Hadoop: Apache's Open Source Implementation of Google's MapReduce Framework

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Cloud Computing

- Clouds are big piles of other people's machines, plus virtualization
- Remote
- Scalable
- Virtual
- High Level API
- Course Grain data processed in parallel

Courtesy Stanzione, Sannier, and Santanam, Arizona State University

How much data?

- Wayback Machine has 2 PB + 20 TB/month (2006)
- Google processes 20 PB a day (2008)
- “all words ever spoken by human being” ~ 5 EB
- NOAA has ~ 1PB climate data (2007)
- CERN’s :HC will generate 15 PB a year (2008)

Stats from The iSchool University of Maryland

Saguaro Cluster

Research Group	High Performance Computing Initiative
Department	Fulton School
Primary Application	Various
# of Processor Cores	4560
Processor Architechture	Intel Xeon
Interconnect	InfiniBand
Memory	10240 GB (Total)
Storage	215 TB
OS	CentOS 5.3
Sys Admin Contact	Douglas Fuller

Google's Map/Reduce

- Google 2004 at The Sixth Symposium on Operating System Design and Implementation
- Processing and Generating large data sets
- Many real world tasks are expressible in this model
- Automatically parallelized for a large cluster of commodity machines

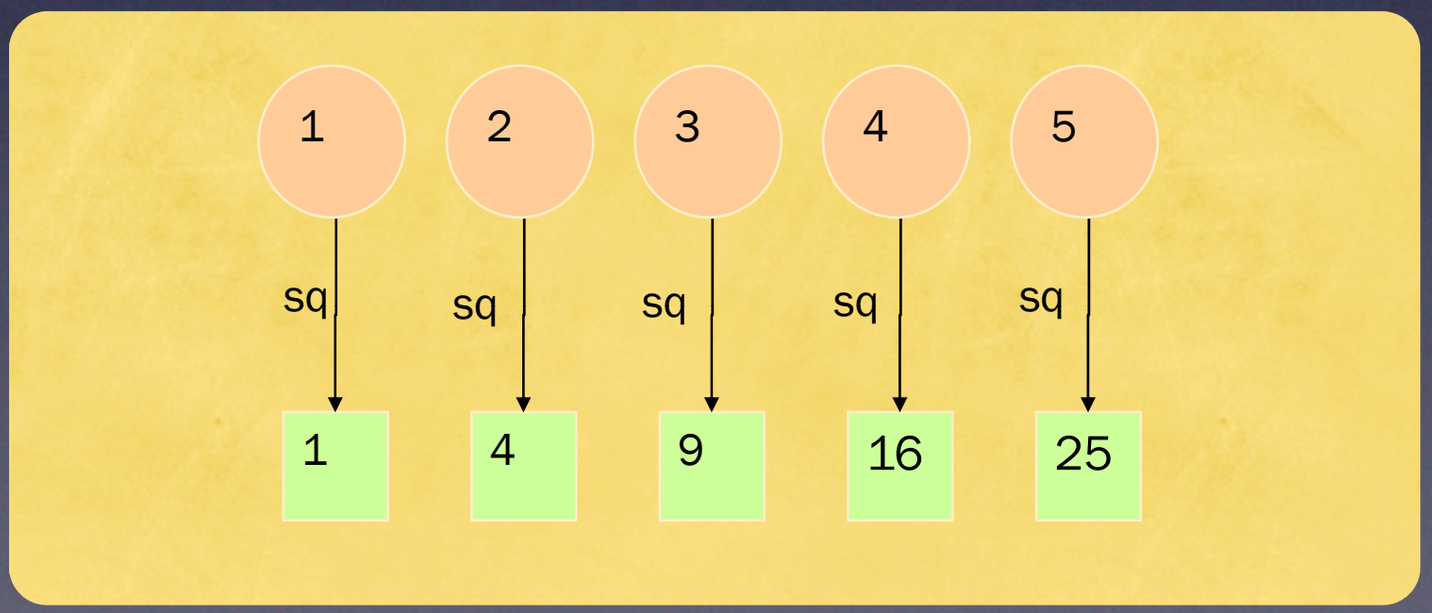
Google's Map/Reduce

- Input -> Mapper -> Intermediate <key/value> Pairs -> Reducer -> Output
- Easy to utilize resources of large distributed system without any experience
- Highly scalable: typically processes many terabytes of data in parallel
- Upwards of 1,000 MapReduce jobs are executed on Googles clusters daily

- Apache Project's Open Source Implementation of MapReduce
- JAVA Based
- Hadoop has been demonstrated on clusters with 2000 nodes. The current design target is 10,000 node clusters.
- http://hadoop.apache.org

Mapper

- Map is a special function that applies the function f to each element in the list
- Map[f,(1,2,3,4,5)] -> {f[1],f[2],f[3],f[4],f[5]}



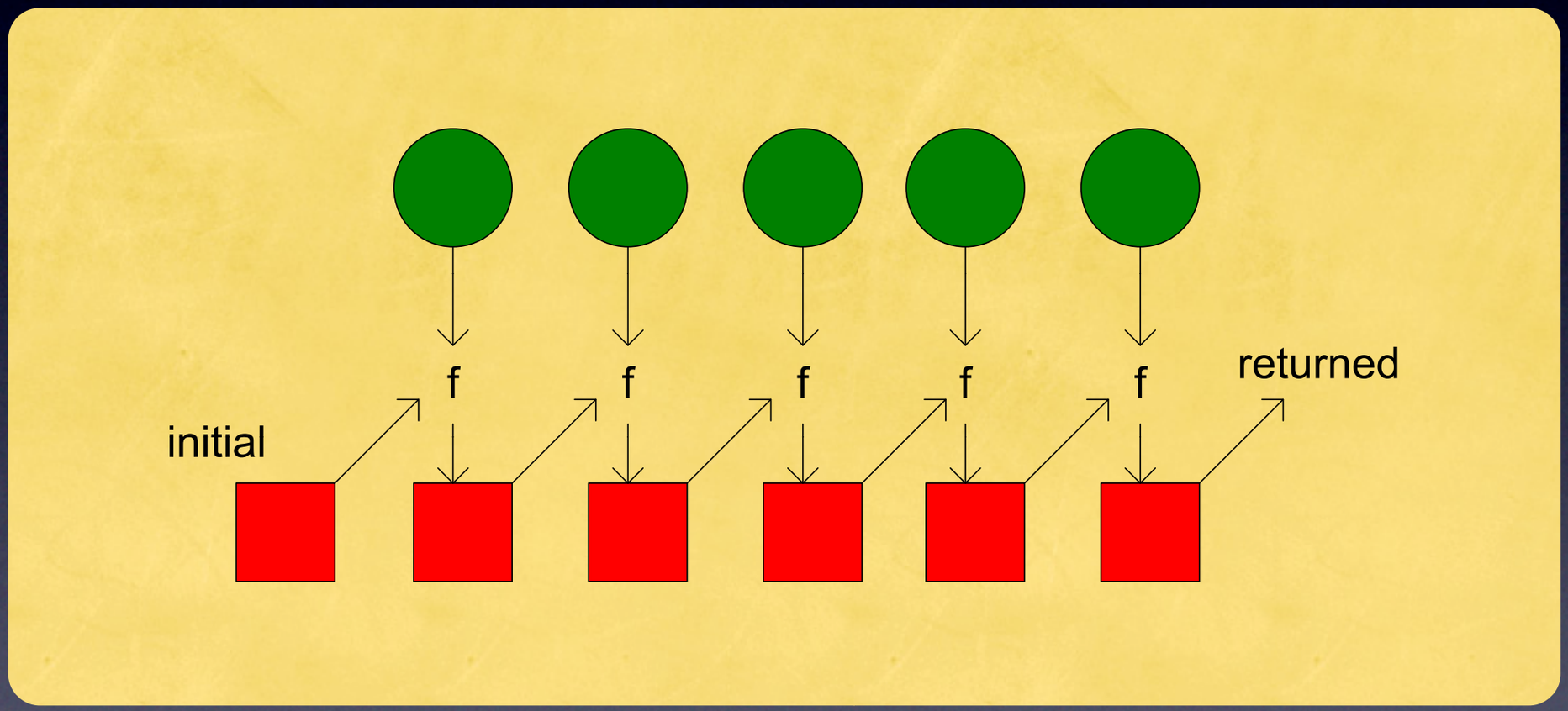
Mapper

- Input:
  - The Entire Data Set
  - Maps all the input values to a key
  - map() is called once for each line of input
- Output
  - Collects <key, value> pairs
  - Passes to reducer as hashmap

Reducer

- Reduce[f,x,list]
- Sets an accumulator
- Initial value is x
- Applies f to each element of the list plus the accumulator
- Result is the final value of the accumulator
- Reduce[f,x,{a,b,c}] => f[f[f[x,a],b],c]

Reducer



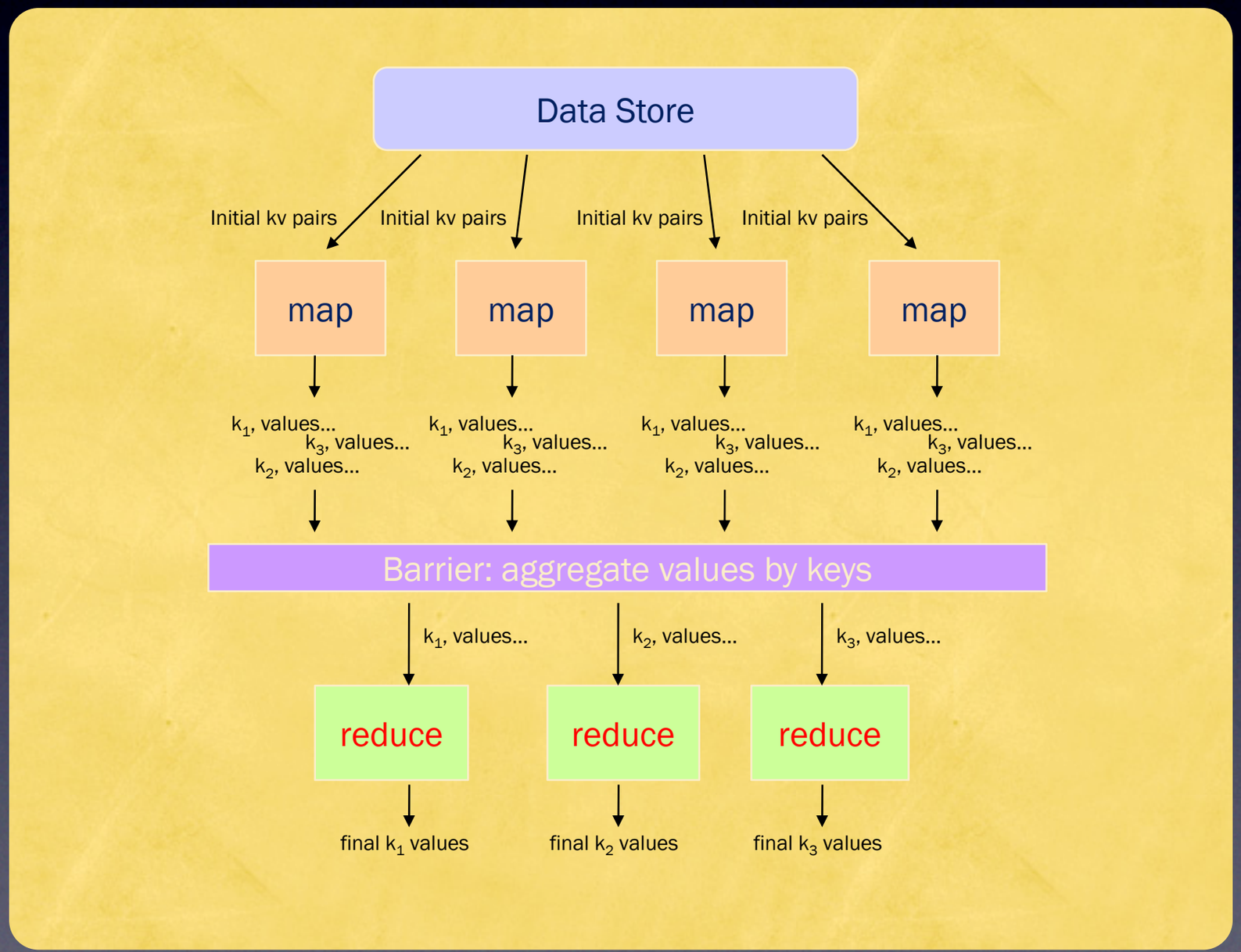
Reducer

- Input
  - The output <KV> hashmap from the mapper
  - f(x) is performed on every x with a common key
- Output
  - A <KV> list of the output of reduce()

Map/Reduce Framework

- Map is implicitly parallel
- Order of application of function does not matter
- Reduce is executed in serial on a single node
- The results of map() are copied and sorted then sent to the reduce()

Map/Reduce Framework



Map/Reduce Framework

- Programmer does not have to handle:
  - Work distribution
  - Scheduling
  - Networking
  - Synchronization
  - Fault recovery (if a map or reduce node fails)
  - Moving data between nodes

Master Node

- Assigns tasks and data to each node
- Hosts an http JobTracker on port 50030
- Queries each node
- Kills any task that does not respond
- Re-Batches killed tasks out to next available node

Streaming

- Ability to port mappers and reducers to any language that is executable on each node
- Input is read from stdin()
- def read_input(file):
    for line in file:
        yield line.rstrip()

Streaming

- Output is a hashmap, which is a string in the form:

  <Key (tab) Value>
- Output is written to stdout()
- print "%s\t%s" % (key, value)

Streaming

- The utility packages all executables into a single JAR
- JAR is sent to all nodes
- Distributed Cache files are symlinked to the current working directory

Streaming

```
$HADOOP_HOME/bin/hadoop jar $HADOOP_HOME/contrib/streaming/hadoop-0.19.0-streaming.jar \
-input inputDirs \
-output outputDir \
-mapper mapperExecutable \
-reducer reducerExecutable \
-file PathOfFilesToBePackaged \
-cacheFile 'hdfs://pathToFile#symlink' \
-jobconf mapred.job.name='jobName'

$HADOOP_HOME/bin/hadoop jar $HADOOP_HOME/contrib/streaming/hadoop-0.19.0-streaming.jar \
-input /datasets/Netflix-dataset/training_set_reorg/* \
-output pyNetflix1Output \
-mapper pyMapper.py \
-reducer pyReducer.py \
-file /home/ranguiano/workspace/pyNetflix1/pyMapper.py \
-file /home/ranguiano/workspace/pyNetflix1/pyReducer.py \
-cacheFile 'hdfs://s49-1.local:9001/datasets/Netflix-dataset/movie_titles.txt#movie_titles.txt' \
-jobconf mapred.job.name='pyNetflix1'
```

Streaming

- -mapper and -reducer can be set to a java class or any file that can be executed locally
- Files and/or Archives can be distributed to each node or to distributed cache

Reporting

- Stdin/Stdout used for data, Stderr used for communication to Master Node
- Counter must be reported after every output line to track job progress

  report:counter:pyNetflix1,mapper,1
- Status messages can be used to track errors in log files

  report:status:Movie not found

HDFS

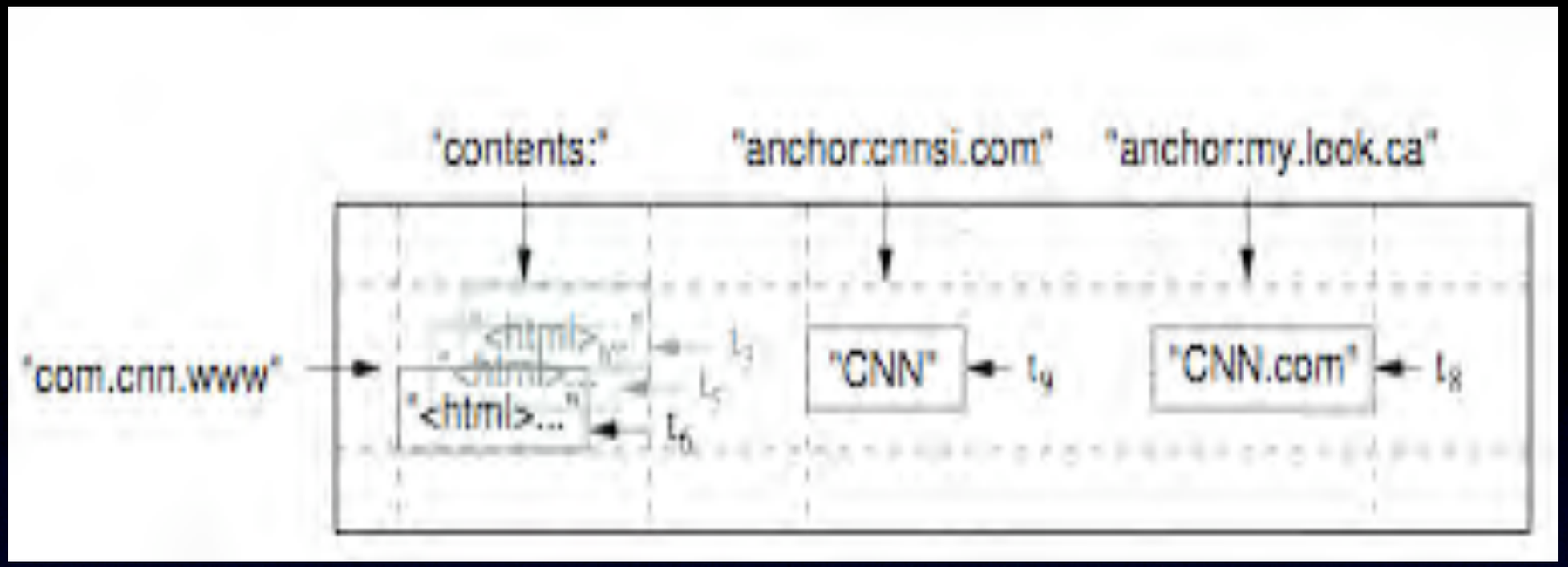
- Hadoop Distributed File System (HDFS) - Google uses GoogleFileSystem (GFS)
- High fault-tolerant, low cost hardware
- High throughput, streaming access to data
- Data is split on 64 meg blocks and replicated in storage

- HBase is equivalent to Google's BigTable
- NON-RELATIONAL DATABASE
- Is not built for real-time querying
- Moving away from per-user actions
- Towards per-action data sets

- Distributed
- Multi-dimensional
- De-Normalized Data
- HBase is not an SQL Database

HBase Tables

- Table Schema defines Column Families
- Column Family contains multiple Columns
- Each Column has Versions (Z-axis)
- Everything except table name stored as byte[]



Row Key	Time Stamp	Column *"contents:"*	Column *"anchor:"*		Column *"mime:"*
"com.cnn.www"	t9		"anchor:cnnsi.com"	"CNN"	
	t8		"anchor:my.look.ca"	"CNN.com"	
	t6	"<html>..."			"text/html"
	t5	"<html>..."			
	t3	"<html>..."			

*Taken from HBase Documentation

Amazon's Elastic Compute Cloud (EC2)

- Web service that provides resizable compute capacity in Amazon's Cloud.
- Hadoop is packaged as a public EC2 image (an AMI) so it is easy for us to get up and running with a cluster.
- ec2-describe-images -a | grep hadoop-ec2-images
- Extremely simple to setup an elastic hadoop cloud
- http://aws.amazon.com/ec2/

Amazon's Pricing

EC2

Standard On-Demand Instances	Linux/UNIX Usage	Windows Usage
Small (Default)	$0.10 per hour	$0.125 per hour
Large	$0.40 per hour	$0.50 per hour
Extra Large	$0.80 per hour	$1.00 per hour
High CPU On-Demand Instances	**Linux/UNIX Usage**	**Windows Usage**
Medium	$0.20 per hour	$0.30 per hour
Extra Large	$0.80 per hour	$1.20 per hour

S3 (Amazon's Simple Storage Service)

Storage

- $0.150 per GB – first 50 TB / month of storage used
- $0.140 per GB – next 50 TB / month of storage used
- $0.130 per GB – next 400 TB /month of storage used
- $0.120 per GB – storage used / month over 500 TB

Data Transfer

- $0.170 per GB – first 10 TB / month data transfer out
- $0.130 per GB – next 40 TB / month data transfer out
- $0.110 per GB – next 100 TB / month data transfer out
- $0.100 per GB – data transfer out / month over 150 TB

Requests

- $0.01 per 1,000 PUT, COPY, POST, or LIST requests
- $0.01 per 10,000 GET and all other requests*

* No charge for delete requests

2 GB dataset of movie/user/ratings

Training_set1.txt...Training_set17770.txt:

- **MovieIDs range from 1 to 17770 sequentially.**
- **CustomerIDs range from 1 to *2649429*, with gaps. There are 480189 users.**
- **Ratings are on a five star scale from 1 to 5.**
- **Dates have the format YYYY-MM-DD.**

1: [Movie 1 of 17770]
[CustomerID,Rating,Date]
1116, 3, 2006-04-17
2, 5, 2007-07-07

Netflix Prize

- Default input dataset creates one mapper per file
- Inefficient when dealing with 17,770 files
- Need to optimize # of files to the number of mappers available
- Awk script used to reorganize input dataset into 104 files to be used on 100 procs
- Insures that all mappers are being utilized while optimizing file I/O

Netflix Prize

netflixReorg.awk:

```
        # tokenize on “:”
BEGIN { FS = ":" }
        # if it is the first line, movieID = first token
{if( FNR == 1) movieID = $1
        # if it is not the first line,
        output movieID  “,” first token
if ( FNR != 1 ) print movieID "," $1}
```

Netflix Prize

- Efficiency gained by reorganizing input dataset
- Netflix1 - 43:27
- Netflix1Reorg - 9:55
- pyNetflix1 - 13:02
- awkNetflix1 - 9:04

Netflix1 Program

- Produce statistical information about each movie in the dataset
- It took the entire Netflix dataset as input
- Produced the first date rated, last date rated, total rating count and average rating for each movie as the output

Netflix1 Mapper

- Input: Netflix Prize Training Set
  - output: <movieID, ratingAndDateRated>
  - one <K,V> pair for each movieID in the input data set

Netflix1 Mapper Code

- Netflix1/MyMapper.java

pyNetflix1 Mapper Code

- pyNetflix1/pyMapper.py

awkNetflix1 Mapper Code

- awkNetflix1/awkMapper.awk

Mapper Comparison

Netflix I	Java	Python	Awk
Map Task	Best: 8 sec Avg: 12 sec	Best: 27 sec Avg: 1 min 5 sec	Best: 9 sec Avg: 15 sec

Netflix2 Reducer

- The Netflix2 program calculates statistics based on the users in the dataset
- Netflix2 Mapper output
  - <userID, movieID : rating : dateRated>
- Netflix2 Reducer output
  - <userID, ratingCount : avgRating : ratingDelay : movieRatingDateList >

Netflix2 Reducer Code

- Netflix2/MyReducer.java

pyNetflix2 Reducer Code

- pyNetflix2/pyReducer.py

Reducer Comparison

Netflix 2	Java	Python
Reduce Task	2 min 58 sec	8 min 45 sec

Shoutouts

- Dr. Adrian Sannier - University Technology Officer
- Dr. Dan Stanzione Jr. - Director of High Performance Computing Initiative
- Dr. Raghu Santanam - Associate Professor
- Nathan Kerr and Jeff Conner

Thank you

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Questions?