

[544] HBase and Cassandra


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Learning Objectives

- describe HBase's approach to reliability (HDFS replication, RegionServer failover)
- describe the data models for HBase and Cassandra (wide row and wide partition, respectively)
- select columns Cassandra table to serve as partition keys, cluster keys, and static columns to make specific operations efficient

Hadoop Ecosystem

Yahoo, Facebook, Cloudera, and others developed open-source Hadoop ecosystem, mirroring Google's systems

	Google (paper only)	Hadoop, 1st gen (open source)	Modern Hadoop
Distributed File System	GFS	HDFS	
Distributed Analytics	MapReduce	Hadoop MapReduce	Spark
Distributed Database	BigTable	HBase	Cassandra
			Dynamo (Amazon) 

Ecosystem: Ambari, Avro, Cassandra, Chukwa, HBase, Hive, Mahout, Ozone, Pig, Spark, Submarine, Tez, ZooKeeper

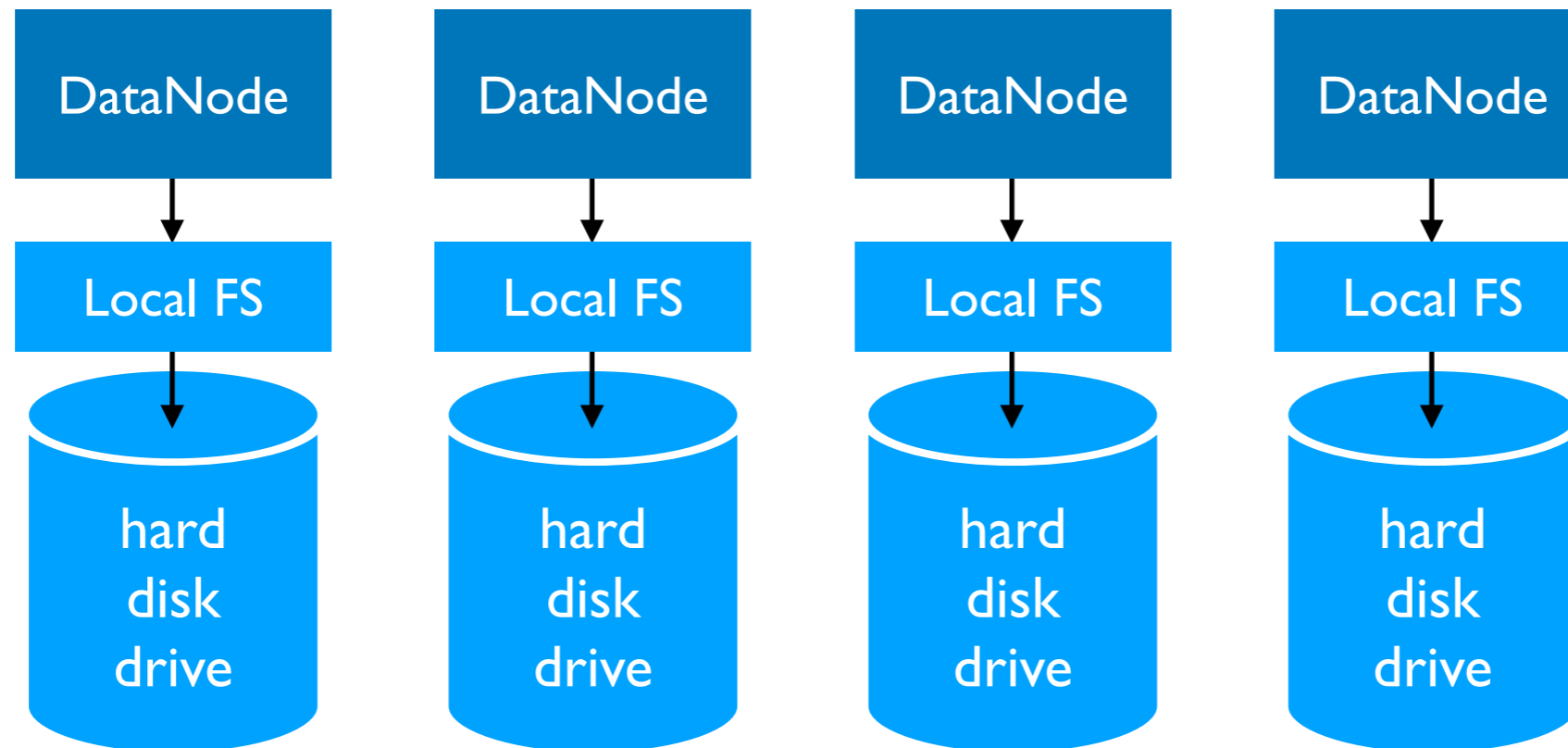
<https://hadoop.apache.org/>

Google Architecture

MapReduce (2004 paper)

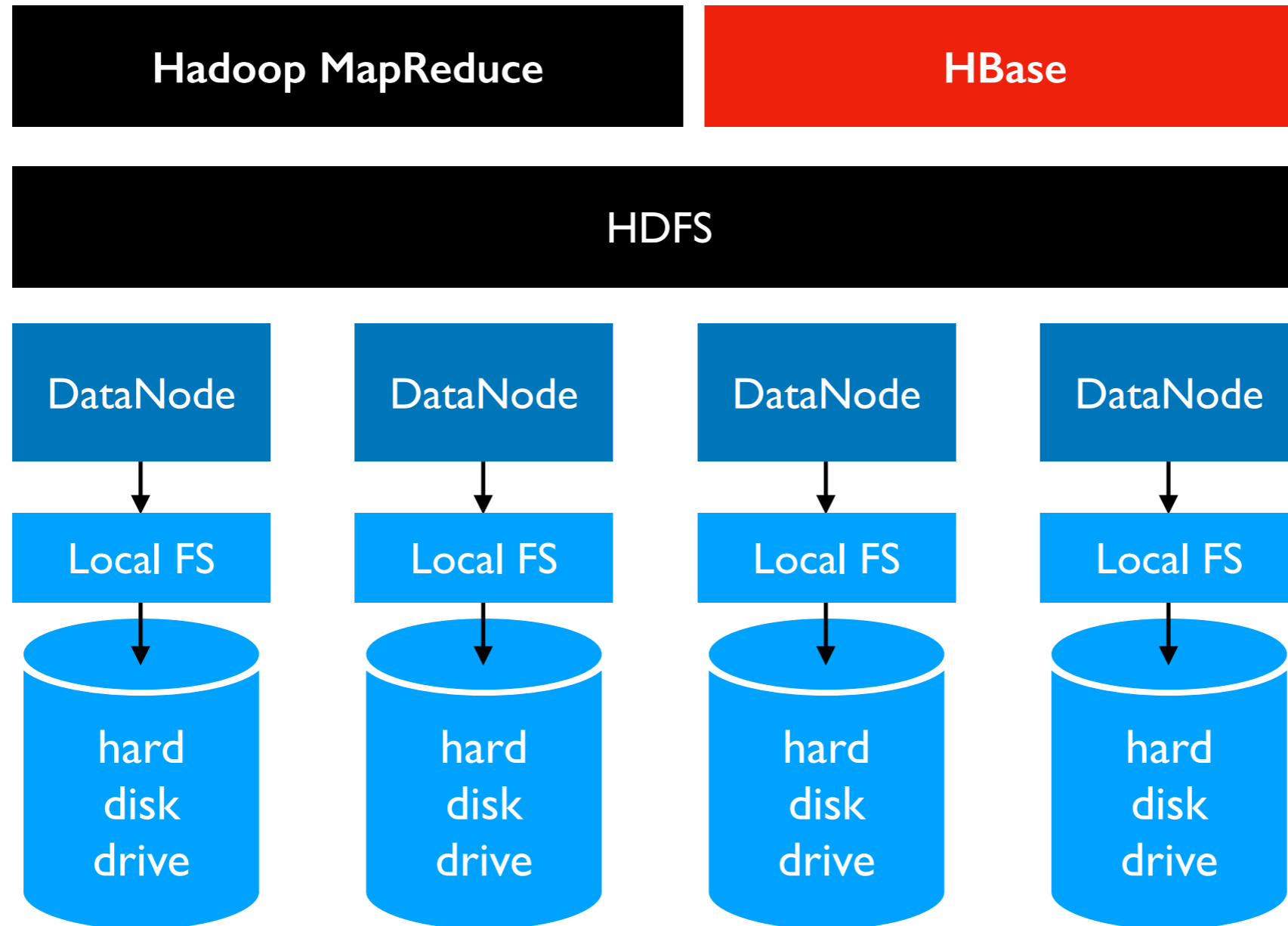
BigTable (2006 paper)

GFS: Google File System (2003 paper)

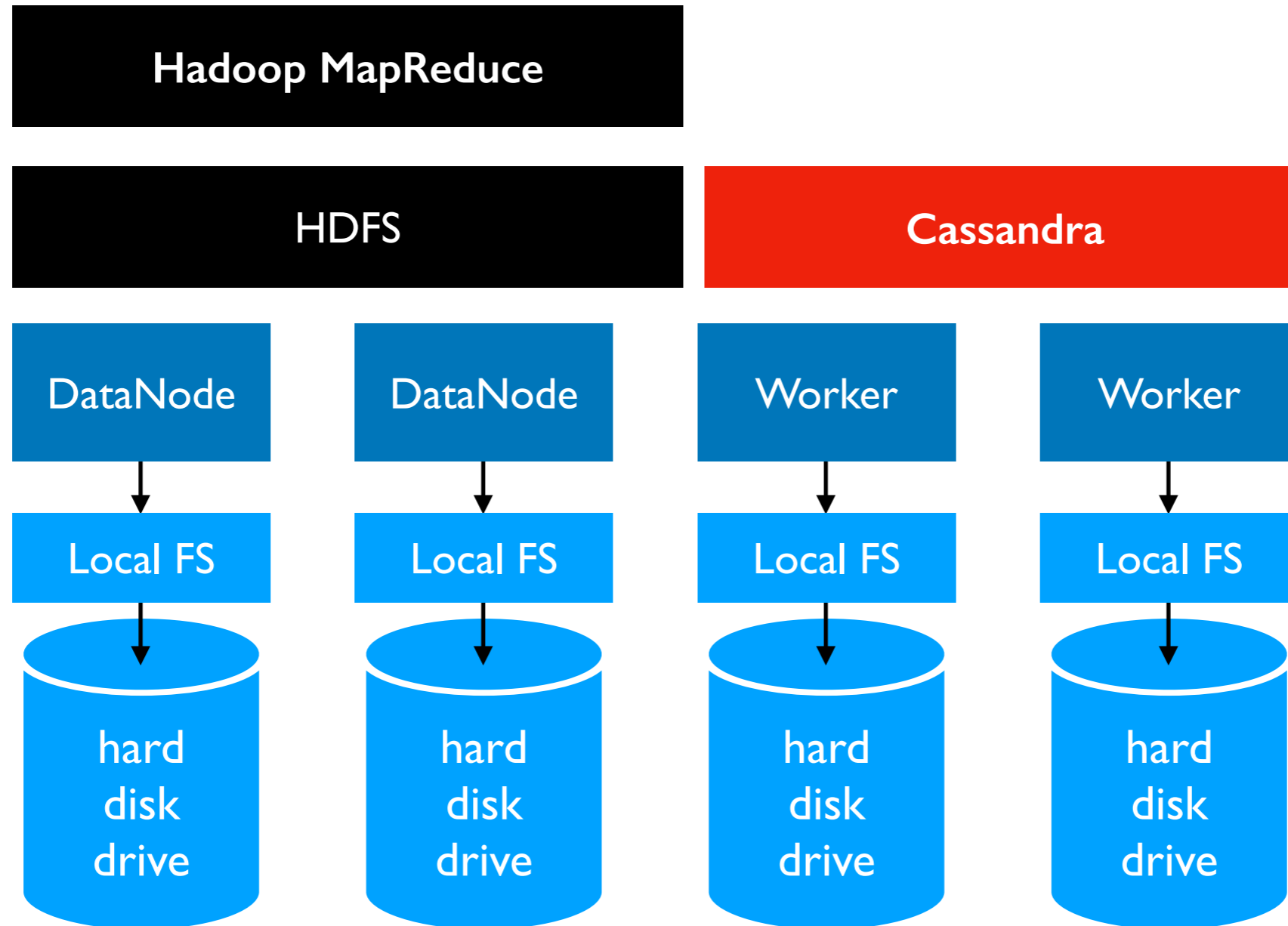


radical idea: base everything on lots of cheap, commodity hardware

Hadoop Ecosystem



Hadoop Ecosystem



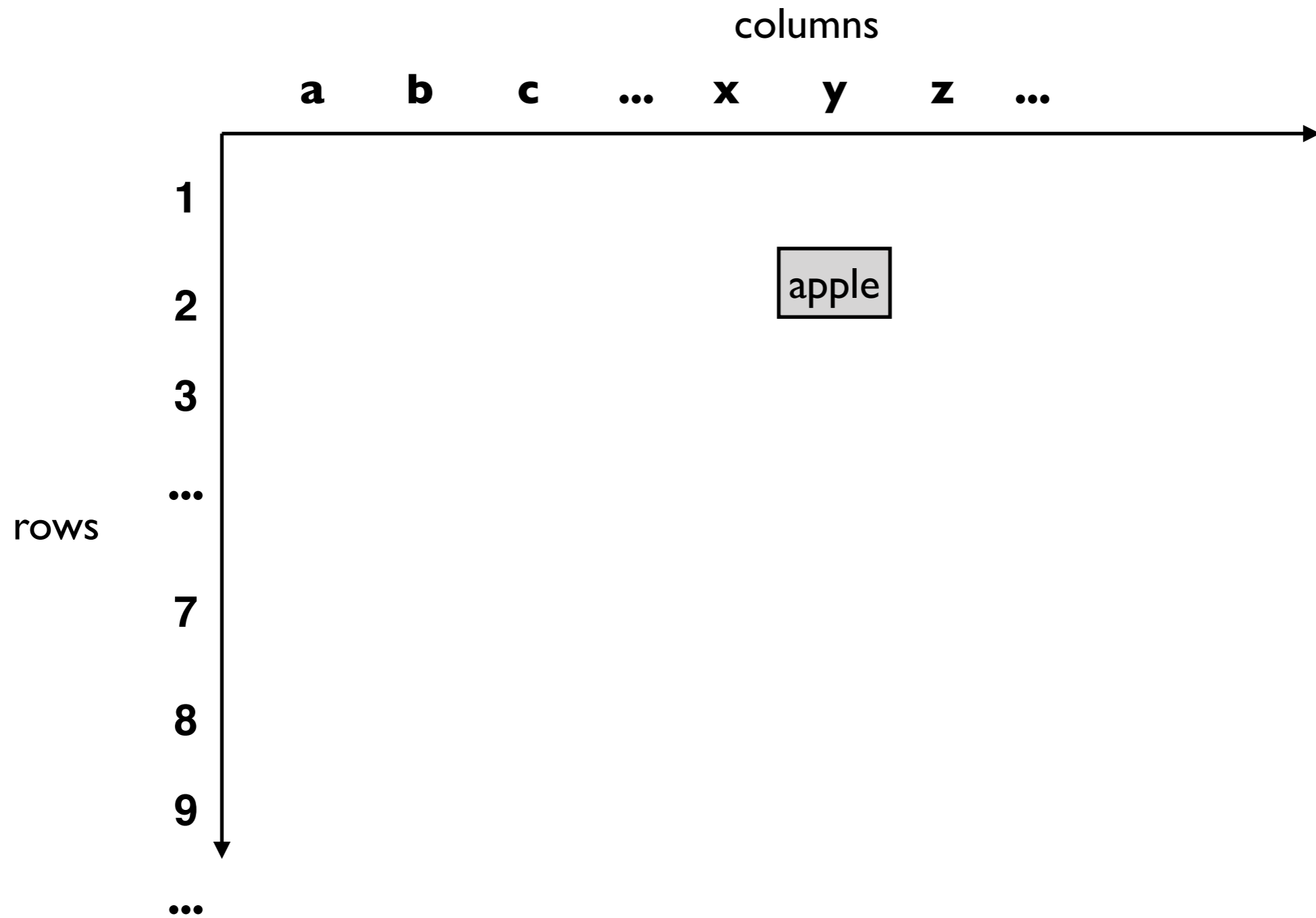
Outline: HBase and Cassandra

HBase

Cassandra Data Model

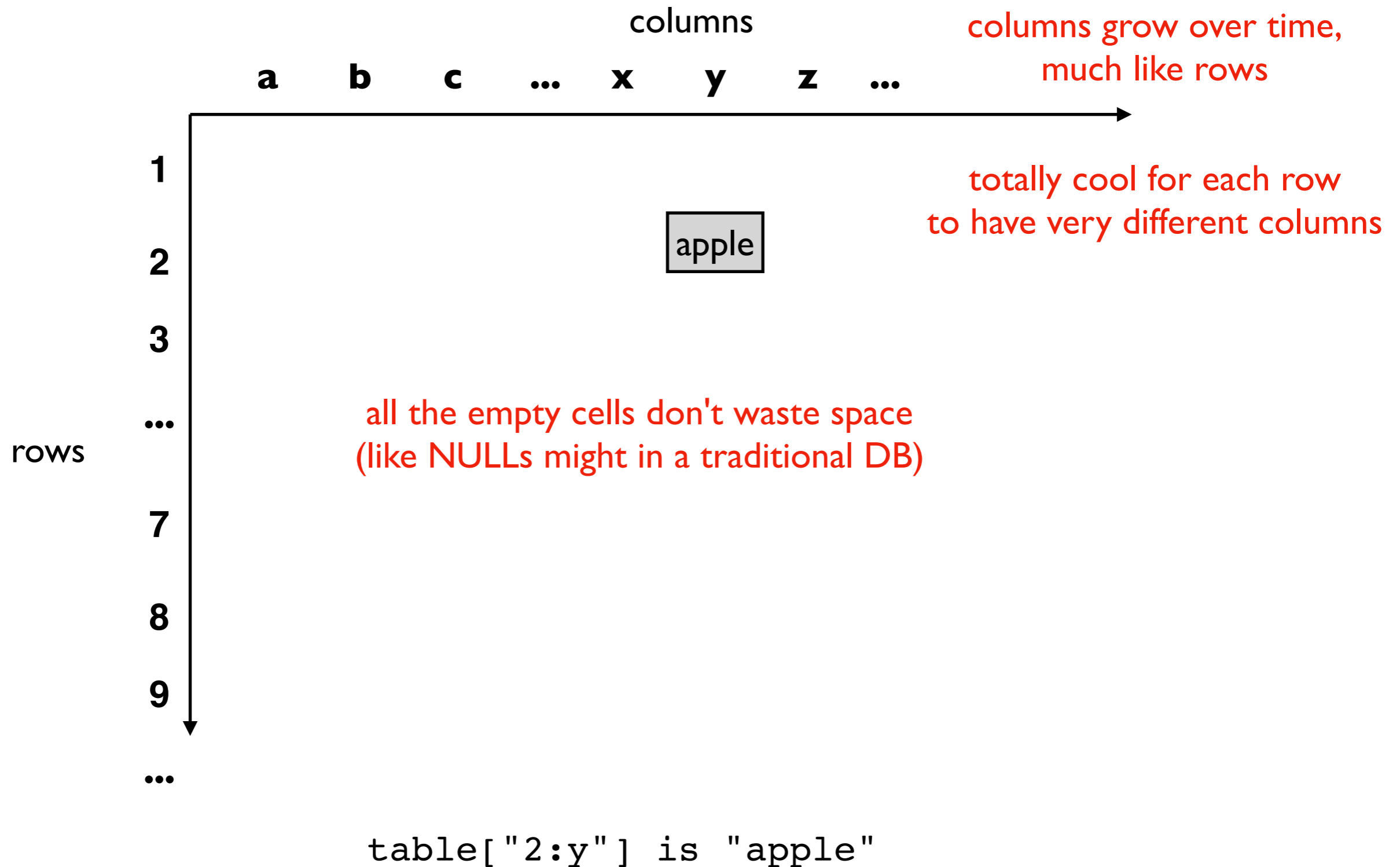
Demos

HBase Data Model: Versioned Sparse Tables

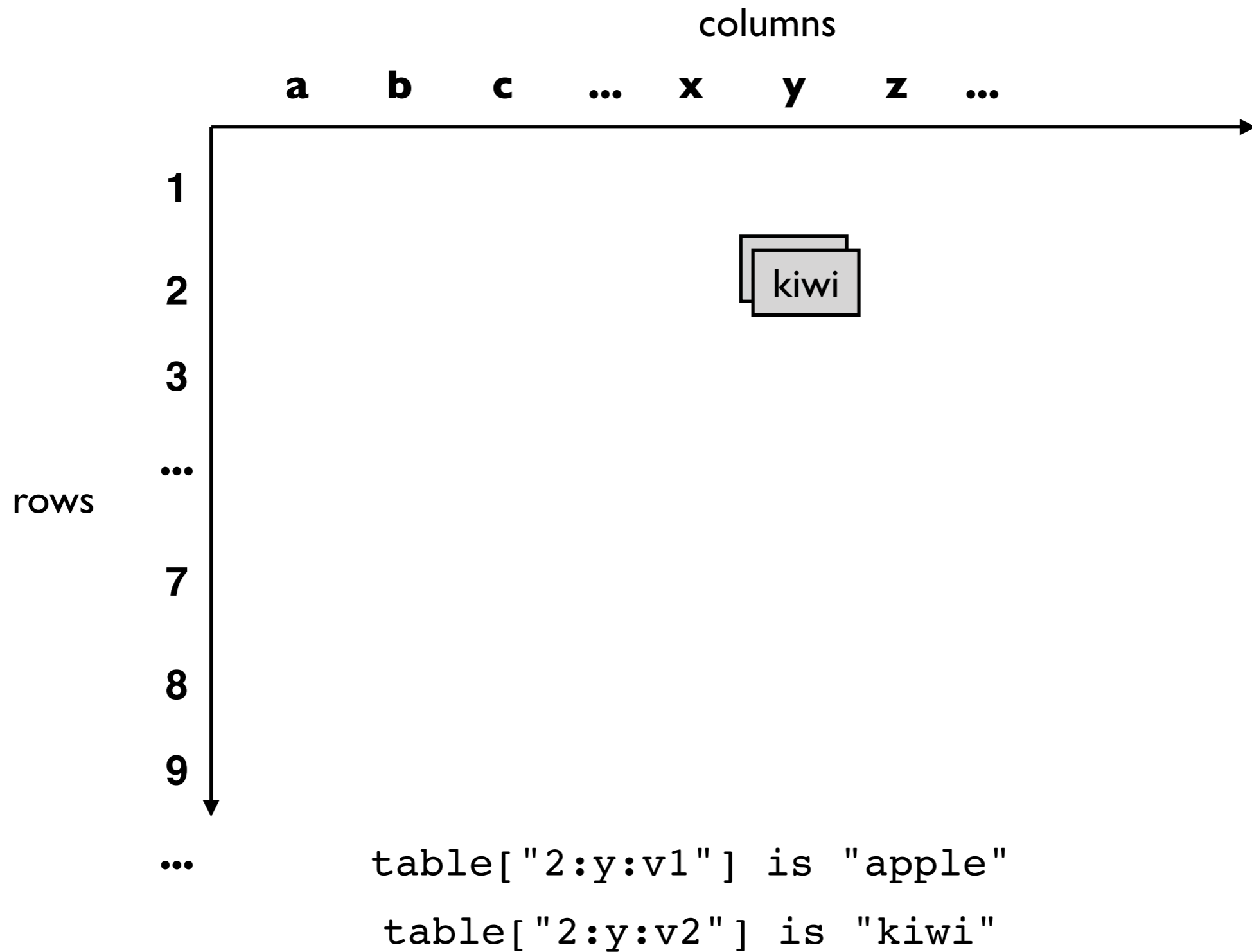


`table["2:y"]` is "apple"

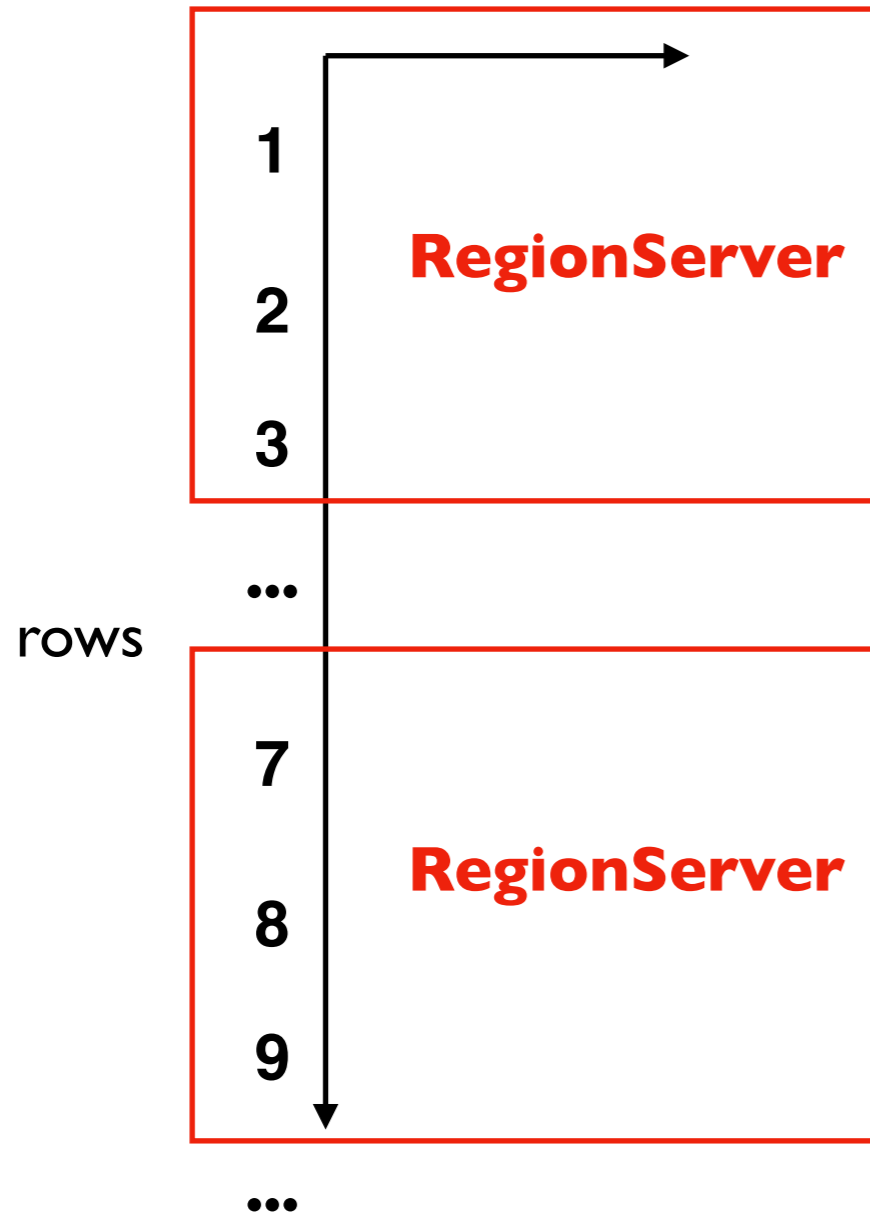
HBase Data Model: Versioned **Sparse** Tables



HBase Data Model: **Versioned** Sparse Tables



Partitioning the Row Space



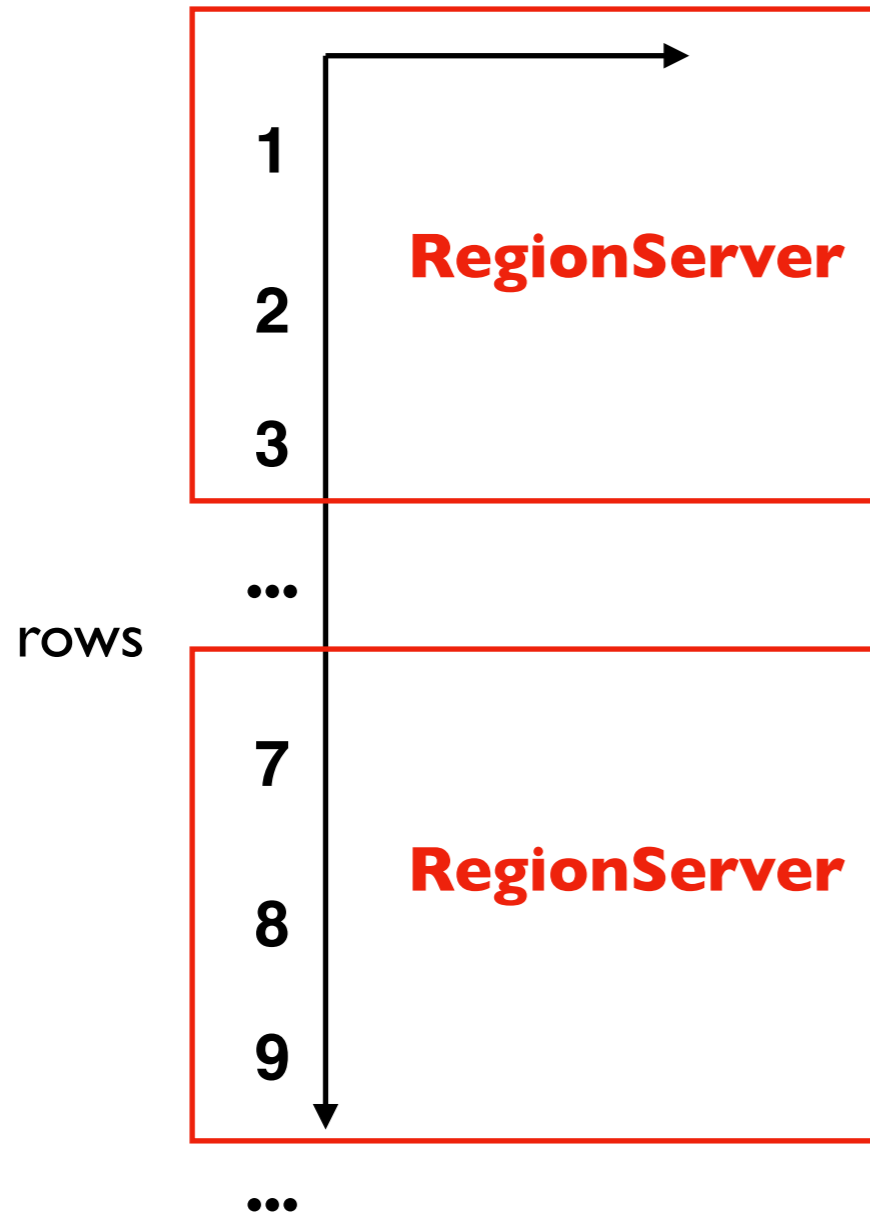
row ranges are called "regions"

regions may grow/split

a region is assigned to ONE HBase
"RegionServer" at any given time

RegionServers could server multiple regions

Transactions

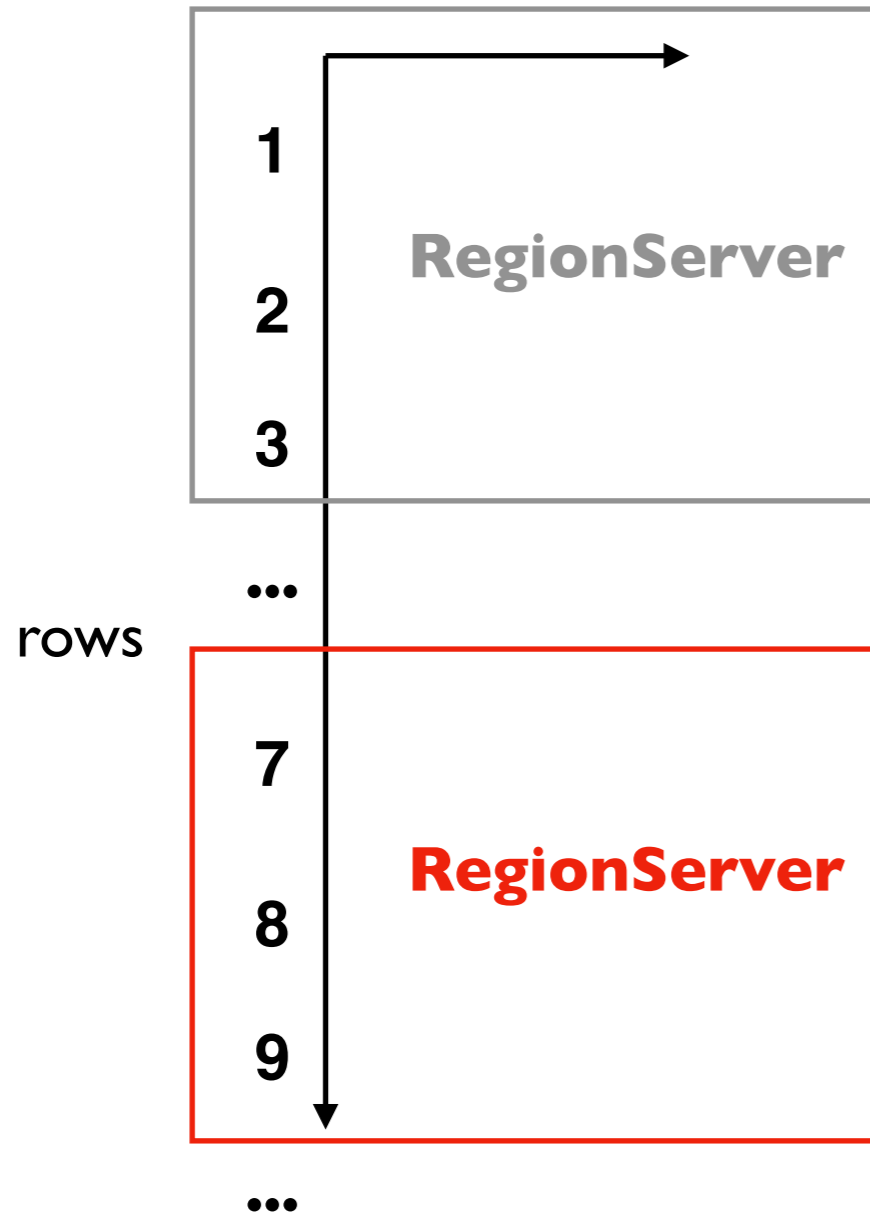


Rows are never split across regions

HBase only support single-row transactions

Design implication: try to keep all of a user's data in **ONE** row, even if it means millions of columns

Fault Tolerance: what if a RegionServer dies?



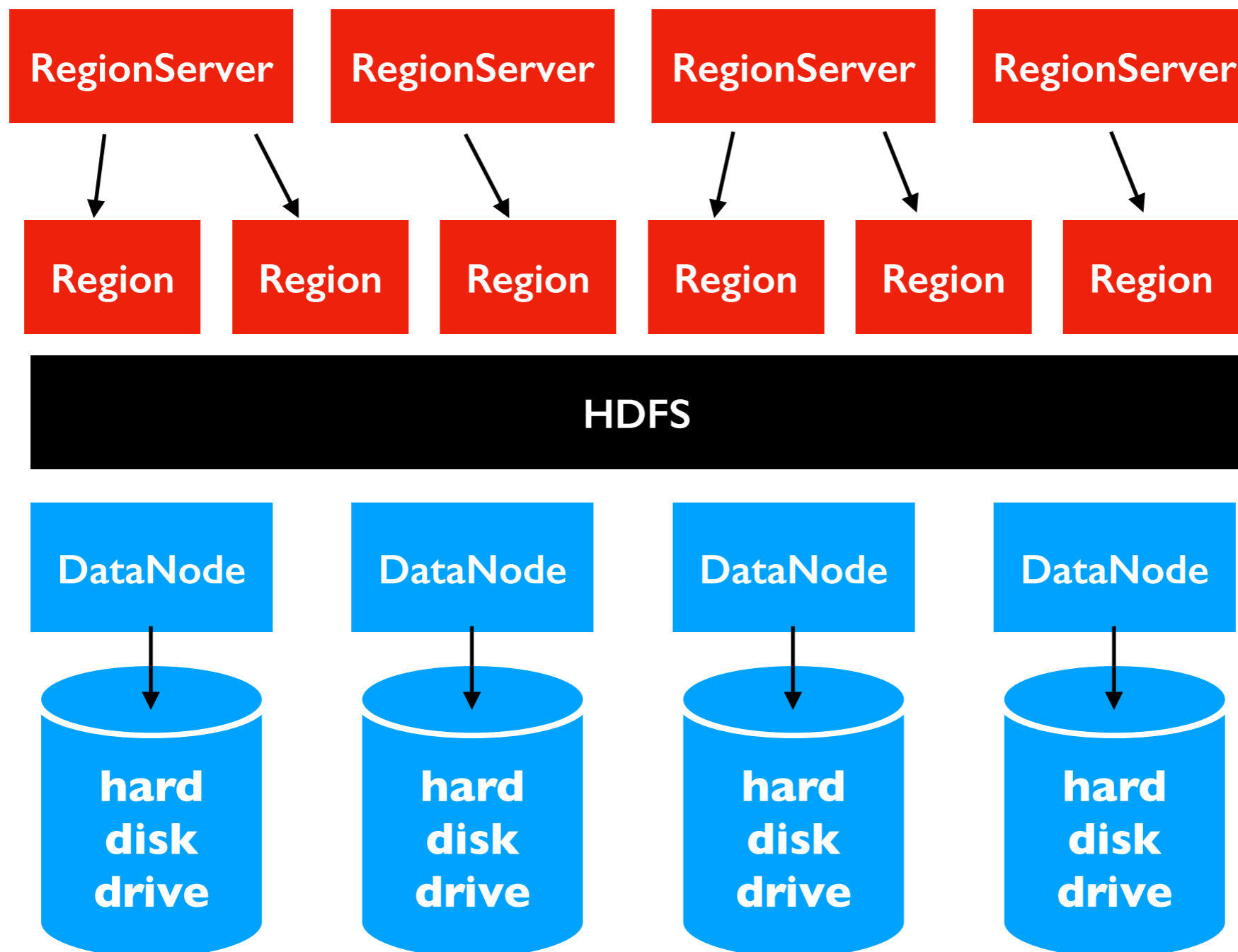
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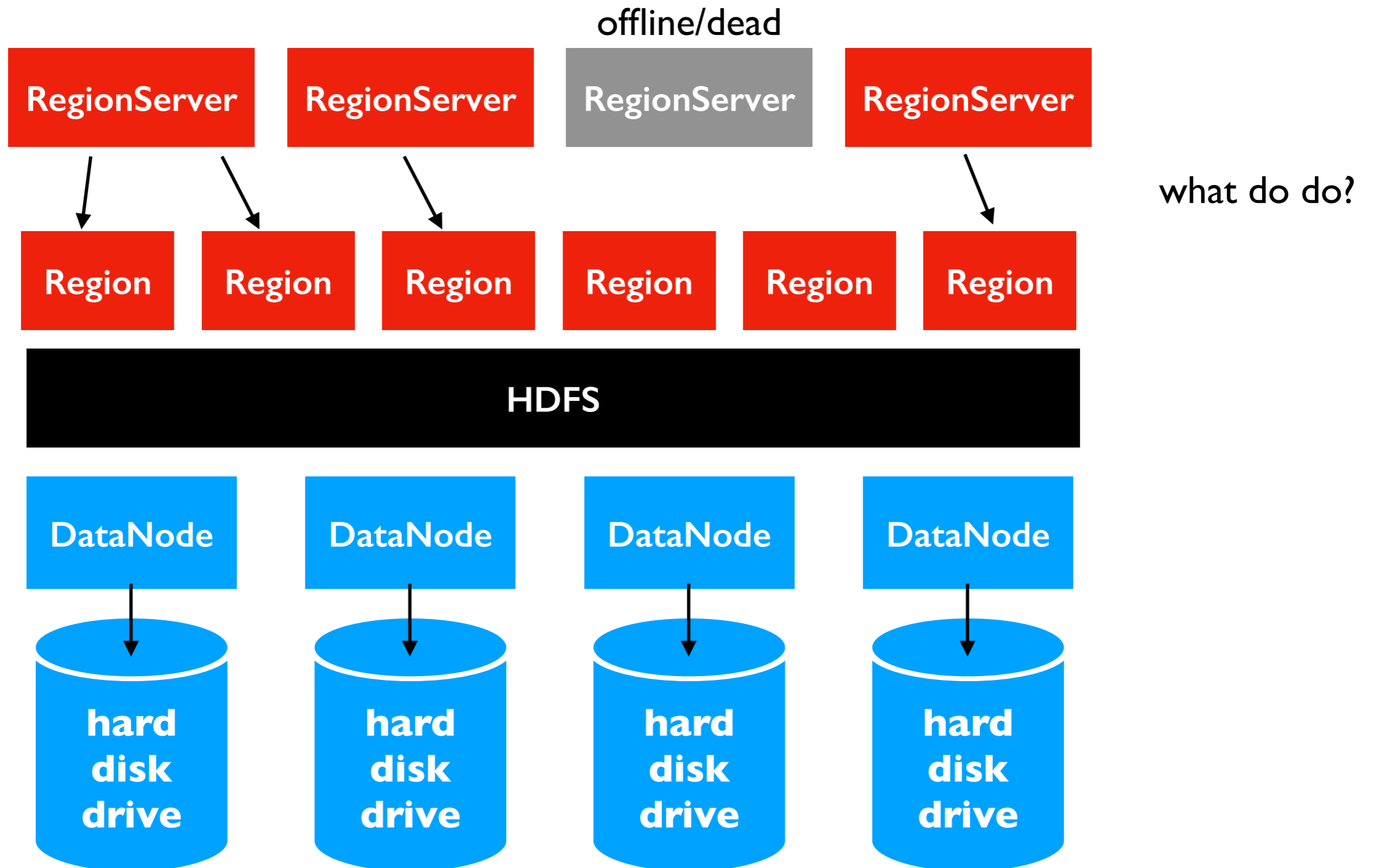
Fault Tolerance: what if a RegionServer dies?

RegionServers store region data inside HDFS files

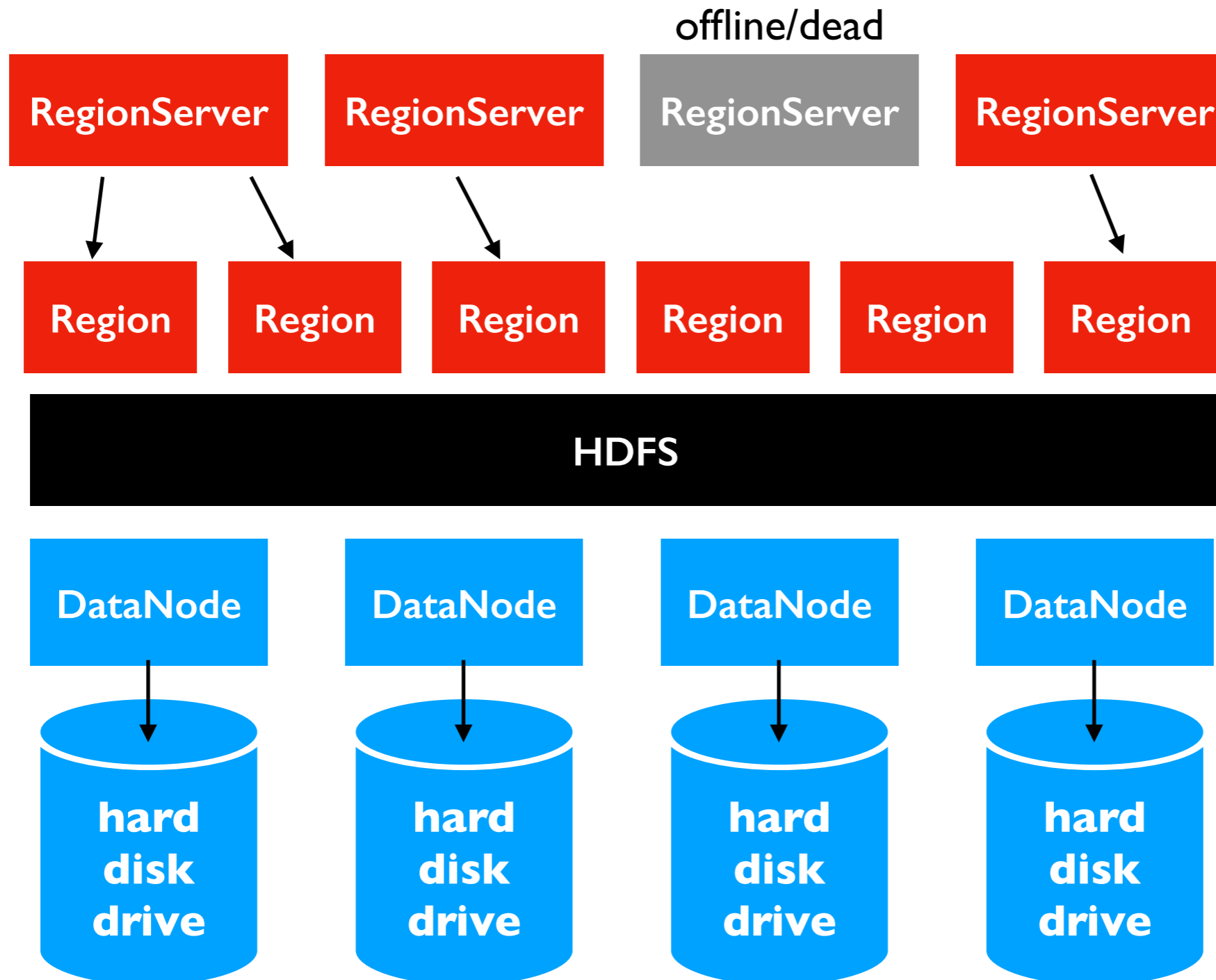


ideally a RegionServer is placed on the same machine as a DataNode holding most of its data

Fault Tolerance: what if a RegionServer dies?

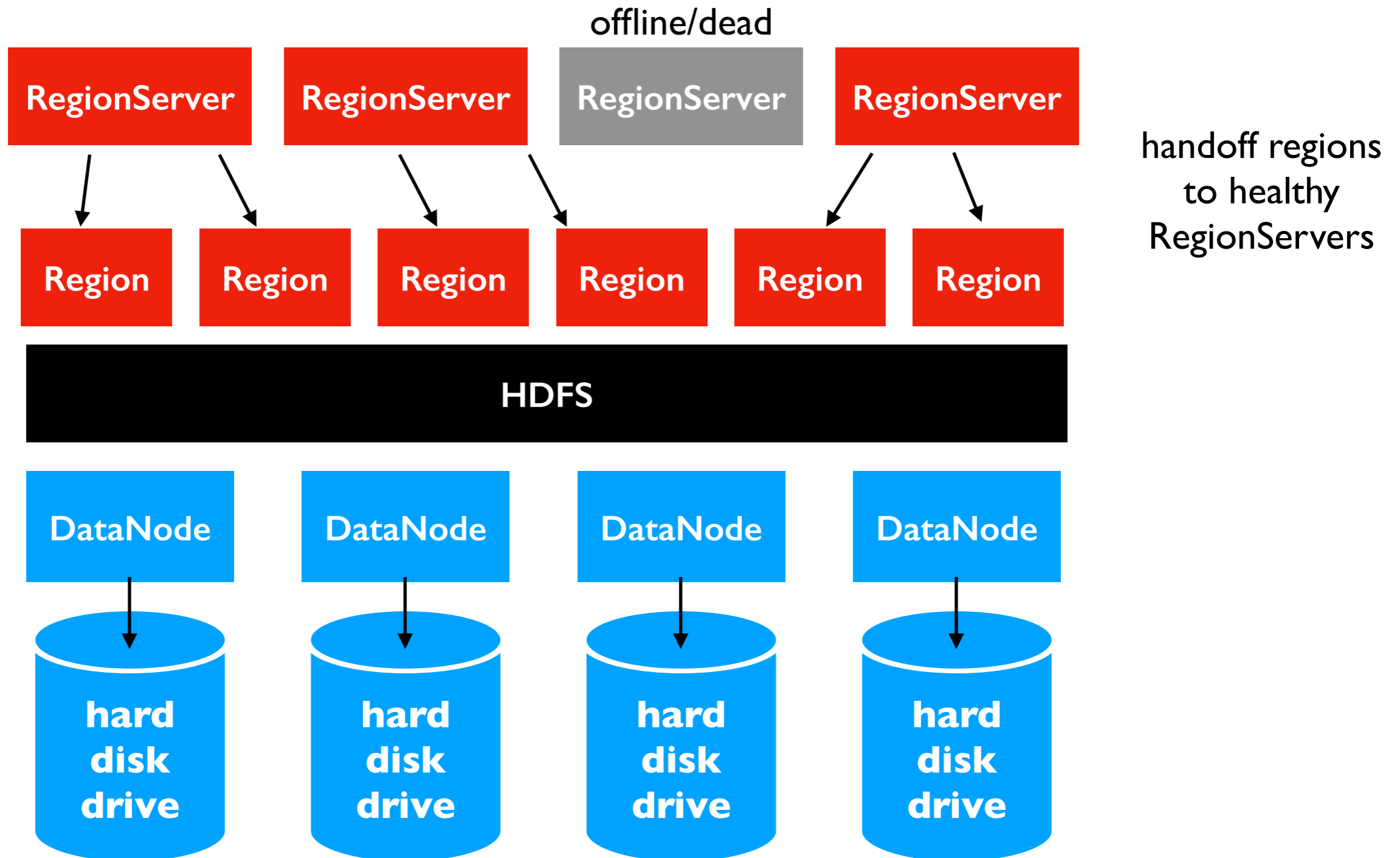


Fault Tolerance: what if a RegionServer dies?



region data
still safely
stored in
3x replicated
HDFS files

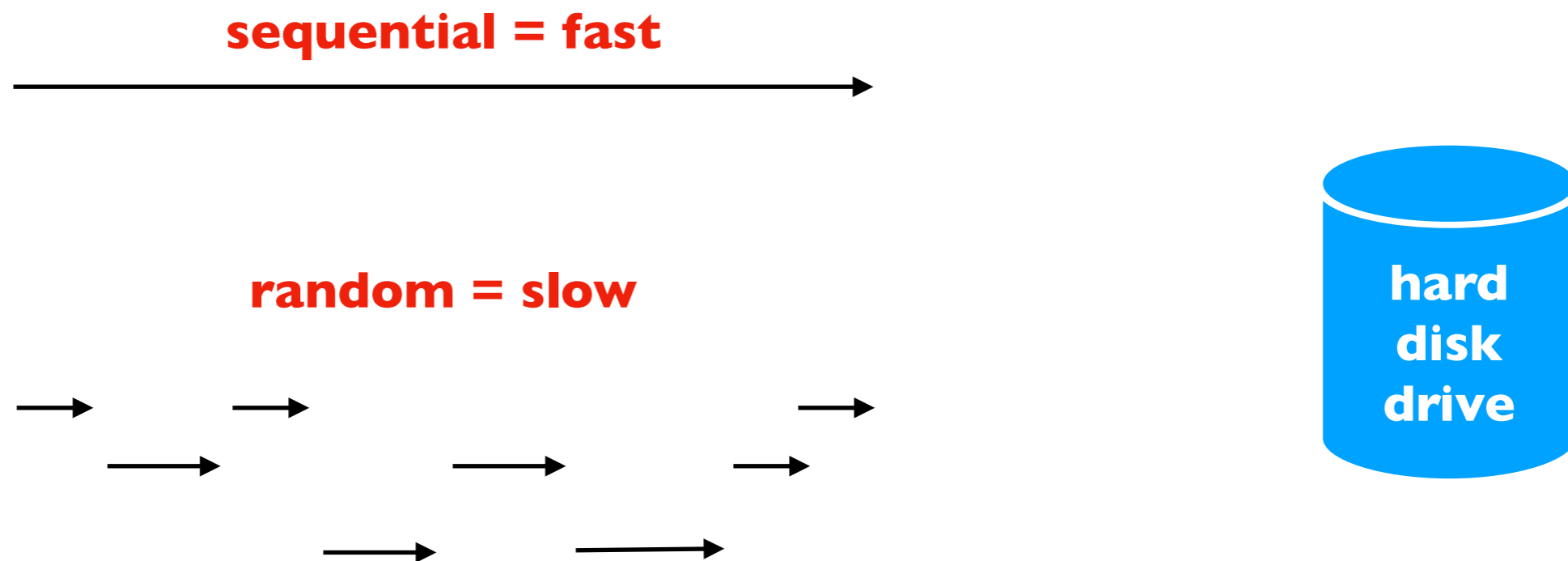
Fault Tolerance: what if a RegionServer dies?



HBase Storage Layout

Observation:

- starting a write operation on disk has a very high fixed cost



Strategy:

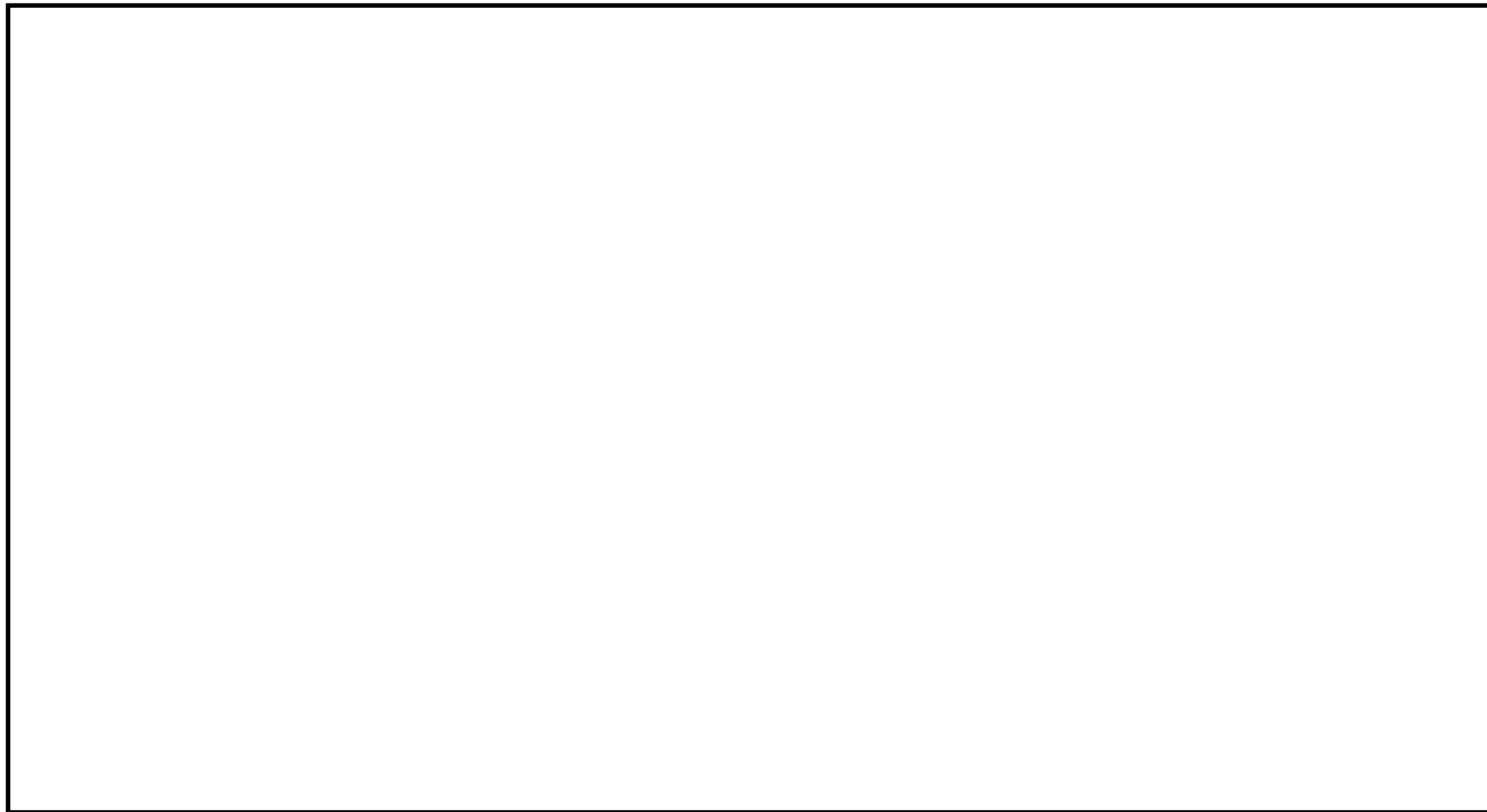
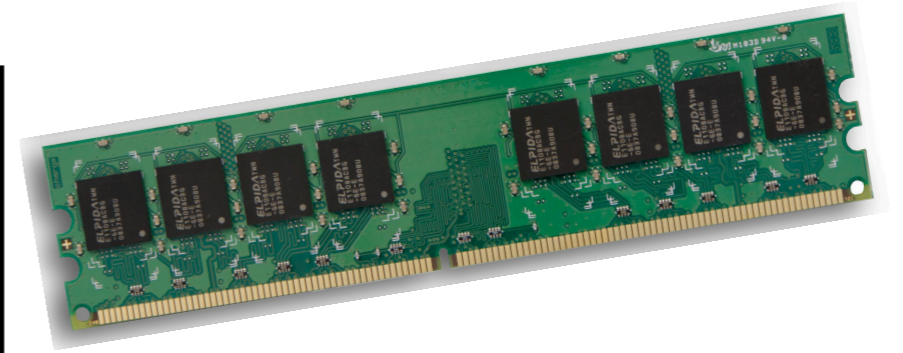
- store new data in **memory** until we have a lot of data
- then do one big write to **disk**

HBase Storage Layout

write



k1=hi



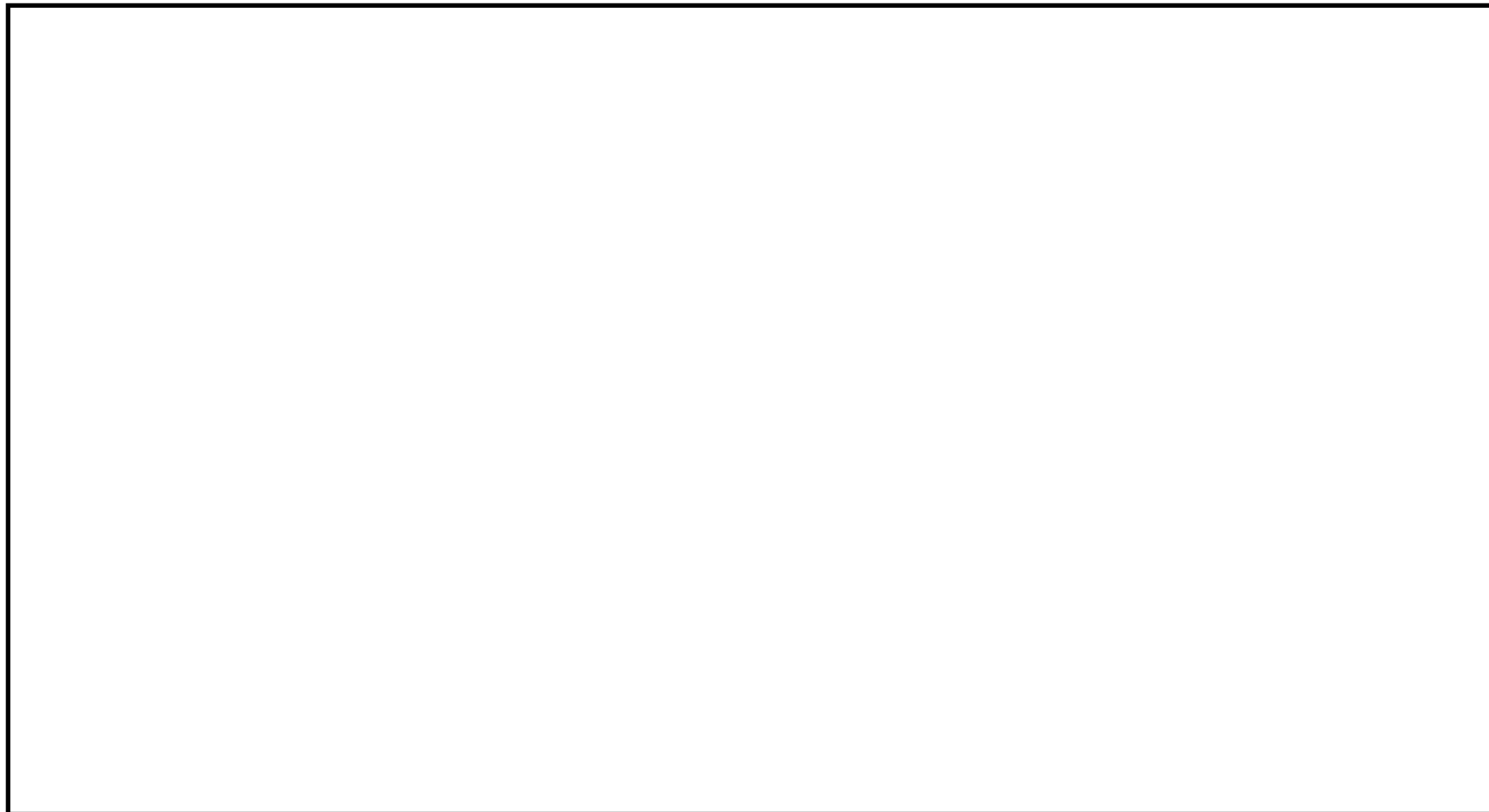
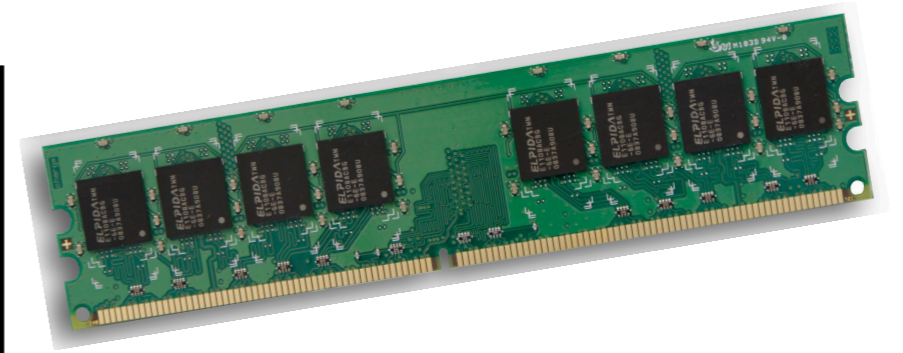
HDFS
(backed by hard drives)

HBase Storage Layout

write



k1=hi | k5=apple



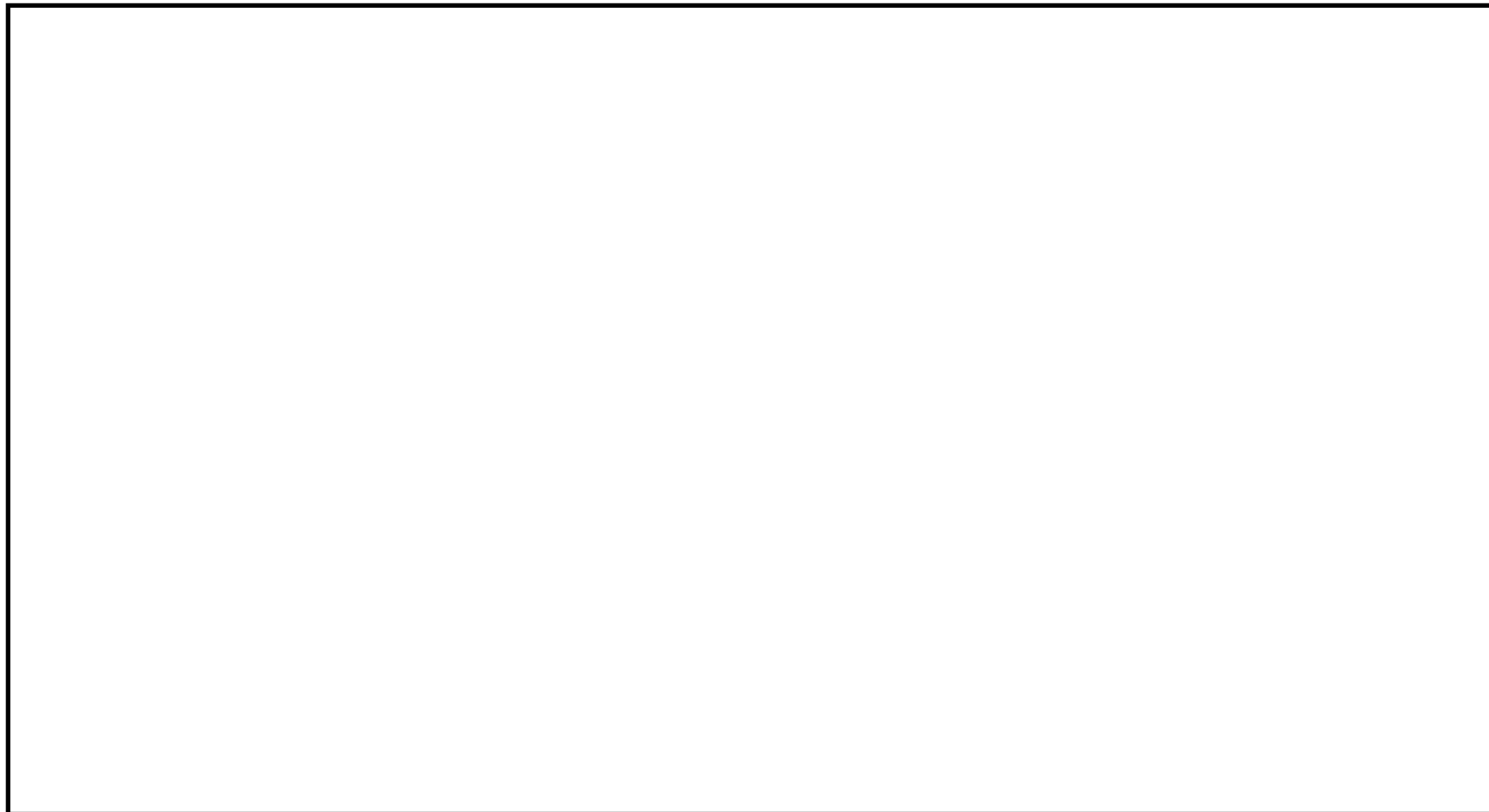
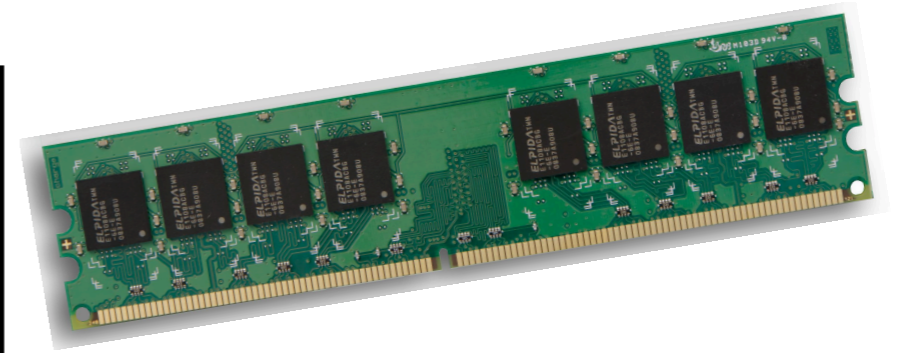
HDFS
(backed by hard drives)

HBase Storage Layout

write



k1=hi | k5=apple | k3=cat



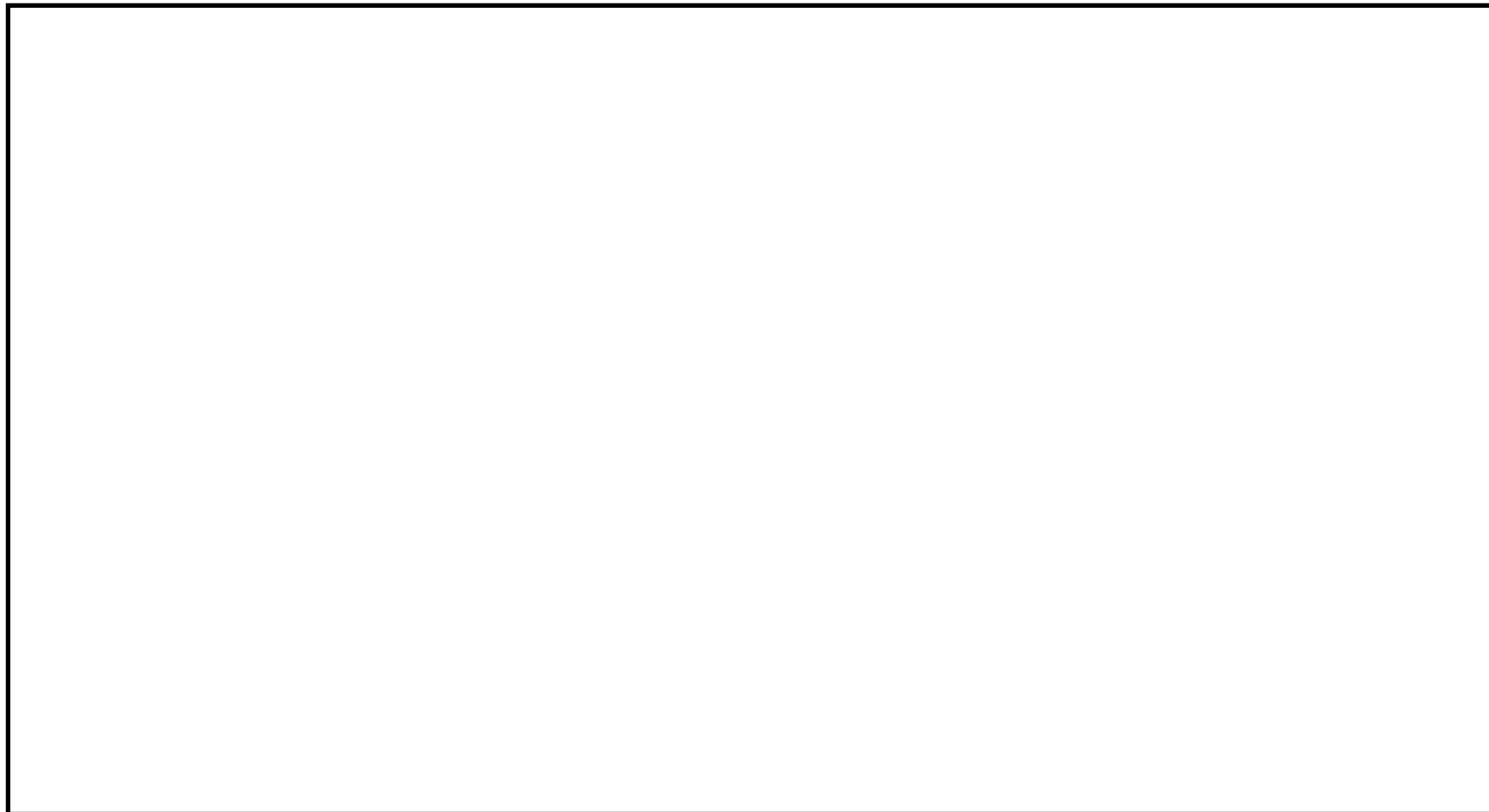
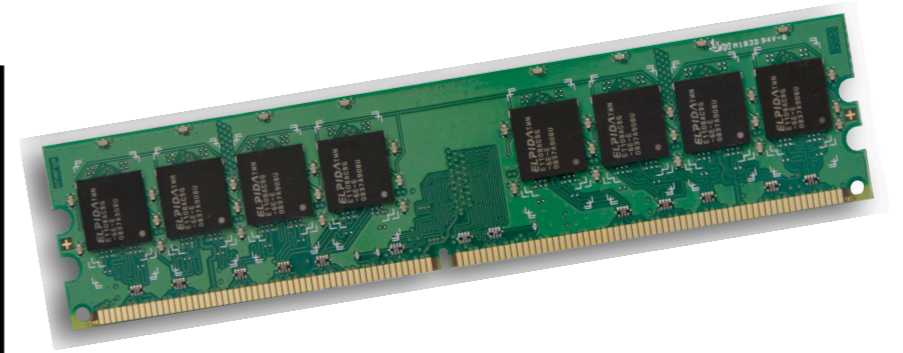
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HBase Storage Layout

write

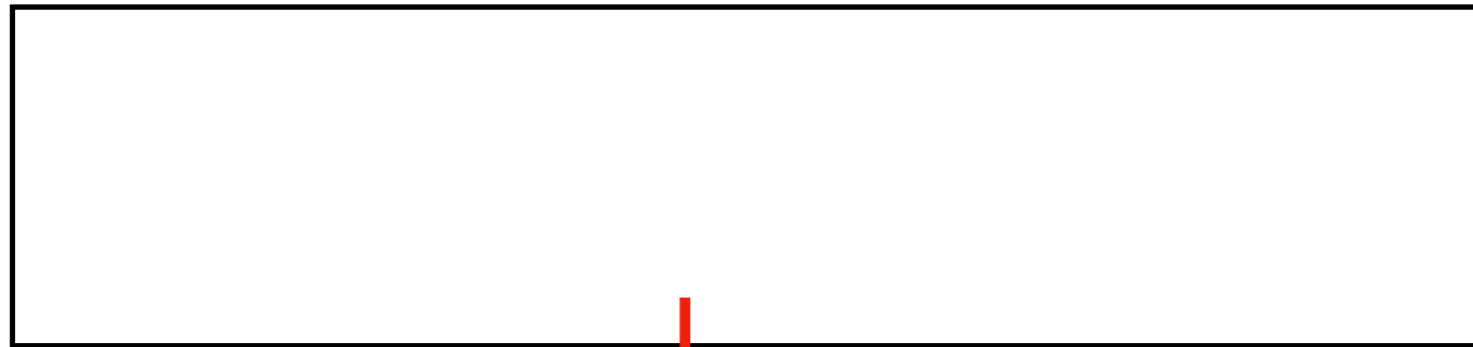
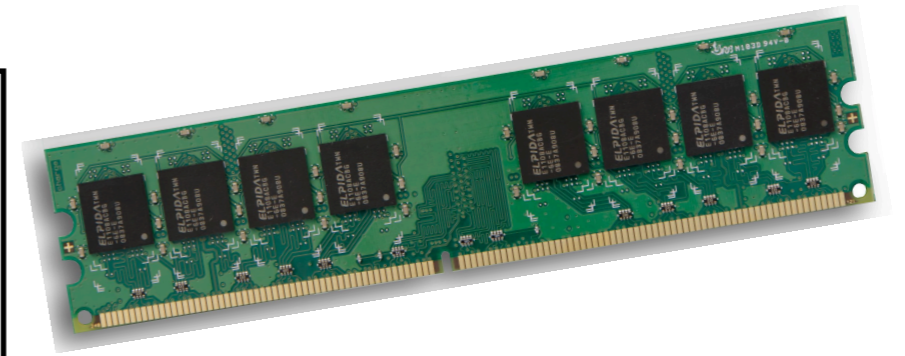


k1=hi | k5=apple | k3=cat | k9=dog



HDFS
(backed by hard drives)

HBase Storage Layout



sort+flush



k1=hi | k3=cat | k5=apple | k9=dog

HDFS
file

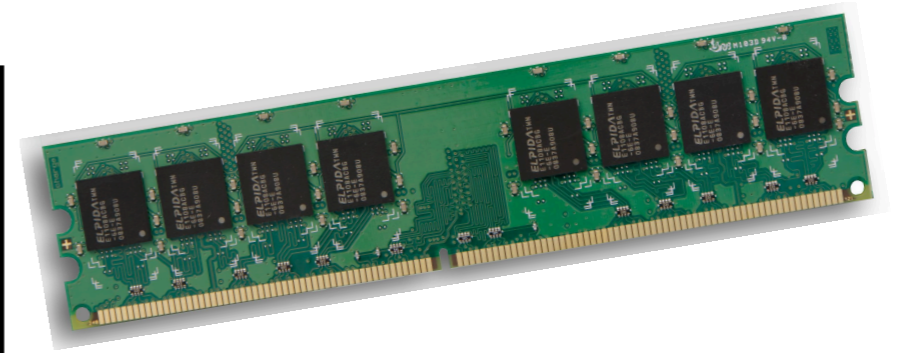
HDFS
(backed by hard drives)

HBase Storage Layout

write



k6=moon | ...

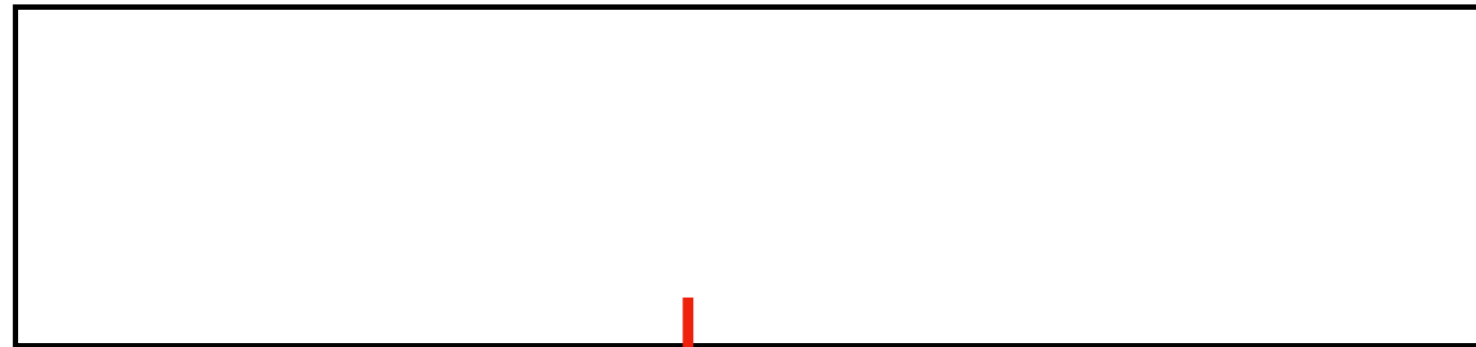
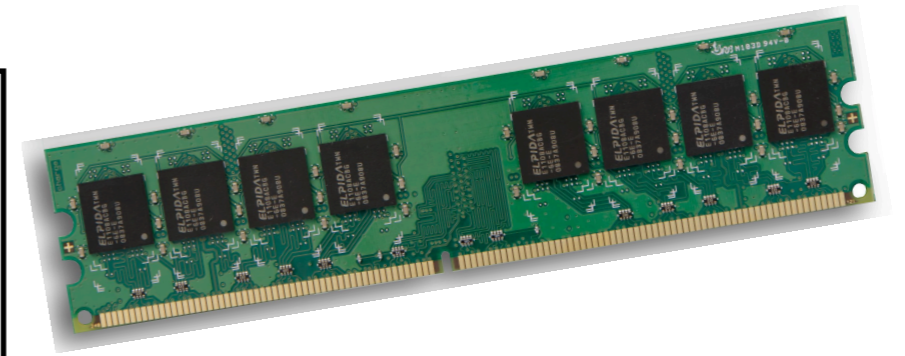


k1=hi | k3=cat | k5=apple | k9=dog

HDFS
file

HDFS
(backed by hard drives)

HBase Storage Layout



sort+flush

k2=bye | k4=sun | k6=moon | k9=pup

HDFS
file

k1=hi | k3=cat | k5=apple | k9=dog

HDFS
file

HDFS
(backed by hard drives)

HBase Reads

check multiple HDFS files when looking up keys

what is the value for **k3**? what about for **k9**?

k2=bye | k4=sun | k6=moon | k9=pup

HDFS
file

k1=hi | k3=cat | k5=apple | k9=dog

HDFS
file

HDFS
(backed by hard drives)

HBase Reads

check multiple HDFS files when looking up keys

what is the value for k3? what about for k9?

"tombstones" are used when we delete data
(need to write something -- can't erase old version in finalized file)

k2=bye | k4=sun | k6=moon | k9=pup

HDFS
file

k1=hi | k3=cat | k5=apple | k9=dog

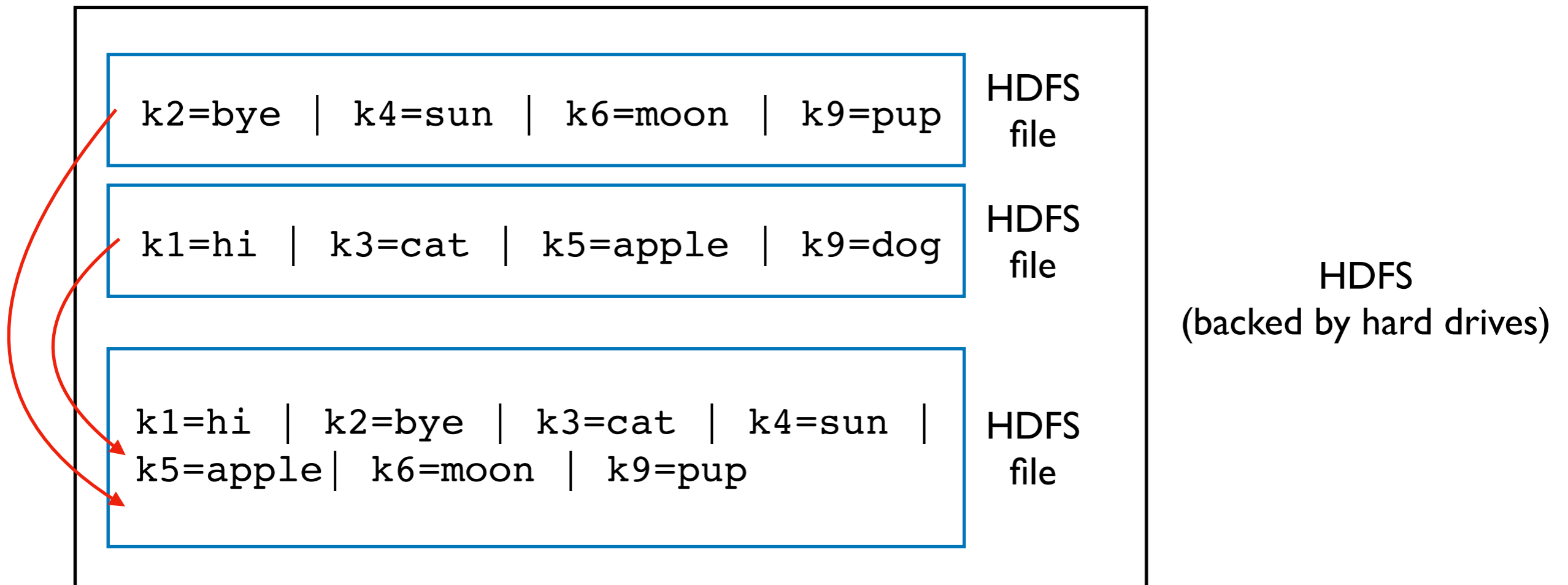
HDFS
file

HDFS
(backed by hard drives)

Compaction: Many Small Files => Few Big Files

If there are too many files, reads become too slow.

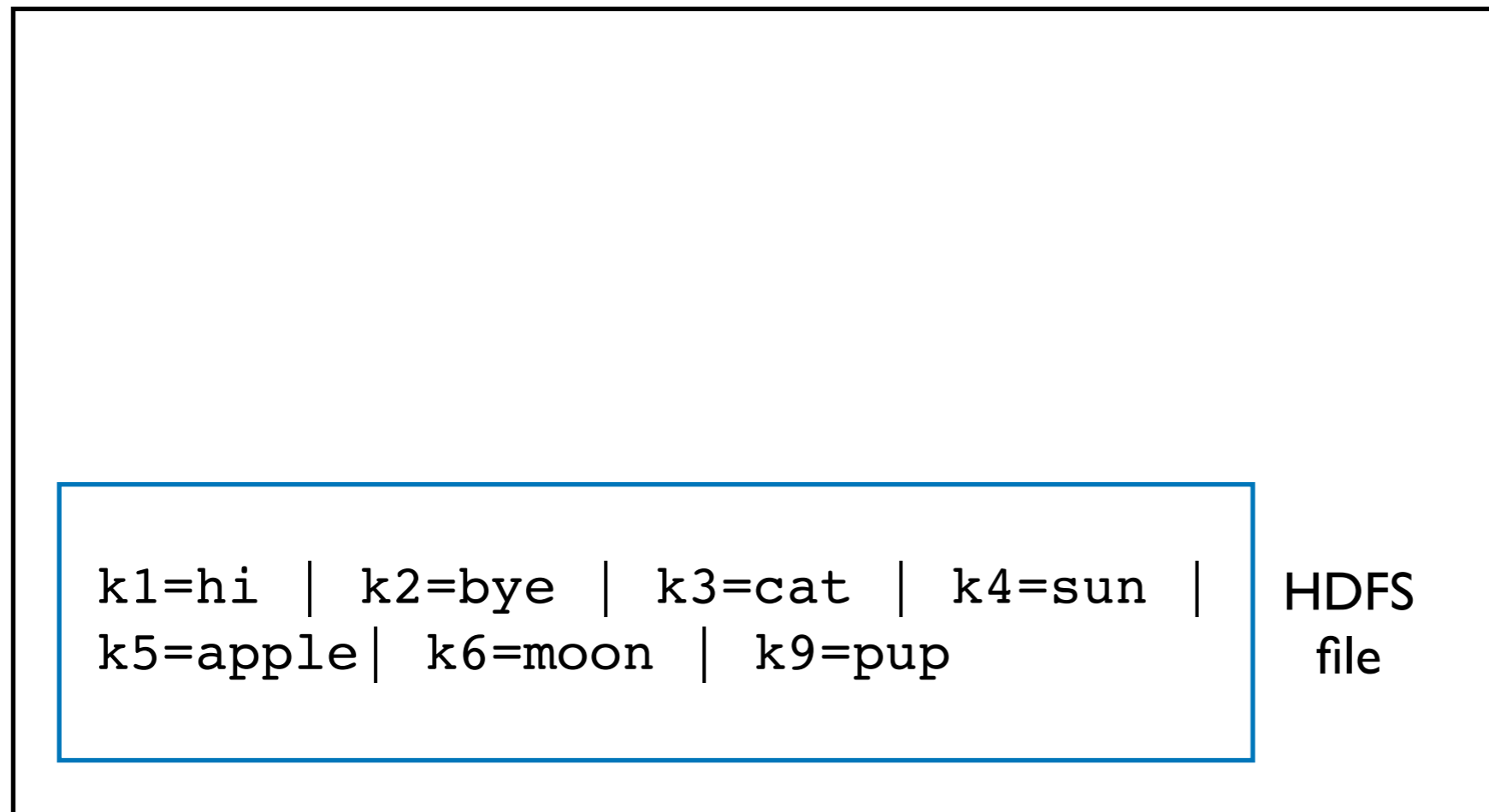
Solution: compact/combine smaller files into bigger files



Compaction: Many Small Files => Few Big Files

If there are too many files, reads become too slow.

Solution: compact/combine smaller files into bigger files



HDFS
(backed by hard drives)

k1=hi | k2=bye | k3=cat | k4=sun |
k5=apple | k6=moon | k9=pup

HDFS
file

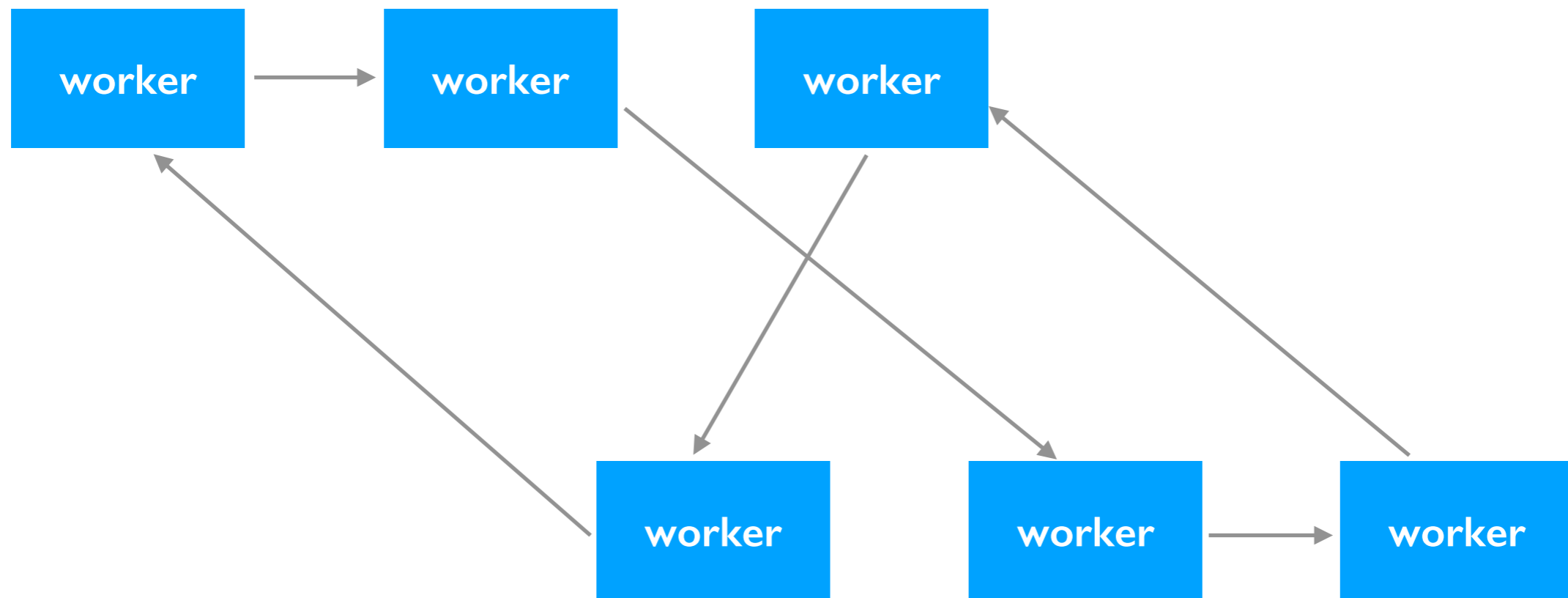
Outline: HBase and Cassandra

HBase

Cassandra Data Model

Demos

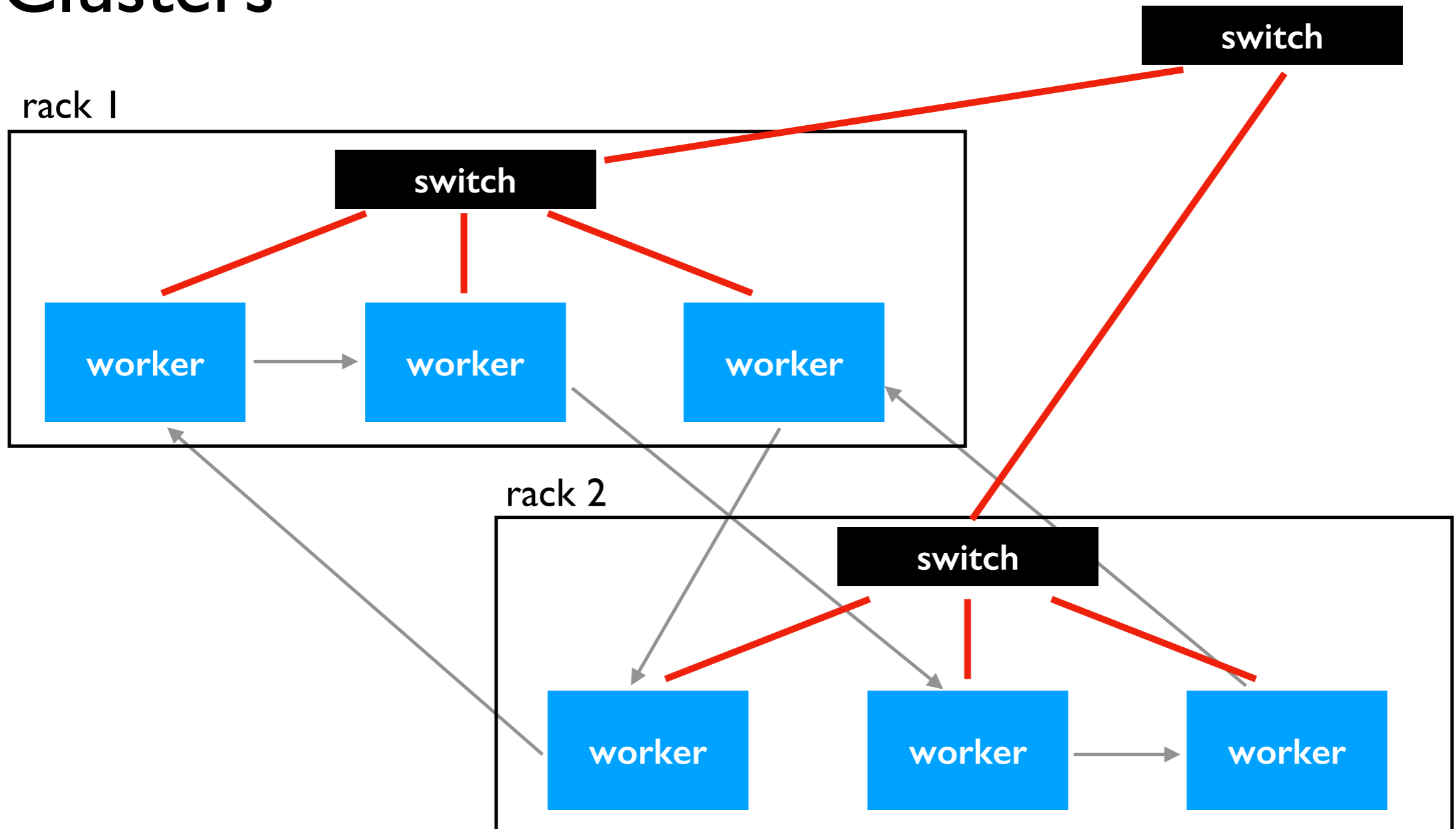
Clusters



Cassandra clusters have many worker nodes

- **No** centralized **boss** node (unlike HDFS, Spark)
- Not necessarily same data center (could be geographically distributed)
- Clusters are called **"rings"** because some nodes are defined to be "adjacent"

Clusters



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- No centralized **boss** node (unlike HDFS, Spark)
- Not necessarily same data center (could be geographically distributed)
- Clusters are called **"rings"** because some nodes are defined to be "adjacent"
- Ring organization doesn't necessarily correspond to network topology

Keyspaces



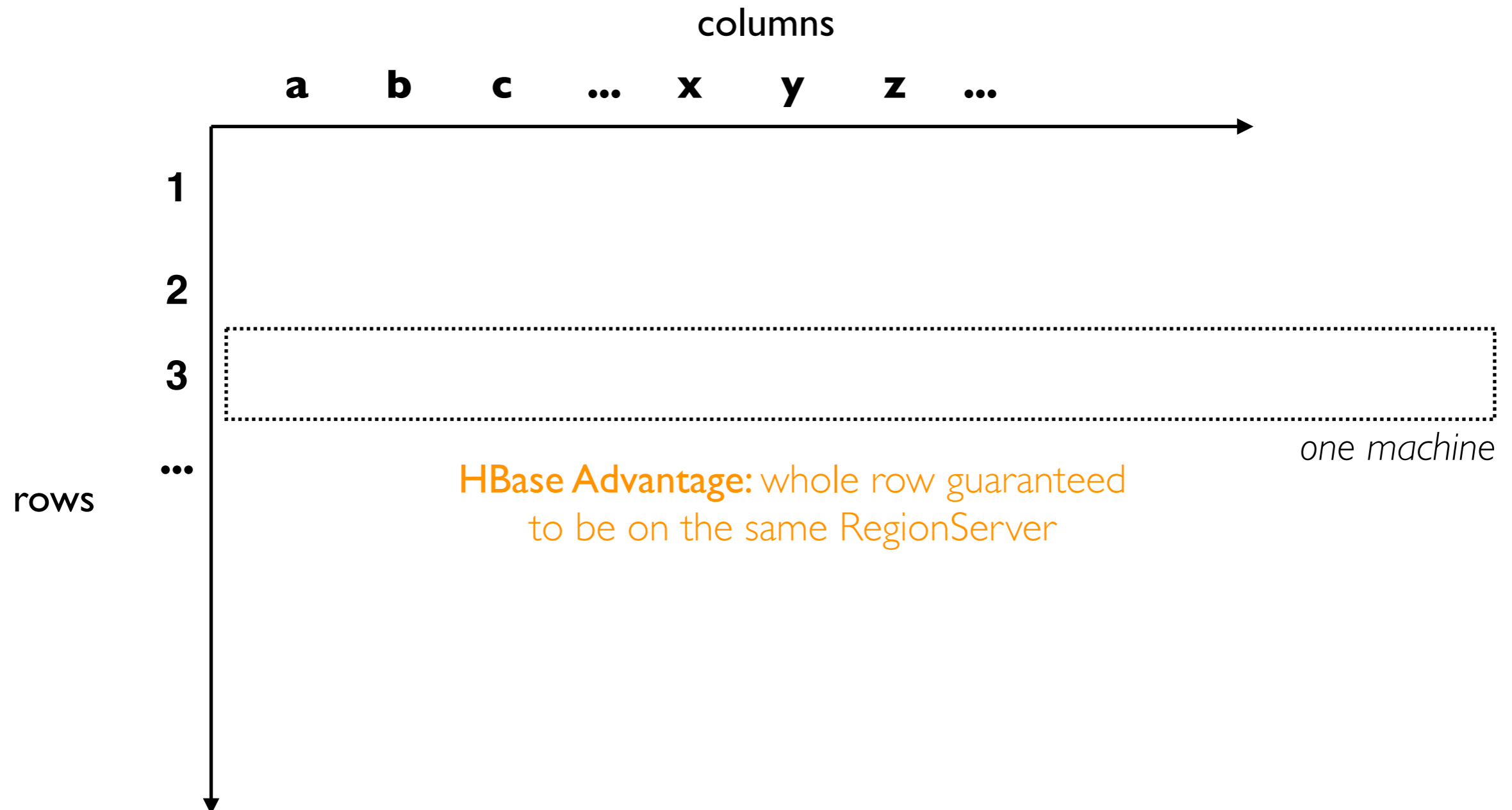
Keyspaces

- similar to databases on database servers
- keyspaces store data across many workers
- different keyspaces can have different replication settings

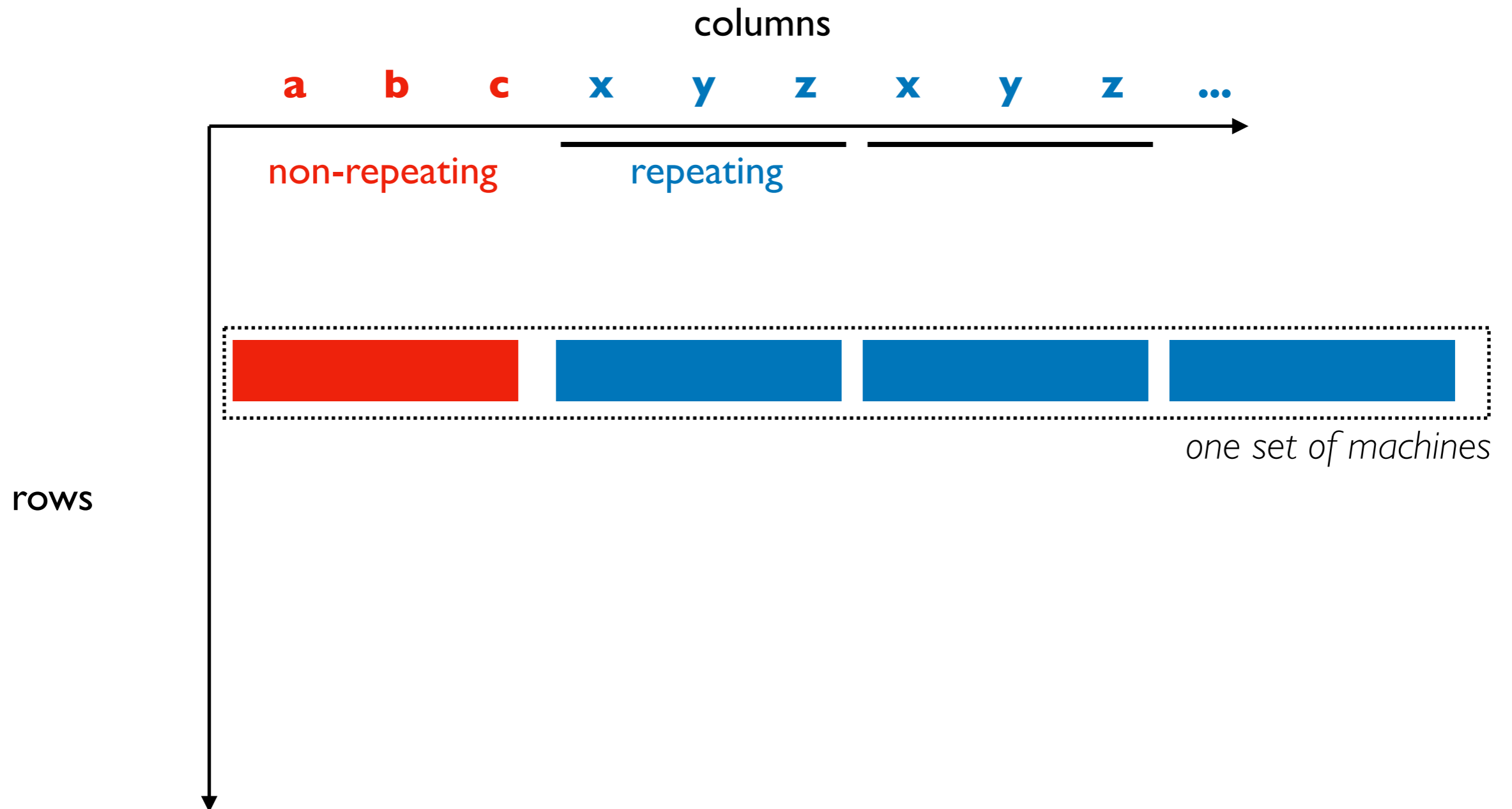
Each keyspace might contain many **tables**.

HBase: "Wide Row" design

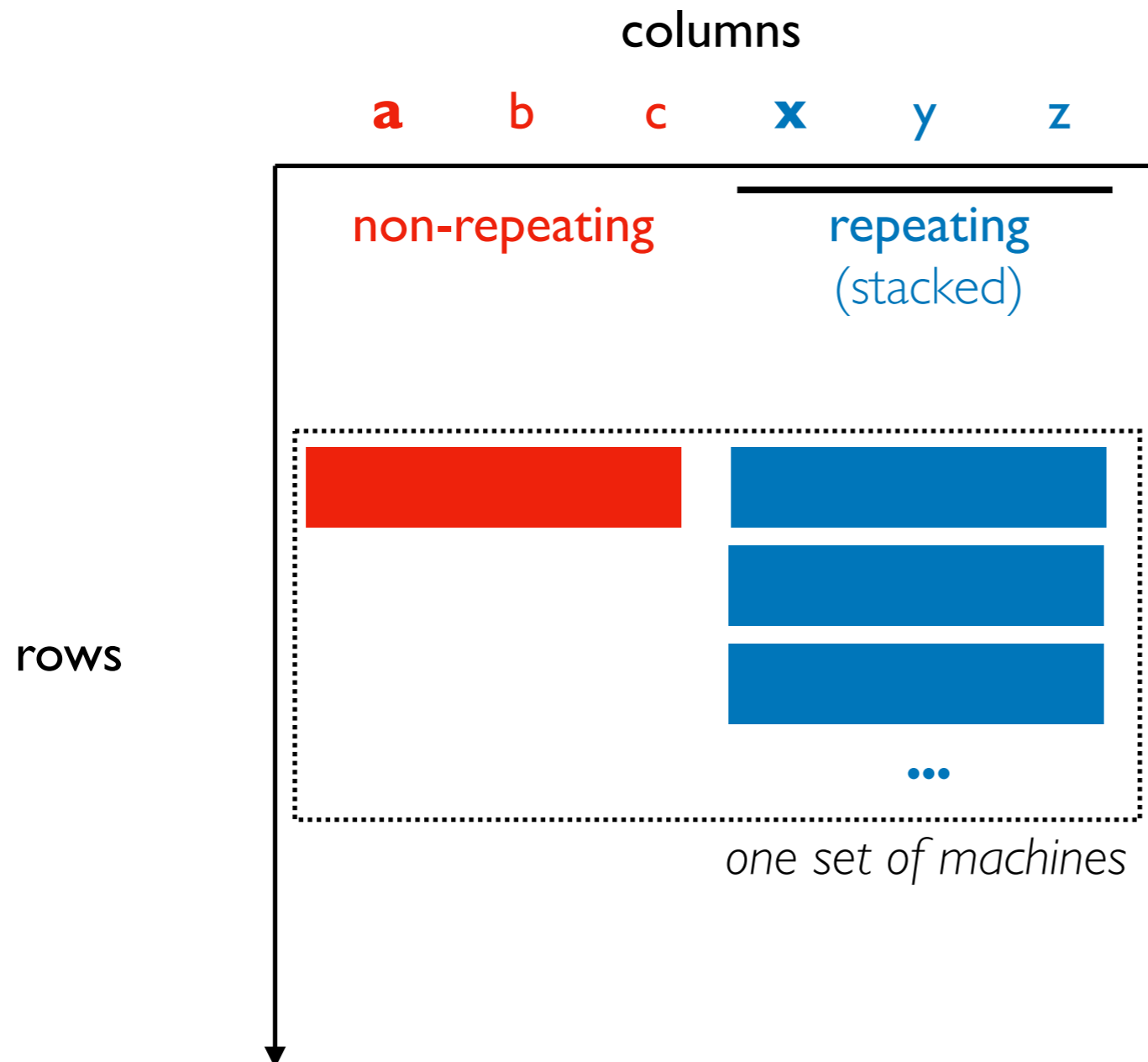
HBase Disadvantage: no efficient way to even know about all the columns (only about "column families").
SQL-like query languages not easily implemented



Cassandra: "Wide Partition" design



Cassandra: "Wide Partition" design



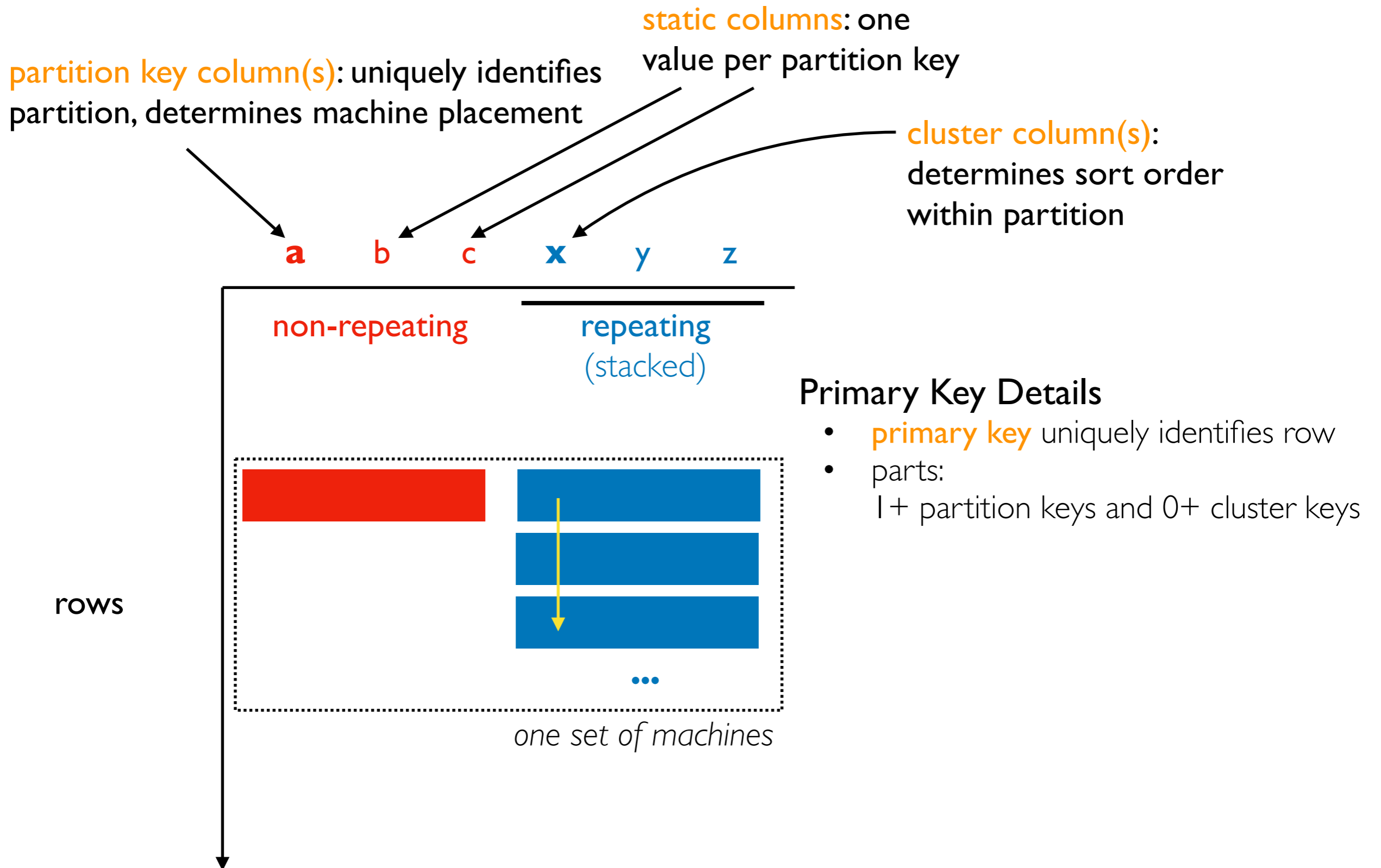
Advantages

- **finite columns**, so can use SQL-like queries: Cassandra Query Language (**CQL**)
- can keep related data on same machines

Disadvantages

- **big** partitions: imbalanced storage
- **hot** partitions: other imbalance

Cassandra: "Wide Partition" design



Schema Example: Weather Data

primary key: (station_id, date)

station_id	station_name	date	temp
non-repeating		repeating	
123	MadisonAP	2023-03-01	50
		2023-03-02	52
		2023-03-03	42
456	Milwaukee	2023-03-01	55
		2023-03-02	48
	

rows

Advantages

- can get all data for one station without scanning the whole cluster (100s of machines)
- looking up dates in a range for a station is fast (pre-sorted)

Challenges

- need to anticipate common queries
- carefully choose partition keys and cluster columns
- too many partitions: queries hit many nodes
- too few partitions: imbalance

Schema Example: Weather Data

station_id	station_name	date	temp
non-repeating		repeating	
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rows

TopHat

Outline: HBase and Cassandra

HBase

Cassandra Data Model

Demos

- Deployment
- cqlsh
- Python (cassandra-driver package)
- Spark (external data source)