Cloud Computing

COMP / ECPE 293A

Google

MapReduce

Jeffrey Dean and Sanjay Ghemawat, “MapReduce: simplified data processing on large clusters”, In *Proceedings of the 6th conference on Symposium on Operating Systems Design & Implementation (OSDI'04)*, Berkeley, CA, USA, 2004

Imagine You're Google

✔

- Yesterday's job: Download web pages
  - 40 billion web pages x 40kb per page = 1.4PB of data

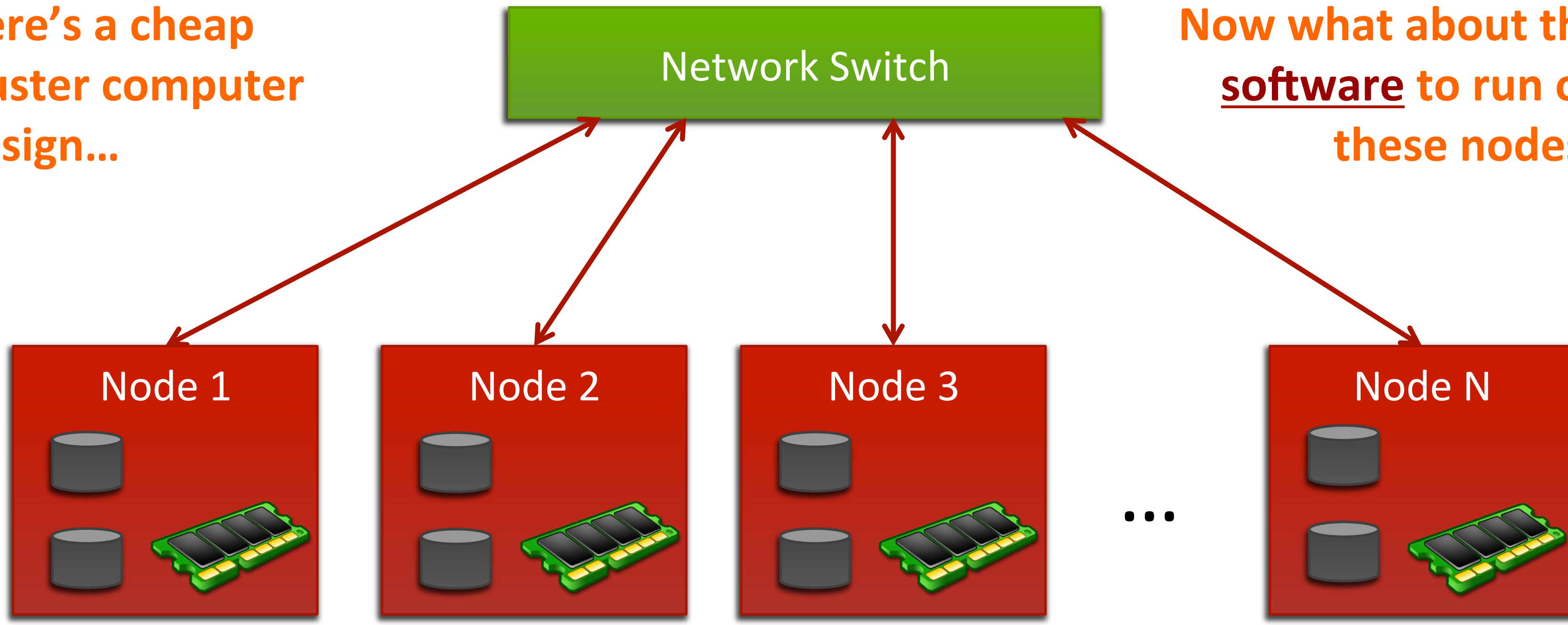
?

- Today's job: Make sense of the data!
  - Imagine the data is stored on one (hypothetical) hard drive
    - Typical hard drive read bandwidth: 100MB/sec
  - **~6 months for one computer to read in the full data set**
- **Obvious conclusion**
  - **This problem needs to be parallelized**
  - **Let's build a cluster computer!**

Imagine You're Google

Here's a cheap cluster computer design…

Now what about the <u>software</u> to run on these nodes?



- Commodity = **<u>cheap</u>** servers
  - Current price "sweet spot"
- Configuration
  - x86 CPUs
  - IDE (now SATA) hard drives
  - Gigabit Ethernet

Imagine You're Google

- Parallelizing programs across a cluster computer is **hard work** *(harder than for a multi-core CPU)*
  - One existing method: MPI (message passing interface)
    - Popular with supercomputer applications
    - API provides fine grained control over all communication between processes running on different nodes
- **Challenges**
  - Communication, coordination, data replication, recovery from failures, debugging, performance optimizing
  - **You need to do this for every program you write**

MapReduce Vision

Tradeoff: Limit the style of programs you can write, but provide automatic parallelization and infrastructure support in return!

MapReduce Vision

What You Do

- Write a program in a special way that can be trivially parallelized
  - **Literally write "*map*" and "*reduce*" functions!**

What the Framework Does

- **Distributes your data** across the cluster
  - Replication
- **Distributes processing** across the cluster
  - Scheduling jobs
- Manages **communication between nodes**
- Detects and **recovers from faults**
  - Re-runs failed tasks
- Provides monitoring and administration tools

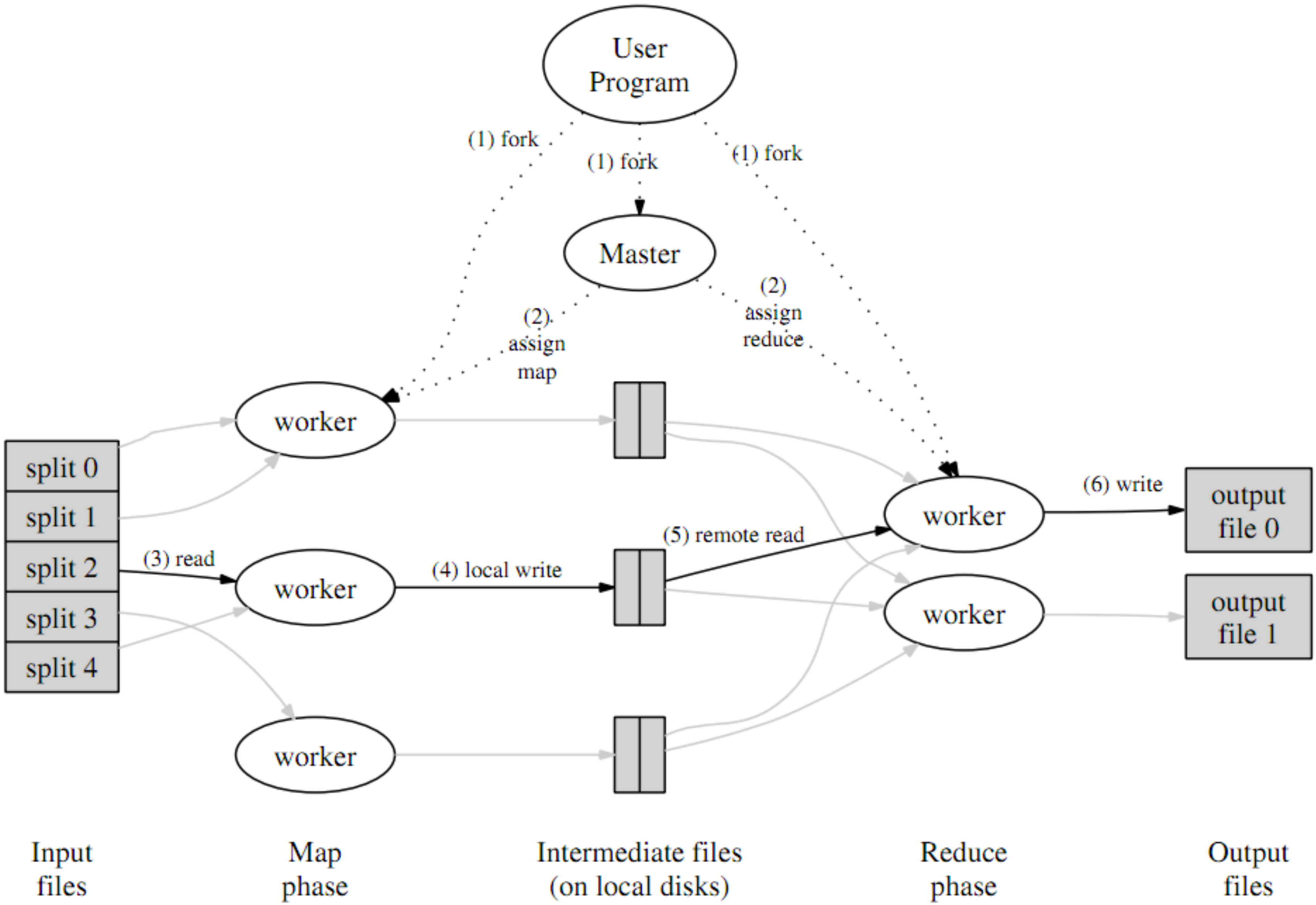


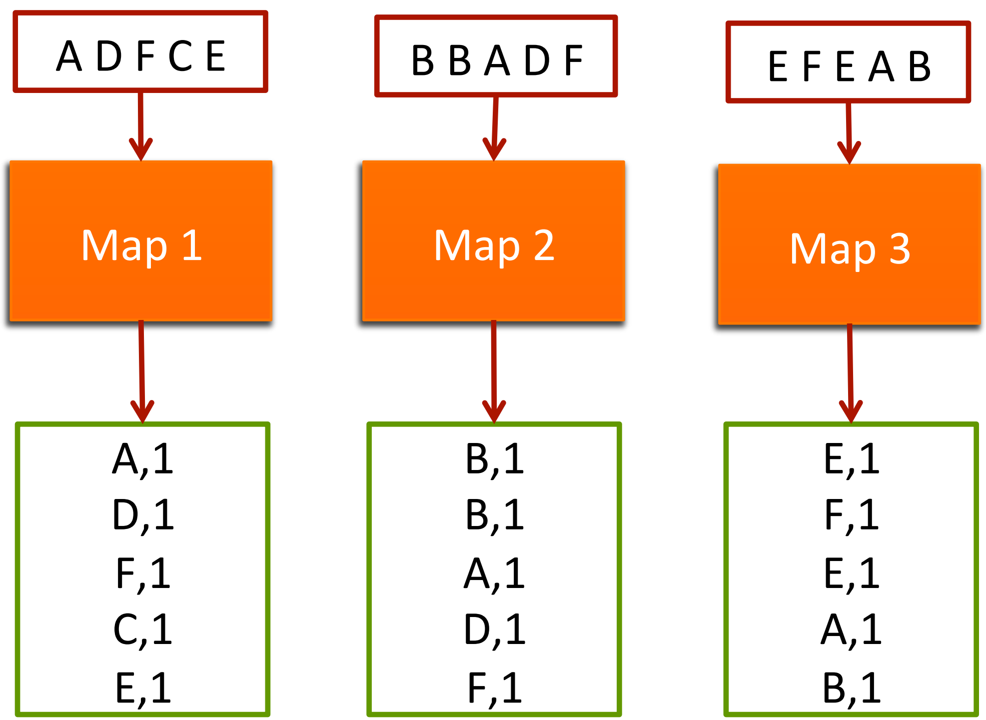
Figure 1: Execution overview

Count of URL Access Frequency From Web Logs (with URLS *A-F*)

Original input data: A D F C E B B A D F E F E A B

Master splits data into *M* pieces: | A D F C E | B B A D F | E F E A B |

Master starts *M* map tasks on the cluster. *(Try to assign based on data locality. Some tasks might wait for idle nodes)*



Each map task
(1) Reads its own data subset
(2) Parses the data into key/value pairs
(3) Emits *intermediate* key/value pairs

Ideally, this is all on local data from the local disk! Nice and parallel…

For this program, each URL is emitted with a count of 1 (e.g. 1 hit for URL A)

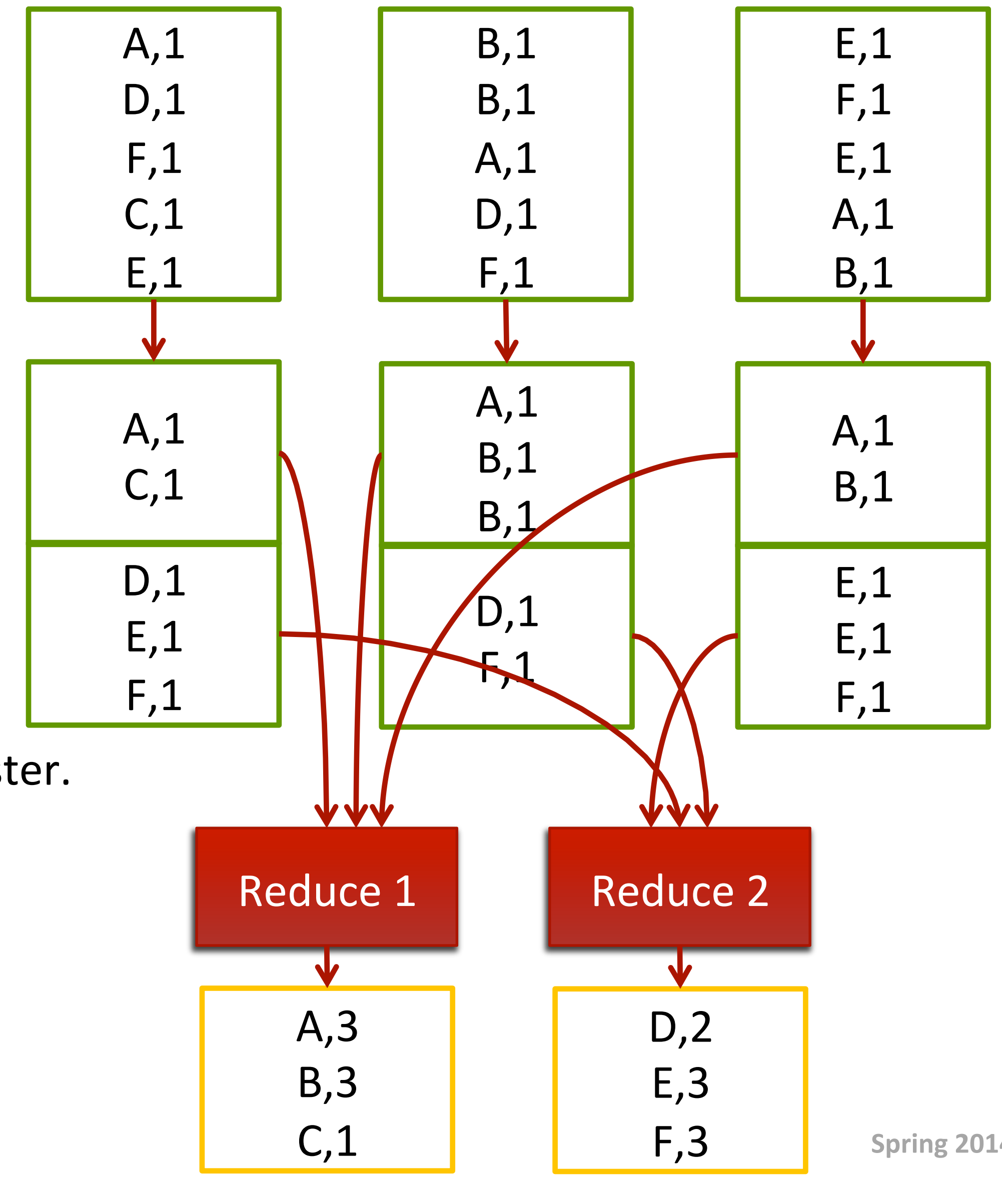
Count of URL Access Frequency From Web Logs (with URLS *A-F*)

Intermediate key/value pairs:

Intermediate pairs are partitioned into *R* partitions. Partitions are sorted by key order. (Either in RAM or on disk if huge) – *Framework does this for you!*

Master starts *R* Reduce tasks on the cluster. Reduce tasks pull in intermediate data (this is across the network)

For this program, Reduce tasks sum up total hits per each URL



Performance

- Skipping details for this talk…
  - *You may want to make a different decision depending on your paper selection…*
- Key question is **not**: Is this the absolute fastest we could perform this job?
- **Rather, key question is: Is this the fastest way we can program the job with reasonable efficiency?**
  - ***We can always buy a few more computers!***

Importance of Locality

- Network *could* be a huge bottleneck in this type of system
- Goal: Process data that is stored *locally* (on your nodes' hard disk)
- Solution
  - Master knows how data is divided and tries to assign map tasks to the same node that stores data
    - Or at least nearby – same rack?
  - Minimizes network communication

Fault Tolerance

- Master probes the other nodes periodically
- Node failed?
  - Master re-assigns tasks to other nodes (which have replicated data)
- What if the master fails?

Optimizations

- Backup tasks
  - Don’t wait for a handful of slow (buggy, failing) nodes – re-execute those tasks somewhere else!
- Skipping bad records
  - Many apps don’t care if a few data points are corrupt in a data set measuring in the terabytes

I’m Not Google!

- Can people outside of Google benefit from MapReduce and related technologies?
- **Yes!** Open-source clone of MapReduce:
- Literally, some engineers read the Google paper and said “We can build that!”
- Now used at Yahoo, Facebook, eBay, Amazon, …

Discussion Questions

- What type of applications are suitable or unsuitable for MapReduce?
  - What type of API would you like for unsuitable apps?
- Where does the input data come from?
  Where is the output data stored to?
- Why was Google the first to build this type of system?
- Did the paper prove that their system is "good"?
- Strengths and weaknesses of the paper?