ECE 574 – Cluster Computing
Lecture 18

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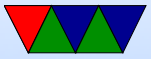
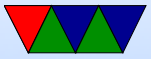
Announcements

- HW#6 was posted
- Don't forget project topics



Hadoop and Map Reduce



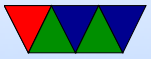
Map Reduce

- Originally popularized by Google, but not really used by them anymore
  Jeffrey Dean, Sanjay Ghemawat (2004) MapReduce: Simplified Data Processing on Large Clusters, Google.

- For processing large data sets in parallel on a cluster

- Similar to MPI reduce and scatter operations

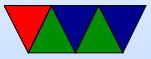
- Map() – filters and sorts data into key/value pairs



Stateless, can run in parallel
can contain Combiner() – combines duplicates?

- Reduce() – the various worker nodes process each group in parallel.
  Shuffle() – redistribute data so all common data on same node

- Can do with single processor systems, but not any faster typically. Shines on parallel systems



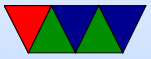
Map Reduce Example

`The quick brown fox jumped over the lazy dog.`

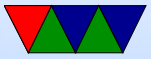
MAP split by key (in this case, number of letters)

```
3: [the, fox, the, dog]
4: [over, lazy]
5: [quick, brown]
6: [jumped]
```

REDUCE each thread/node gets one of these. Reduce might simply count.



```
3: 4
4: 2
5: 2
6: 1
```



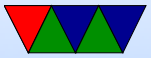
Map Reduce Hello World

This is the example they like to use.

Map: key is the word

```
To be or not to be, that is the question.
```

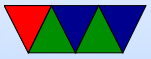
```
to: [1, 1]
be: [1, 1]
or: [1]
not: [1]
that: [1]
is: [1]
```



```
the: [1]
question: [1]
```

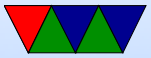
Reduce:

```
to: 2
be: 2
or: 1
not: 1
that: 1
is: 1
the: 1
question: 1
```

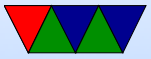


Hadoop

- Apache
- Distributed Processing and Distributed Storage on commodity clusters
- Java based
- Data spread throughout nodes
  Large data sets split up and spread throughout the cluster

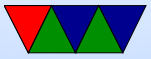


- Unlike traditional HPC clusters, code sent *to the nodes* that have data of interest, rather than taking data over network to running code.
- HADOOP common – libraries
- HADOOP YARN – thread scheduling
- Hadoop Distributed File System – HDFS
- Hadoop MapReduce – processing algorithm
- Originally developed at Yahoo by Cutting and Cafarella.



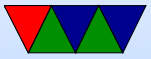
Named after toy elephant.

- Many users. As of 2012 Facebook had 100PB of data, said it grew at 0.5PB/day



Scheduling

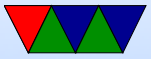
- Each location of system known. Try to run code on same system as data for locality, If not possible, run on one nearby.
- Small cluster has single master node, and multiple worker nodes.



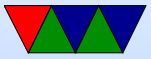
Hadoop Distributed Filesystem

`https://hadoop.apache.org/docs/r1.2.1/hdfs_design.html`

- Keeps working in face of hardware failures
- Streaming data access – optimize for bandwidth, not latency
  Relaxes some POSIX assumptions
- Large data sizes – optimized for files of gigabytes to terrabytes

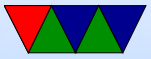


- Write-once-read-many – assumption is the data isn't being actively written.
- "Moving computation easier than moving data"
- blocksize and replication factor per-file
- Rack-aware filesystem
- "location awareness" Tries to spread code out multiple copies distributed physically
- Data spread throughout nodes. Default replication value

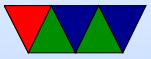


of 3, duplicated three times, twice on same rack and once on different

- Namenode plus cluster of datanodes
- Namenode tracks filenames and locations, keeps entire map in memory
- Datanode stores data. Uses local computer's underlying filesystem. Just blocks of data, makes directories as appropriate but doesn't necessarily have any relationship to the files as seen from within HDFS.

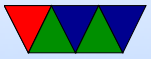


- Communication is over TCP

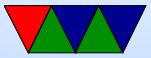


HDFS Fault Handling

- Datanodes send heartbeats to namenode. When datanodes go missing, marked as dead, no new I/O sent to them. If any files fall below replication level they can be replicated on remaining nodes
- Rebalancing – if disk availability changes files might be moved around
- Integrity – checksums on files to detect corruption
- Namenode is a single point of failure. Keeps the edit log

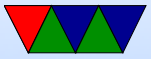


and fsimage, only syncs at startup



Data Organization

- Data broken up into chunks, default 64MB
- Creating a file does not necessarily allocate a chunk; it is cached locally and only sent out once enough data has accumulated to fill a block
- Replication pipeline: once file created starts being sent in smaller chunks (4kb) and it gets forwarded 1 to 2 to 3 in a pipeline until file in all places.
- Deleting a file does not delete right away, moved to



/trash After configurable time gets deleted from trash and the blocks are marked as free. It can take a while for this to all happen, deletes do not free up space immediately.