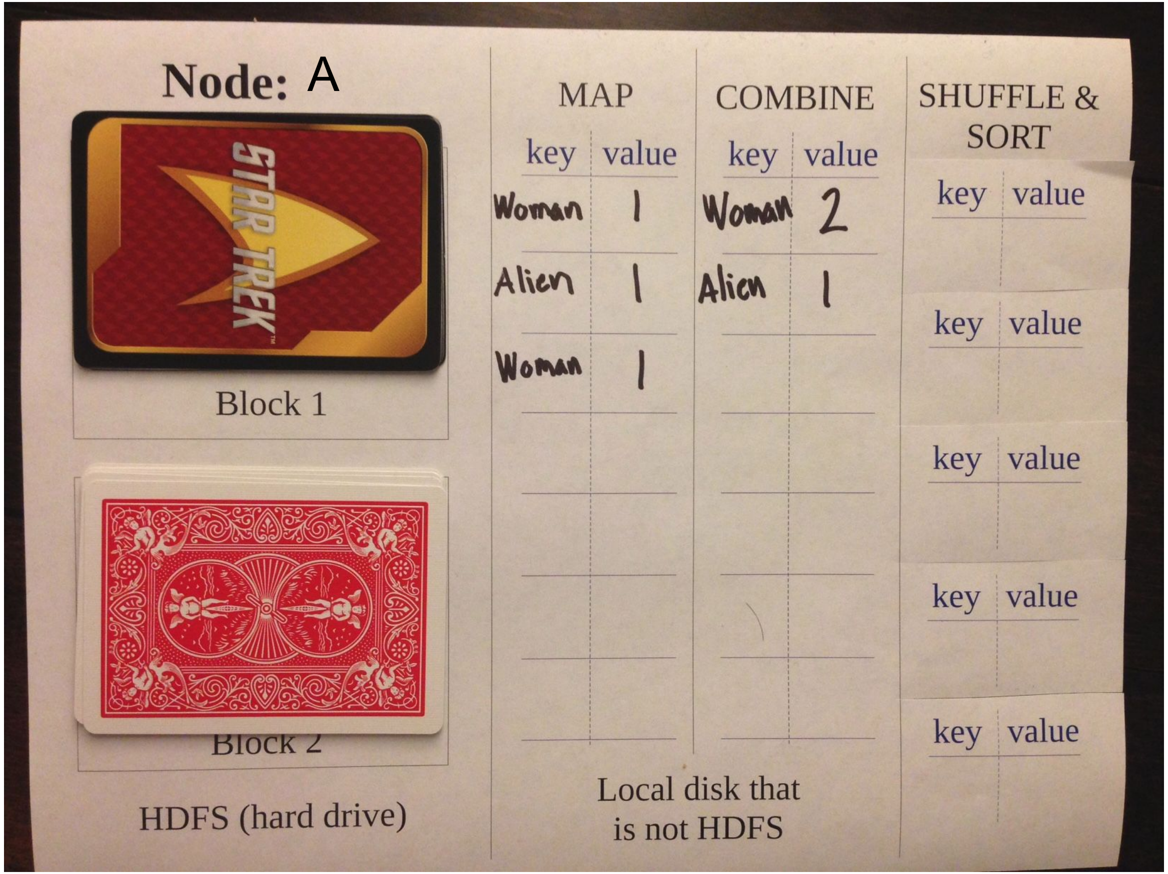
Directive: Number of women and aliens.

Just a node on a rack, Map step



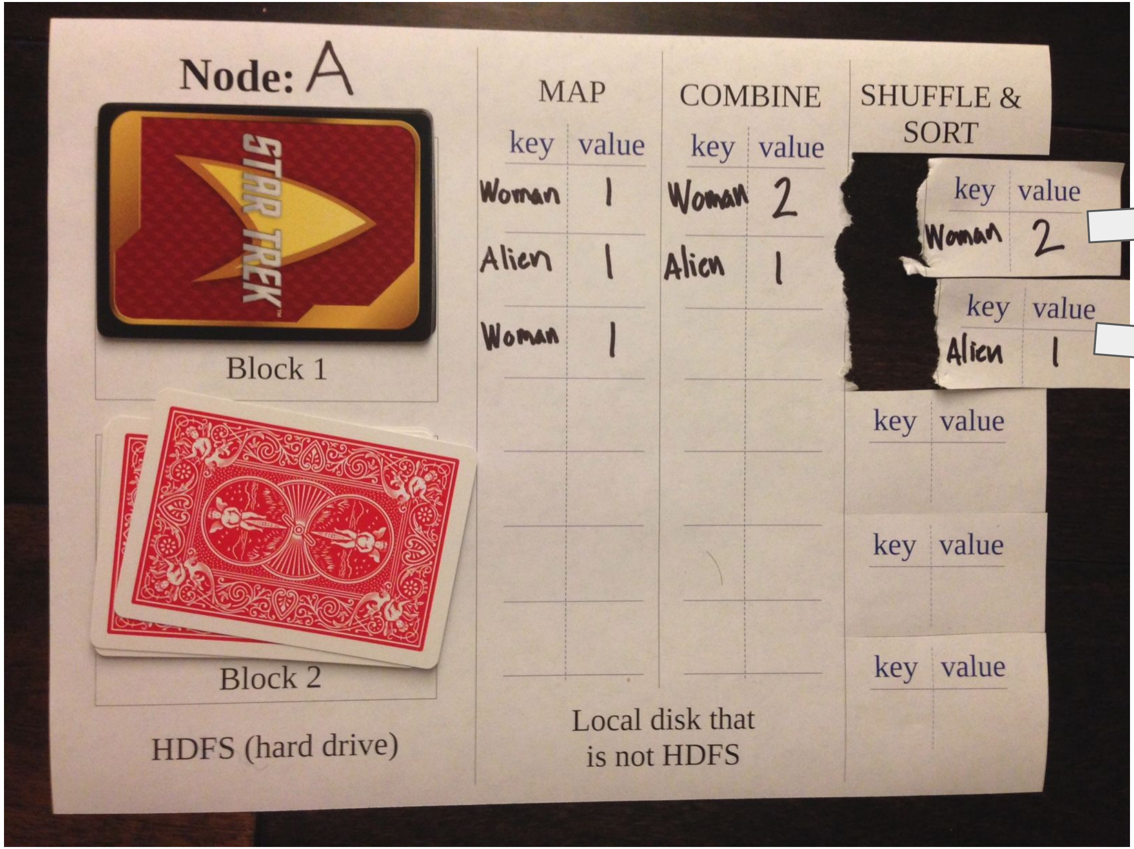
Directive:
Number of women and aliens.

Just a node on a rack, Combine step



Directive:
Number of women and aliens.

Just a node on a rack, Shuffle & Sort step



To Node Y for reduction

To Node Z for reduction

Class exercise

Jupyter notebook - `mrjob`

References

- https://en.wikipedia.org/wiki/Apache_Hadoop
- https://wiki.apache.org/hadoop/