USC Viterbi
School of Engineering

INF 553: Foundations and Applications of Data Mining

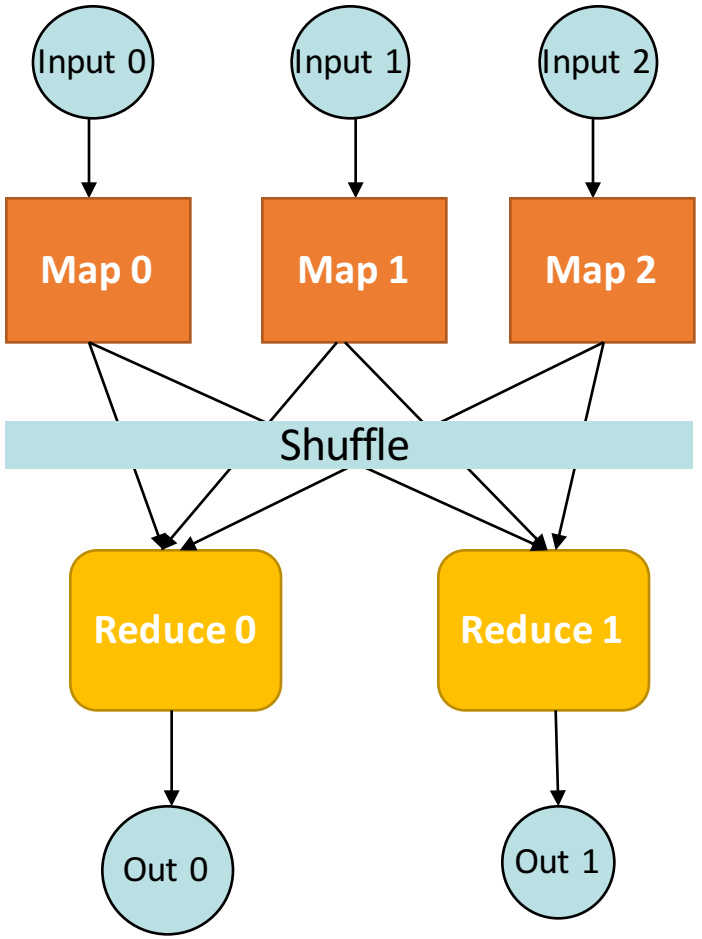
Map-Reduce:
Scheduling and Data Flow
Combiners and Partition Functions

Dr. Anna Farzindar
farzinda@usc.edu

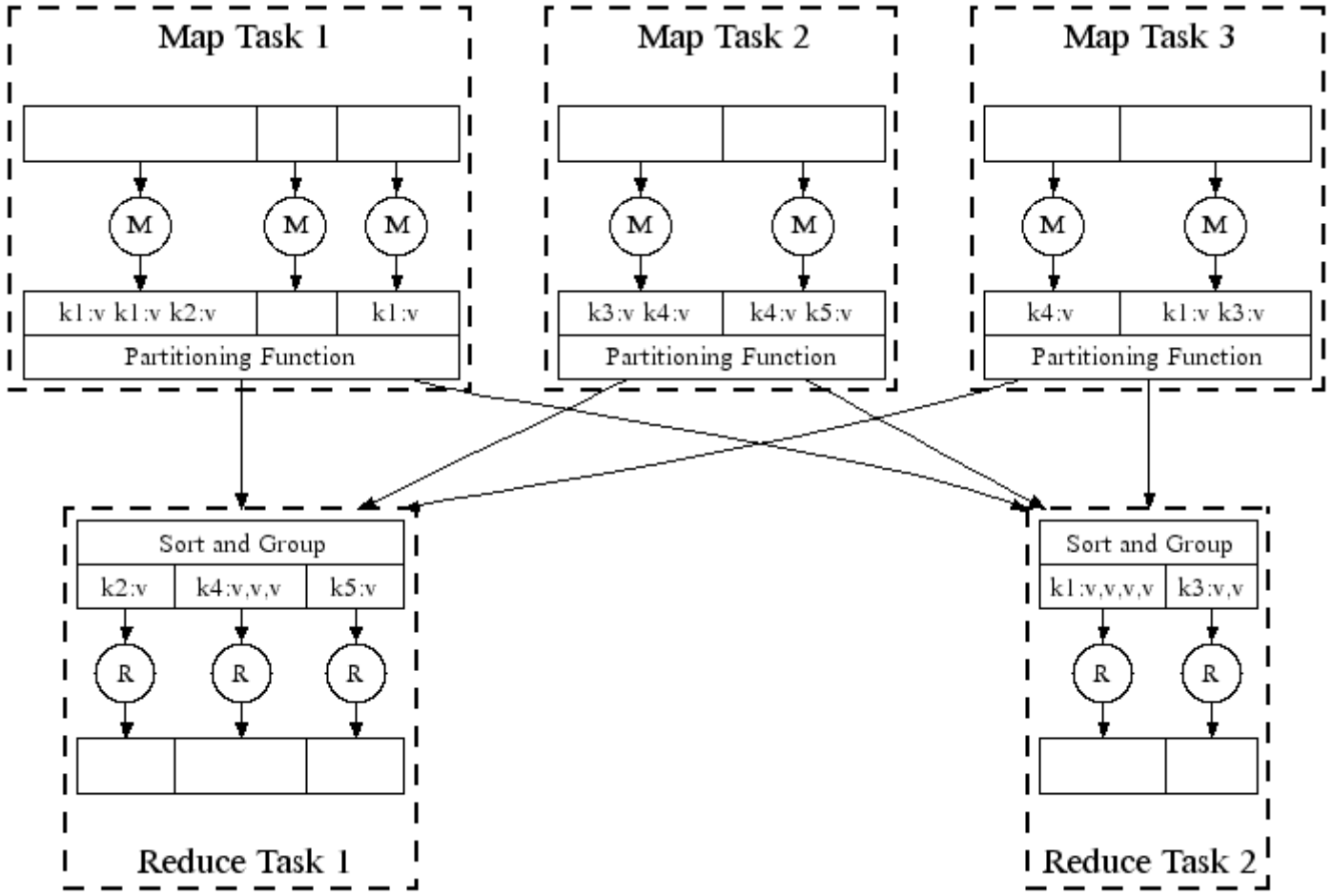
Thanks for source slides and material to: J. Leskovec, A. Rajaraman, J. Ullman: Mining of Massive Datasets

Map-Reduce

- Programmer specifies:
  - Map and Reduce and input files
- **Workflow:**
  - Read inputs as a set of key-value-pairs
  - **Map** transforms input kv-pairs into a new set of k'v'-pairs
  - Sorts & Shuffles the k'v'-pairs to output nodes
  - All k'v'-pairs with a given k' are sent to the same **reduce**
  - **Reduce** processes all k'v'-pairs grouped by key into new k''v''-pairs
  - Write the resulting pairs to files
- All phases are distributed with many tasks doing the work.



Map-Reduce: In Parallel



All phases are distributed with many tasks doing the work

MapReduce: Environment

MapReduce environment takes care of:

- **Partitioning** the input data
- **Scheduling** the program's execution across a set of machines
- Performing the **group by key** step
  - In practice this is the bottleneck
- Handling machine **failures**
- Managing required inter-machine **Communication.**

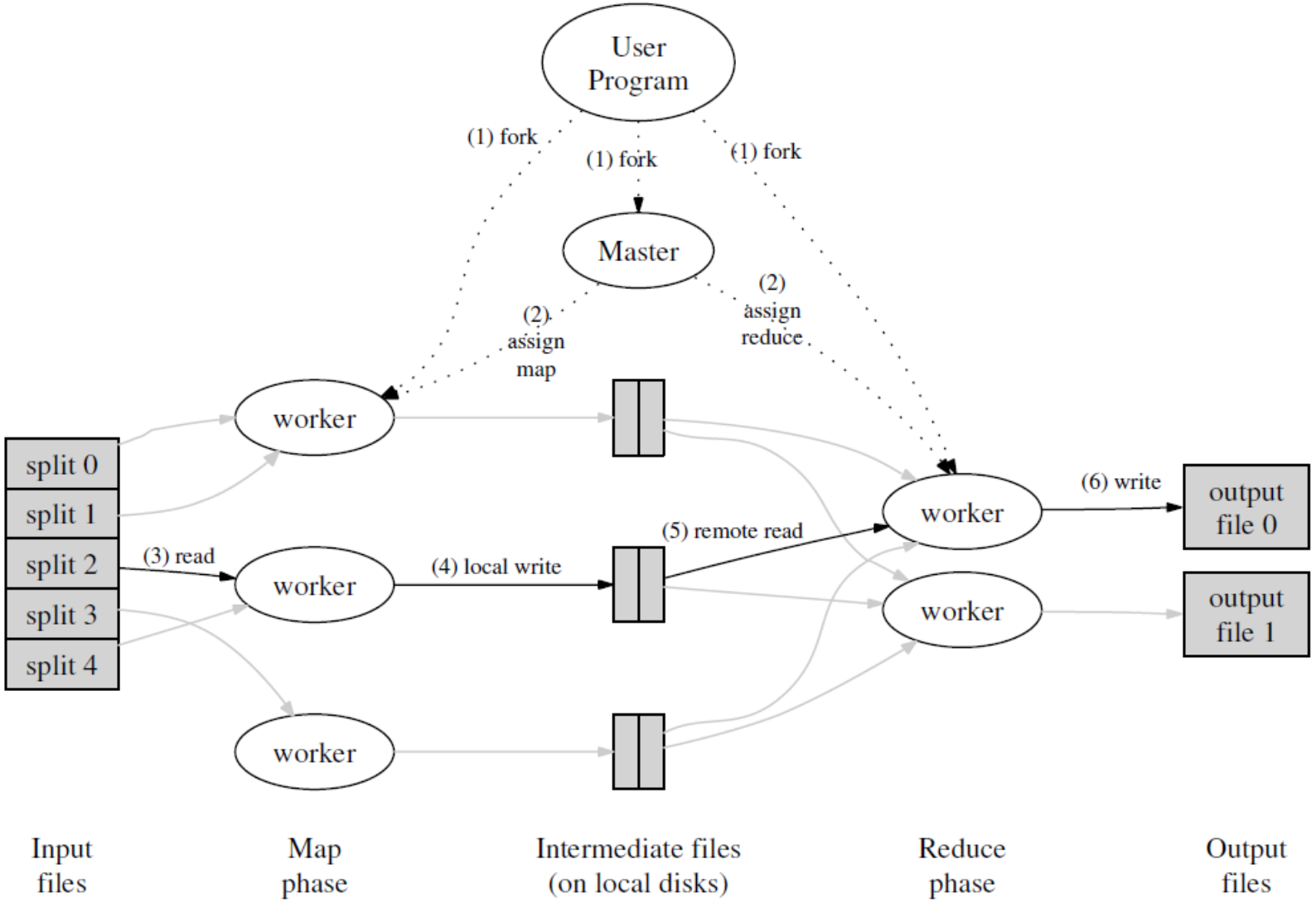
Data Flow

- Input and final output are stored on a distributed file system (HDFS):
  - Scheduler tries to schedule map tasks “close” to physical storage location of input data
- Intermediate results are stored on local FS of Map and Reduce workers
- Output is often input to another MapReduce task.

Coordination: Master

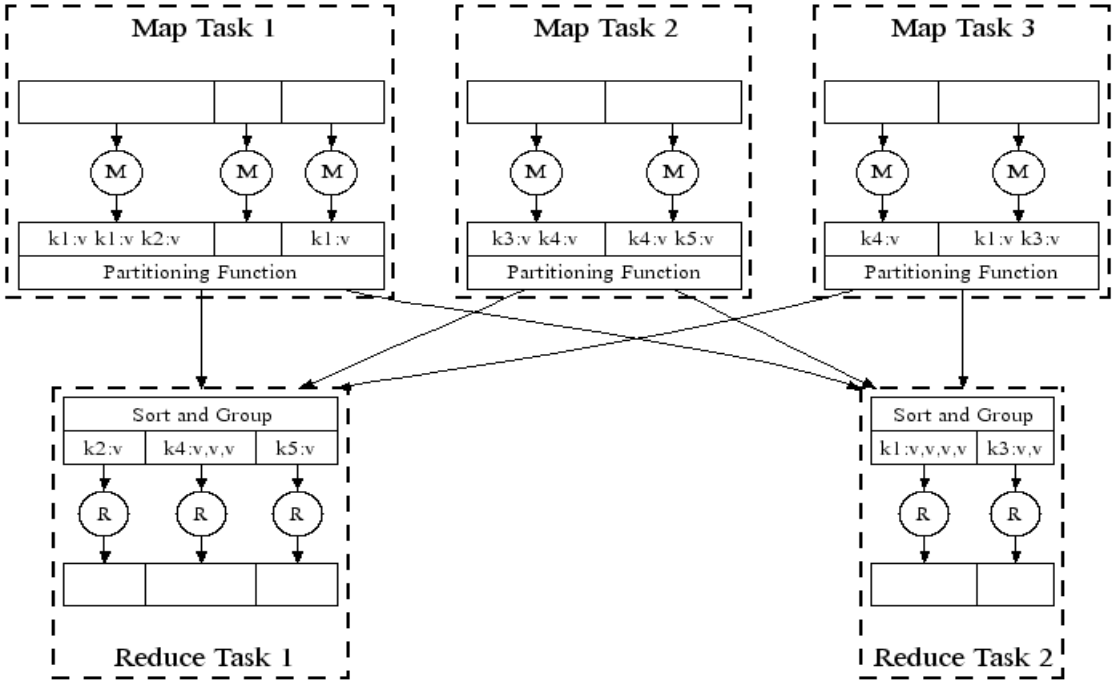
- **Master node takes care of coordination:**
  - **Task status:** (idle, in-progress, completed)
  - **Idle tasks** get scheduled as workers become available
  - When a map task **completes**, it sends the master the **location and sizes** of its intermediate files, one for each reducer
  - Master pushes this info **to reducers**
- **Master pings workers** periodically to detect **failures**.

Coordination



Dealing with Failures

- **Map worker failure**
  - **Map tasks** completed or in-progress at worker are **reset to idle**
  - **Reduce workers** are **notified** when task is rescheduled on another worker
- **Reduce worker failure**
  - Only **in-progress** tasks are reset to idle
  - Reduce task is restarted
- **Master failure** **Could handle (master failure unlikely, one machine lost in 1000days)**
  - MapReduce task is aborted and client is notified.

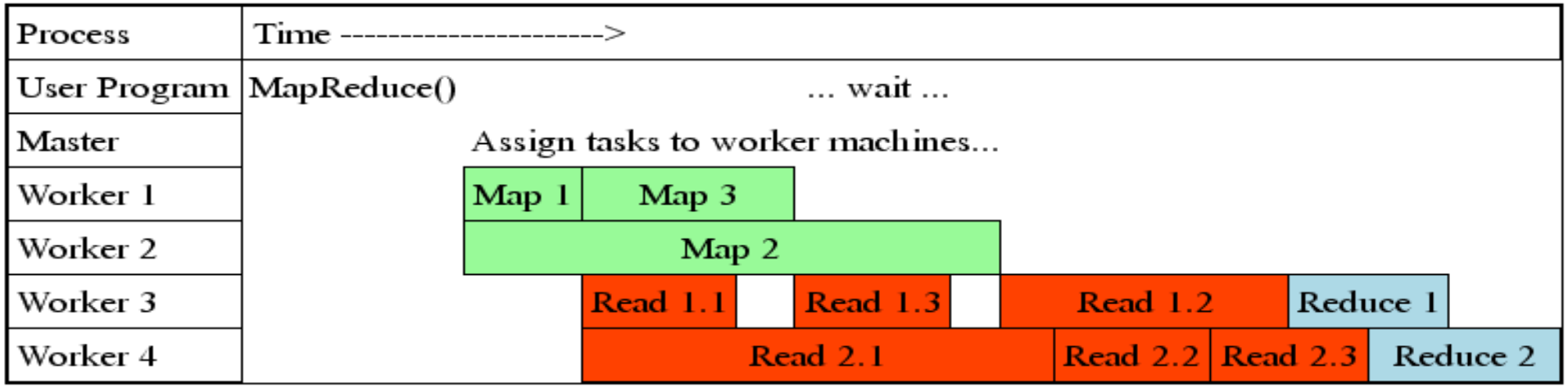


How many Map and Reduce jobs?

- ***M*** map tasks, ***R*** reduce tasks
- **Rule of a thumb:**
  - Make ***M*** much larger than the number of nodes in the cluster
  - One DFS chunk per map is common
  - Improves dynamic load balancing and speeds up recovery from worker failures
- **Usually *R* is smaller than *M***
  - Because output is spread across ***R*** files
- **Google example:** Often use 200,000 map tasks, 5000 reduce tasks on 2000 machines.

Task Granularity & Pipelining

- **Fine granularity tasks ->** Granularity affects the performance of parallel computers. Using fine grains or small tasks results in more parallelism and hence increases the seedup.
  - ->many more **map tasks** than machines
- Minimizes **time** for **fault recovery**
- Can do pipeline **shuffling** with map execution
- Better dynamic **load balancing**.



Refinements: Backup Tasks

- **Problem**
  - Slow workers significantly lengthen the job completion time:
    - Other jobs on the machine
    - Bad disks
    - Weird things
- **Solution**
  - Near end of phase, spawn backup **copies of tasks**
    - Whichever one finishes first "wins"
- **Effect**
  - Dramatically shortens job completion time.

Refinement: Combiners

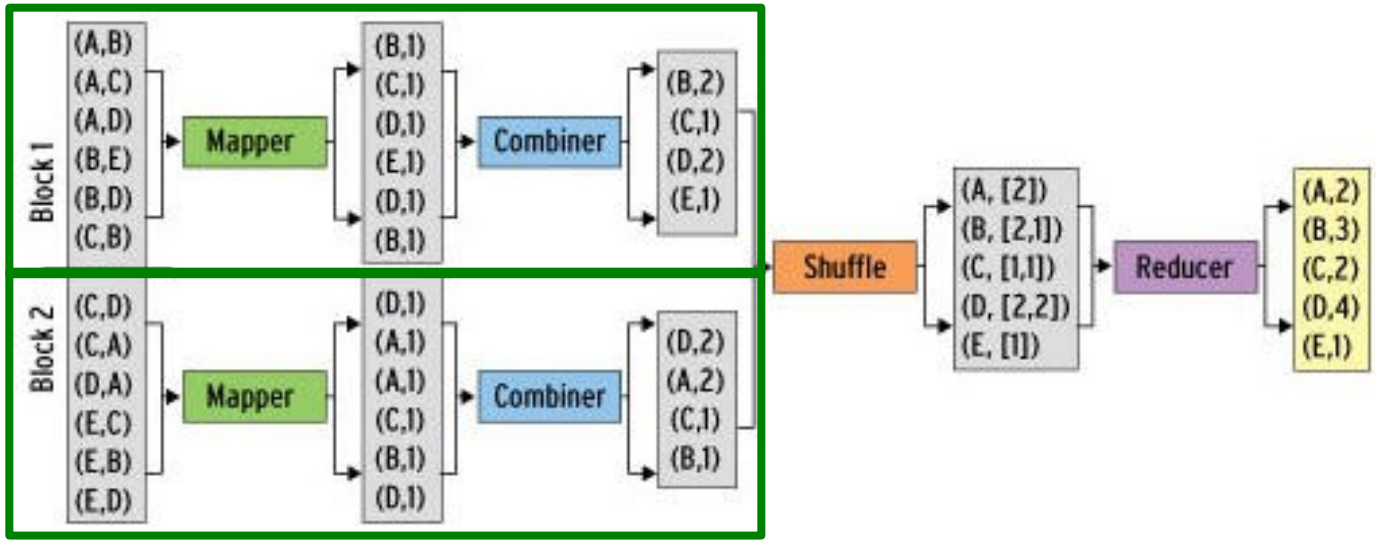
- Combiners are **an optimization** in MapReduce
  - allow for local aggregation **before the shuffle and sort** phase
- When the **map operation outputs its pairs** they are already available in **memory**
- For efficiency reasons, sometimes it makes sense to take advantage of this fact by supplying a combiner class to perform a **reduce-type function**.

Refinement: Combiners

- If a combiner is used then the **map key-value** pairs are not immediately written **to the output**
  - They will be collected in lists, one list per each key value
- When a certain number of key-value pairs have been written,
- **This buffer** is flushed by passing all the values of each key to the combiner's **reduce method** and
- **Outputting** the key-value pairs of the combine operation as if they were created by the **original map operation.**

Refinement: Combiners

- **Back to our word counting example:**
  - **Combiner** combines the values of all keys of a single mapper (single machine):



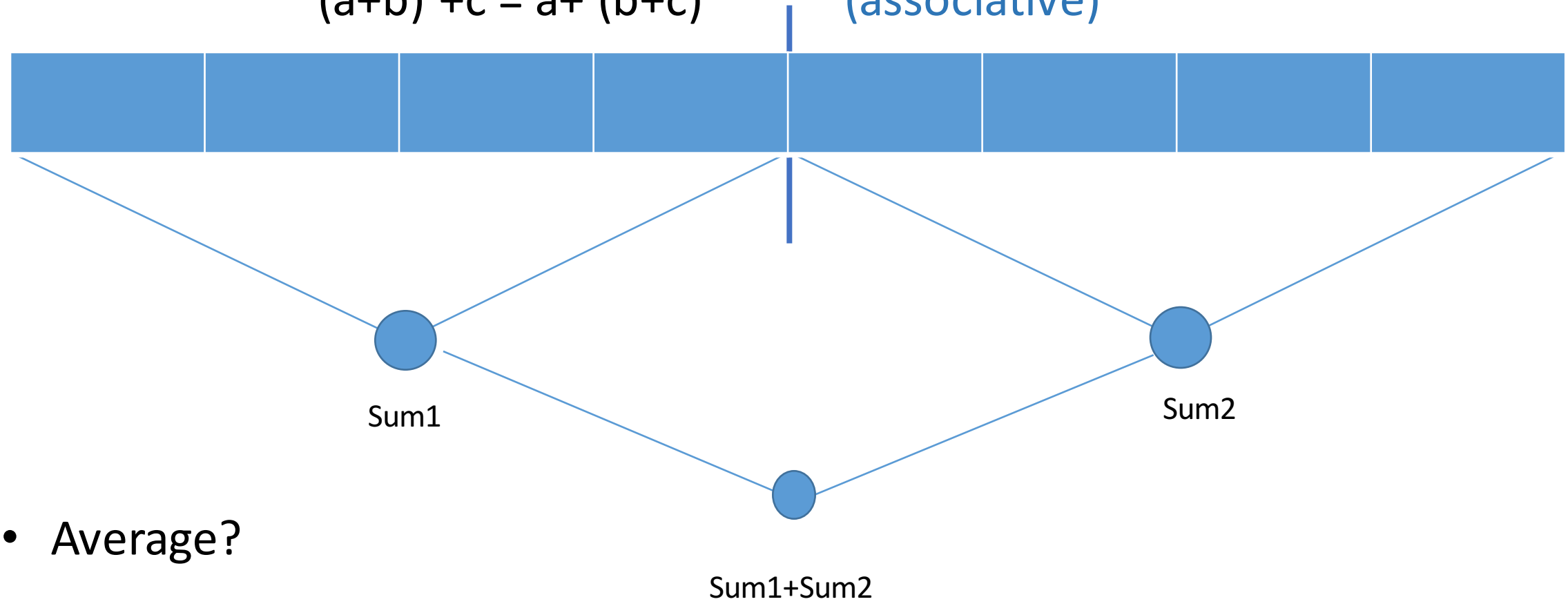
  - Much less data needs to be copied and shuffled!
  - Works if reduce function is commutative and associative.

Commutative and associative

- A binary operation is **commutative** if changing the order of the operands does not change the result.
  - A binary operation on a set S is called commutative if:
  - x * y = y * x for all x, y in S
- A binary operation on a set S is called **associative** if it satisfies the associative law:
  (x* y) * z= x* (y* z)
- **Example:** functions both commutative and associative
  - Max().

Refinement: Combiner

- Combiner trick works only if reduce function is commutative and associative
- Sum a+b = b+a (commutative)
  (a+b) +c = a+ (b+c) (associative)

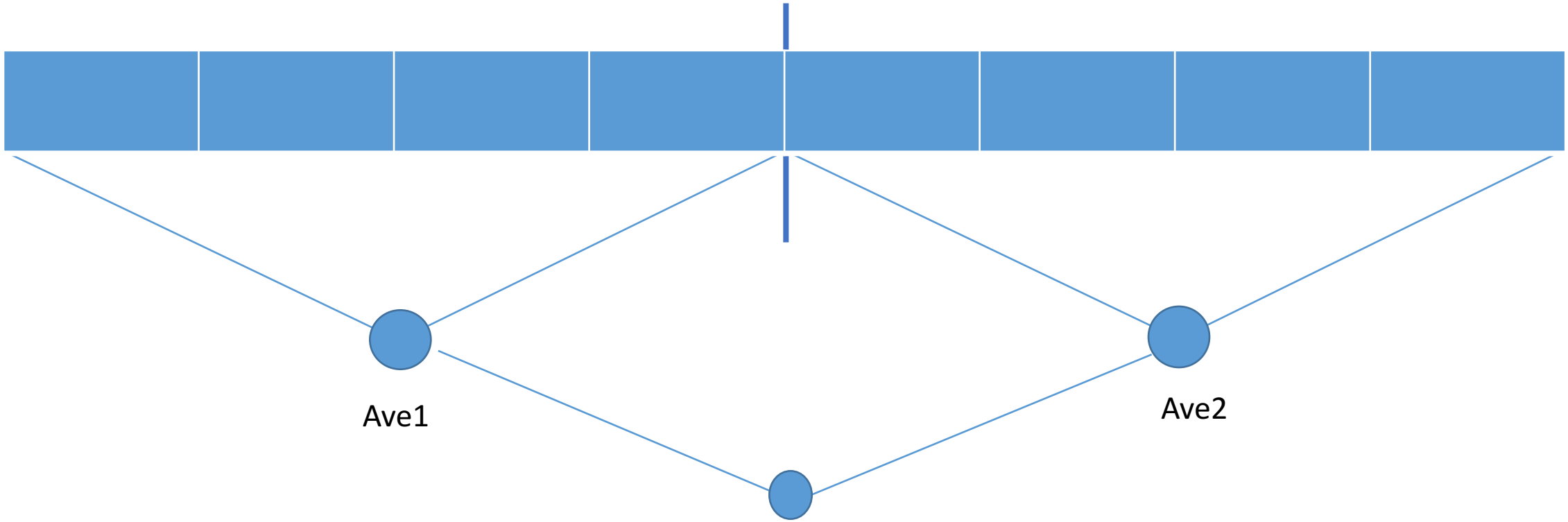


- Average?

Refinement: Combiner

Combiner trick works only if reduce function is commutative and associative

Average:

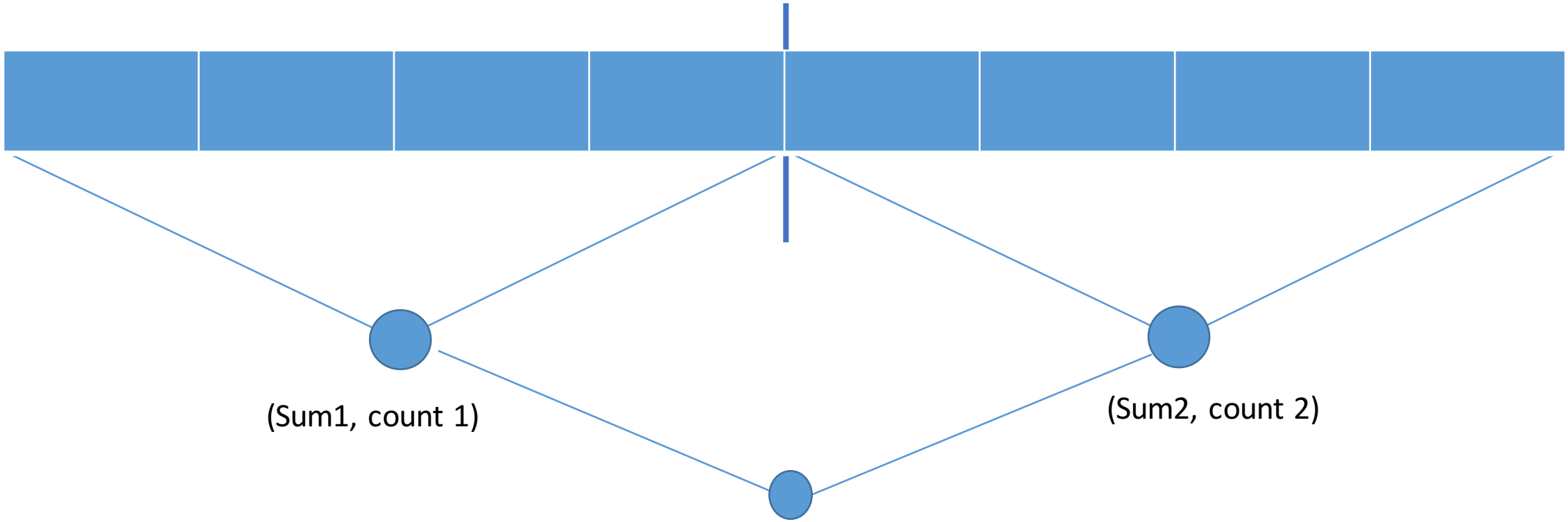


(Ave1+Ave2)/2 NOT Correct

Refinement: Combiner

Combiner trick works only if reduce function is commutative and associative

Average: change of (Key, Value)



Refinement: Combiner

- Combiner trick works only if reduce function is commutative and associative
- Sum
- Average
- Median?
  - The *median* of a set of values is computed as follows: Sort the values
  - If the number of values is odd, the median is the middle value
  - If the number of values is even, the median is the average of the two middle values.

--> Not commutative and associative then can't use combiner

Refinement: Partition Function

- **Want to control how keys get partitioned**
  - Inputs to map tasks are created by contiguous splits of input file
  - **Reducer** needs to ensure that **records with the same intermediate key end up at the same worker**
- **System uses a default partition function:**
  - **hash(key) mod *R***
- **Sometimes useful to override the hash function:**
  - E.g., want to have **alphabetical or numeric ranges** going to different Reduce tasks
  - E.g., **hash(hostname(URL)) mod *R*** ensures URLs from a host end up in the same output file.

Implementations

- **Google's MapReduce**
  - Not available outside Google
- **Hadoop**
  - An open-source implementation in Java
  - Uses HDFS for stable storage
  - Download: http://hadoop.apache.org/releases.html
  - Many variations.

Cloud Computing

- Ability to rent computing by the hour
  - Additional services e.g., persistent storage
- Amazon's "Elastic Compute Cloud" (EC2)
  - Aster Data and Hadoop can both be run on EC2
  - S3 (stable storage)
    - **Amazon S3** has a simple web services interface: to store and retrieve any amount of data, at any time, from anywhere on the web.
  - Elastic Map Reduce (EMR).

Summary

- MapReduce environment
- Data Flow
- Master node and coordination
- Refinement
- Combiner: useful for saving network bandwidth
- Implementation